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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,403	06/21/2022	11368667	0079124-000370-T1	9694

21839 7590 06/01/2022

BUCHANAN, INGERSOLL & ROONEY PC
1737 KING STREET
SUITE 500
ALEXANDRIA, VA 22314-2727

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Patents Stakeholder Experience (OPSE), Stakeholder Support Division (SSD) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site http://pair.uspto.gov for additional inventors):

Rune FISKER, Virum, DENMARK;
Henrik ÖJELUND, Lyngby, DENMARK;
Rasmus KJAER, Kobenhavn K, DENMARK;
Mike VAN DER POEL, Rodovre, DENMARK;
Arish A. QAZI, Toronto, CANADA;

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

3SHAPE A/S, Copenhagen K, DENMARK

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
17/533,403	11/23/2021	2484	2920	0079124-000370-T1	30	3

CONFIRMATION NO. 9694

CORRECTED FILING RECEIPT

21839
BUCHANAN, INGERSOLL & ROONEY PC
1737 KING STREET
SUITE 500
ALEXANDRIA, VA 22314-2727

OC000000134029729

Date Mailed: 05/24/2022

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Rune FISKER, Virum, DENMARK;
Henrik ÖJELUND, Lyngby, DENMARK;
Rasmus KJAER, Kobenhavn K, DENMARK;
Mike VAN DER POEL, Rodovre, DENMARK;
Arish A. QAZI, Toronto, CANADA;
Karl-Josef HOLLENBECK, Copenhagen O, DENMARK;

Applicant(s)

3SHAPE A/S, Copenhagen K, DENMARK

Assignment For Published Patent Application

3SHAPE A/S, Copenhagen K, DENMARK

Power of Attorney: The patent practitioners associated with Customer Number 21839

Domestic Priority data as claimed by applicant

This application is a CON of 17/340,806 06/07/2021
which is a CON of 17/206,581 03/19/2021 PAT 11076146
which is a CON of 16/774,843 01/28/2020 PAT 11051002
which is a CON of 16/433,369 06/06/2019 PAT 10595010
which is a CON of 16/217,943 12/12/2018 PAT 10326982
which is a CON of 15/974,105 05/08/2018 PAT 10349041
which is a CON of 14/502,230 09/30/2014 PAT 10097815
which is a CON of 13/376,427 12/06/2011 PAT 8878905
which is a 371 of PCT/DK2010/050148 06/17/2010

which claims benefit of 61/231,118 08/04/2009
and claims benefit of 61/187,744 06/17/2009

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 12/06/2021

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/533,403**

Projected Publication Date: Not Applicable

Non-Publication Request: No

Early Publication Request: No
Title

INTRAORAL SCANNING APPARATUS

Preliminary Class

348

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application

serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

Exhibit 1004 page 4 of 1621
DENTAL IMAGING

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,403	11/23/2021	Rune FISKER	0079124-000370-T1	9694

21839 7590 05/23/2022

BUCHANAN, INGERSOLL & ROONEY PC
1737 KING STREET
SUITE 500
ALEXANDRIA, VA 22314-2727

EXAMINER
MESA, JOSE M

ART UNIT	PAPER NUMBER
2484	

NOTIFICATION DATE	DELIVERY MODE
05/23/2022	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ADIPDOC1@BIPC.com

Response to Rule 312 Communication	Application No.	Applicant(s)	
	17/533,403	FISKER et al.	
	Examiner	Art Unit	AIA (FITF) Status
	JOSE M MESA	2484	No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☑ The amendment filed on 25 April 2022 under 37 CFR 1.312 has been considered, and has been:
   a) ☑ entered.
   b) ☐ entered as directed to matters of form not affecting the scope of the invention.
   c) ☐ disapproved because the amendment was filed after the payment of the issue fee.
      Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.
   d) ☐ disapproved. See explanation below.
   e) ☐ entered in part. See explanation below.
   f) ☐ not entered because the supplemental or corrected Application Data sheet (ADS)
      ☐ was not accompanied by a petition to accept an unintentionally delayed claim under 37 CFR 1.55 or 27 CFR 1.78;
      ☐ did not identify the information being changed in accordance with 37 CFR 1.76(c)(2);
      ☐ was not properly signed in accordance with 37 CFR 1.76(e) (or 37 CFR 1.33(b) for applications filed prior to September 16, 2012).

/JOSE M MESA/ Examiner, Art Unit 2484	/THAI Q TRAN/ Supervisory Patent Examiner, Art Unit 2484

OK TO ENTER: /J.M.M/

AMENDMENTS TO THE SPECIFICATION:

Please amend the title as follows:

~~FOCUS~~ INTRAORAL SCANNING APPARATUS

United States Patent and Trademark Office

Office of the Chief Financial Officer

Document Code:WFEE

User :C46167

Sale Accounting Date:05/11/2022

Sale Item Reference Number	Effective Date
17533403	05/10/2022

Document Number	Fee Code	Fee Code Description	Amount Paid	Payment Method
I20225A857564966	1501	UTILITY APPL ISSUE FEE	$1,200.00	Salea

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PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

OIPAP
MAY 10 2022
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PTOL-85

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P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

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21839 7590 05/10/2022
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SUITE 500
ALEXANDRIA, VA 22314-2727

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Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,303	11/23/2021	Rune FISKER	0079124-000370-T1	9694

TITLE OF INVENTION: FOCUS SCANNING APPARATUS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$1200.00	$0	08/10/2022

Issue Fee was previously paid

EXAMINER	ART UNIT	CLASS-SUBCLASS
MESA, JOSE M	2484	348-046000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 BUCHANAN INGERSOLL & ROONEY PC
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: **3SHAPE A/S**

(B) RESIDENCE: (CITY and STATE OR COUNTRY): **COPENHAGEN K, DENMARK**

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. **02-4800**

5. Change in Entity Status (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature: /WCRowland/ Date: **May 10, 2022**

Typed or printed name: **William C. Rowland** Registration No.: **30,888**

PTOL-85 Part B (08-18) Approved for use through 01/31/2020 OMB 0651-0033 U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Exhibit 1004 page 10 of 1621
DENTAL IMAGING

PART B - FEE(S) TRANSMITTAL

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Commissioner for Patents
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Alexandria, Virginia 22313-1450

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21839 7990 05/10/2022
BUCHANAN, INGERSOLL & ROONEY PC
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ALEXANDRIA, VA 22314-2727

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(Typed or printed name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,403	11/23/2021	Rune FISKER	0079124-000370-T1	9694

TITLE OF INVENTION: FOCUS SCANNING APPARATUS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$1200.00	$0	08/10/2022

Issue Fee was previously paid

EXAMINER	ART UNIT	CLASS-SUBCLASS
MESA, JOSE M	2484	348-046000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

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(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 BUCHANAN INGERSOLL & ROONEY PC
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: 3SHAPE A/S

(B) RESIDENCE: (CITY and STATE OR COUNTRY): COPENHAGEN K, DENMARK

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

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☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

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NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
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NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /WCRowland/ Date May 10, 2022

Typed or printed name William C. Rowland Registration No. 30,888

PTOL-85 Part B (08-18) Approved for use through 01/31/2020 OMB 0651-0033 U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Exhibit 1004 page 11 of 1621
DENTAL IMAGING

Electronic Acknowledgement Receipt

EFS ID:	45680091
Application Number:	17533403
International Application Number:	
Confirmation Number:	9694
Title of Invention:	FOCUS SCANNING APPARATUS
First Named Inventor/Applicant Name:	Rune FISKER
Customer Number:	21839
Filer:	William C. Rowland/David Avila
Filer Authorized By:	William C. Rowland
Attorney Docket Number:	0079124-000370-T1
Receipt Date:	10-MAY-2022
Filing Date:	23-NOV-2021
Time Stamp:	17:03:15
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Fees_Transmittal.pdf	535081 3967423beb5d32aa929ae4a5e43cf3ed5fe4 14c7	no	1

Warnings:

Information:	
Total Files Size (in bytes):	535081

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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NOTICE OF ALLOWANCE AND FEE(S) DUE

21839 7590 05/10/2022

BUCHANAN, INGERSOLL & ROONEY PC
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EXAMINER
MESA, JOSE M

ART UNIT	PAPER NUMBER
2484	

DATE MAILED: 05/10/2022

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,403	11/23/2021	Rune FISKER	0079124-000370-T1	9694

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APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$1200.00	$0	08/10/2022

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

21839 7590 05/10/2022

BUCHANAN, INGERSOLL & ROONEY PC
1737 KING STREET
SUITE 500
ALEXANDRIA, VA 22314-2727

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,403	11/23/2021	Rune FISKER	0079124-000370-T1	9694

TITLE OF INVENTION: FOCUS SCANNING APPARATUS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1200	$0.00	$1200.00	$0	08/10/2022

EXAMINER	ART UNIT	CLASS-SUBCLASS
MESA, JOSE M	2484	348-046000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/AIA/122 or PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/AIA/47 or PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑ Issue Fee ❑ Publication Fee (if required) ❑ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

Exhibit 1004 page 15 of 1621
DENTAL IMAGING

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/533,403	11/23/2021	Rune FISKER	0079124-000370-T1	9694

21839 7590 05/10/2022

BUCHANAN, INGERSOLL & ROONEY PC
1737 KING STREET
SUITE 500
ALEXANDRIA, VA 22314-2727

EXAMINER	
MESA, JOSE M	
ART UNIT	PAPER NUMBER
2484	

DATE MAILED: 05/10/2022

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 17/533,403	Applicant(s) FISKER et al.	
	Examiner JOSE M MESA	Art Unit 2484	AIA (FITF) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 02/21/2022.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 2-20 and 22-33 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☑ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 04/22/2022.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/JOSE M MESA/ Examiner, Art Unit 2484	/THAI Q TRAN/ Supervisory Patent Examiner, Art Unit 2484

DETAILED ACTION

Notice of Pre-AIA or AIA Status

The present application is being examined under the pre-AIA first to invent provisions.

Terminal Disclaimer

The terminal disclaimers filed on 02/02/2022 and 02/22/2022 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of U.S. Patent No. 11,076,146 and U.S. Patent No. 10,595,010 have been reviewed and are accepted. The terminal disclaimers have been recorded.

Allowable Subject Matter

1. Claims 2-20 and 22-33 are allowed.

The following is an examiner's statement of reasons for allowance: **Independent claim 2** recites the uniquely distinct features for: "...a patiern generator configured to generate, using a light source, a probe light with a plurality of configurations in the form of a time-varying illumination pattern; an optical system configured to transmit the probe light, via the tip, towards the object along an optical path thereby illuminating at least a part of the object with the time-varying illumination pattern, and to transmit at least a part of the light returned from the object to the at least one camera to form a plurality of 2D images, wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern;..." **And independent claim 15** recites the uniquely distinct features for: "...a pattern generator configured to generate, using a light source, a probe light with a plurality of configurations in the form of a time-varying illumination pattern; an optical system configured to transmit the probe light, via the tip,

towards the object along an optical path thereby illuminating at least a part of the object with the time-varying illumination pattern, and to transmit at least a part of the light returned from the object to the at least one camera to form a plurality of 2D images, wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern,..." **And independent claim 28** recites the uniquely distinct features for: "...a pattern generator configured to generate, using a light source, a probe light with a plurality of configurations in the form of a time-varying illumination pattern; an optical system configured to transmit the probe light, via the tip, towards the object along an optical path thereby illuminating at least a part of the object with the time-varying illumination pattern, and to transmit at least a part of the light returned from the object to the at least one camera to form a plurality of 2D images, wherein the 3D geometry is determined based on the plurality of 2D images and the time-varying illumination pattern;..." The closest prior art in Babayoff et al. (US 2005/0283065) teaches a device 100 comprises a main illumination source 31 for illuminating the object of interest 26, typically a part of the intraoral cavity, and is optically coupled to main optics 41 to provide depth Z values for an array range of X-Y points (according to a known frame of reference) along the surface of the object 26. Detection optics 60 comprises an image sensor, typically a CCD, that is preferably monochromatic to maximise the resolution of the device, and which typically defines the X-Y frame of reference. Alternatively, the CCD may be adapted to receive color images. The detection optics 60 receives image data from the main optics 41 and the image processor 24 determines the depth Z values for each X-Y point illuminated on the object 26 based on this image data, Heinz et al. (US 2007/0041729) teaches an illustrative illumination arrangement 800 using a multimode optical fiber 802 to monitor a surface 804 with a detector 805 (e.g., detector 104 of FIG. 1,

detector 302 of FIG. 3A, or detector A of FIG. 7, 7A). Optical radiation 806 that reflects from surface 804 will exhibit time-varying changes if surface 804 vibrates, if fiber 802 moves across surface 804, or if distance d changes (e.g., through tilt or movement of surface 804). The multimode interference pattern that illuminates detector 805 is time-varying in accordance with the movement of surface 804 (or end 814 or d), however, either singular or in combination, fails to anticipate or render the above underlined limitations obvious.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to JOSE M MESA whose telephone number is (571)270-1706. The examiner can normally be reached on Monday-Friday 8:30AM-6:00PM ET.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thai Tran can be reached on 571-272-7382. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a

USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

4/27/2022

/JOSE M MESA/
Examiner, Art Unit 2484

/THAI Q TRAN/
Supervisory Patent Examiner, Art Unit 2484

Notice of References Cited	Application/Control No. 17/533,403	Applicant(s)/Patent Under Reexamination FISKER et al.	
	Examiner JOSE M MESA	Art Unit 2484	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20050283065-A1	12-2005	Babayoff, Noam	G01J3/508	600/407
*	B	US-20070041729-A1	02-2007	Heinz; Philip	H01L31/02024	398/25
	C					
	D					
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FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/533,403	FISKER et al.
	Examiner	**Art Unit**
	JOSE M MESA	2484

CPC						
Symbol					**Type**	**Version**
H04N	/	13	/	296	F	2018-05-01
A61B	/	5	/	0068	I	2013-01-01
G01B	/	11	/	2513	I	2013-01-01
G01B	/	11	/	2518	I	2013-01-01
A61B	/	5	/	1077	I	2013-01-01
A61B	/	5	/	4547	A	2013-01-01
G01B	/	2210	/	58	A	2013-01-01
A61B	/	5	/	1075	A	2013-01-01
A61B	/	5	/	1076	A	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

/JOSE M MESA/ Examiner, Art Unit 2484	27 April 2022	**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	31	
/THAI Q TRAN/ Supervisory Patent Examiner, Art Unit 2484	03 May 2022	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	2	8

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/533,403	FISKER et al.
	Examiner	**Art Unit**
	JOSE M MESA	2484

INTERNATIONAL CLASSIFICATION				
CLAIMED				
H04N	/	13	/	296

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

/JOSE M MESA/ Examiner, Art Unit 2484 (Assistant Examiner)	27 April 2022 (Date)	**Total Claims Allowed:** 31	
/THAI Q TRAN/ Supervisory Patent Examiner, Art Unit 2484 (Primary Examiner)	03 May 2022 (Date)	O.G. Print Claim(s) 2	O.G. Print Figure 8

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/533,403	FISKER et al.
	Examiner	**Art Unit**
	JOSE M MESA	2484

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
-	1	9	10	18	19	26	28								
1	2	10	11	19	20	27	29								
2	3	11	12	-	21	28	30								
3	4	12	13	20	22	29	31								
4	5	13	14	21	23	30	32								
5	6	14	15	22	24	31	33								
6	7	15	16	23	25										
7	8	16	17	24	26										
8	9	17	18	25	27										

/JOSE M MESA/ Examiner, Art Unit 2484 (Assistant Examiner)	27 April 2022 (Date)	**Total Claims Allowed:** 31	
/THAI Q TRAN/ Supervisory Patent Examiner, Art Unit 2484 (Primary Examiner)	03 May 2022 (Date)	O.G. Print Claim(s) 2	O.G. Print Figure 8

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/533,403	FISKER et al.
	Examiner	Art Unit
	JOSE M MESA	2484

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/27/2022								
	1	-								
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/533,403	FISKER et al.
	Examiner	Art Unit
	JOSE M MESA	2484

CPC - Searched*		
Symbol	Date	Examiner
H04N13/296, A61B5/0068, A61B5/1077, G01B11/2513, G01B11/2518, A61B5/1075, A61B5/1076, A61B5/4547, G01B2210/58	04/27/2022	JM

CPC Combination Sets - Searched*		
Symbol	Date	Examiner
H04N13/296, A61B5/0068, A61B5/1077, G01B11/2513, G01B11/2518, A61B5/1075, A61B5/1076, A61B5/4547, G01B2210/58	04/27/2022	JM

US Classification - Searched*			
Class	Subclass	Date	Examiner
348		02/02/2022	JM

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
PE2E Search History, US-PGPUB, USPAT, USOCR, FIT, EPO, JPO, DERWENT, IBM_TDB.	04/27/2022	JM
Searched inventor's name in PALM and PE2E for double patenting.	02/02/2022	JM

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
	See PE2E Search History for interference search.	04/27/2022	JM

/JOSE M MESA/ Examiner, Art Unit 2484	/THAI Q TRAN/ Supervisory Patent Examiner, Art Unit 2484

Exhibit 1004 page 28 of 1621
DENTAL IMAGING

PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L67	51	("20070172112"|"20050283065"|"20060092133"|"7230771"|"20070041729"|"7077647"|"10695151"|"10349042"|"8571397"|"11076146"|"20050237581"|"20060212260"|"RE48221"|"4781448"|"5675407"|"20100009308"|"5605459"|"5702249"|"20050283065").PN.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:03 PM
L68	2	L2 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:04 PM
L69	1	L4 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:05 PM
L70	1	L6 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS,	OR	ON	ON	2022/04/27 02:05 PM

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L71	2	L8 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:06 PM
L72	1	L10 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:06 PM
L73	3	L12 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:06 PM
L74	2	L14 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU,	OR	ON	ON	2022/04/27 02:07 PM

			CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)				
L75	2	L17 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:07 PM
L76	2	L19 AND L67	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:07 PM
L77	9	L67 AND (H04N13/296 A61B5/0068 A61B5/1077 G01B11/2513 G01B11/2518 A61B5/1075 A61B5/1076 A61B5/4547 G01B2210/58).CPC.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:08 PM
L78	2990	(tim$4 near20 var$4	(US-PGPUB; USPAT;	OR	ON	ON	2022/04/27

		near20 illuminat$4 near20 pattern)	USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)				02:12 PM
L79	3	L67 AND L78	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:13 PM
L80	4290	(tim$4 near60 var$4 near60 illuminat$4 near60 pattern)	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:14 PM
L81	3	L67 AND L80	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN,	OR	ON	ON	2022/04/27 02:14 PM

			WO); EPO; JPO; DERWENT; IBM_TDB)				
L82	93	(segment$4 near60 ((led) light near2 emitting near2 diode) near60 scanner)	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:14 PM
L83	1	L67 AND L82	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:15 PM
L84	166	(tim$4 near60 var$4 near60 illuminat$4 near60 line near60 pattern)	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:16 PM
L85	0	L67 AND L84	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL,	OR	ON	ON	2022/04/27 02:16 PM

			PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)				
L86	226	(tim$5 WITH (var$4 chang$4 modif$4 alter$4) WITH (illuminat$4 light$4) WITH pattern WITH (teeth tooth))	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:16 PM
L87	0	L67 AND L86	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:16 PM
L88	445	(fisker-rune).in.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:21 PM
L89	93	(ojelund-henrik).in.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS,	OR	ON	ON	2022/04/27 02:21 PM

			IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)				
L90	26	(kjaer-rasmus).in.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:22 PM
L91	111	(van-der-poel-mike).in.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:22 PM
L92	34	(qazi-arish-a).in.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY, CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/04/27 02:22 PM
L93	156	(hollenbeck-karl-josef).in.	(US-PGPUB; USPAT; USOCR; FIT (AP, AT, AU, BE, BG, BR, BY,	OR	ON	ON	2022/04/27 02:22 PM

			CA, CH, CN, CS, CU, CZ, DD, DE, DK, EA, EE, EP, ES, FI, FR, GB, HR, HU, ID, IE, IL, IS, IT, JP, KR, LT, LU, LV, MA, MC, MD, MY, NL, NO, NZ, OA, PH, PL, PT, RO, RS, RU, SE, SG, SI, SK, SU, TH, TN, TR, TW, UA, VN, WO); EPO; JPO; DERWENT; IBM_TDB)				

PE2E SEARCH - Search History (Interference)

There are no Interference searches to show.

Bibliographic Data

Application No: 17/533,403

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /JOSE M MESA/ (Examiner's Signature) | (Initials)

Title: FOCUS SCANNING APPARATUS

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
11/23/2021	348	2484	0079124-000370-T1
RULE			

APPLICANTS

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Arish A. QAZI, Toronto, CANADA

Karl-Josef HOLLENBECK, Copenhagen O, DENMARK

CONTINUING DATA

This application is a CON of 17340806 06/07/2021

17340806 is a CON of 17206581 03/19/2021 PAT 11076146

17206581 is a CON of 16774843 01/28/2020 PAT 11051002

16774843 is a CON of 16433369 06/06/2019 PAT 10595010

16433369 is a CON of 16217943 12/12/2018 PAT 10326982

16217943 is a CON of 15974105 05/08/2018 PAT 10349041

15974105 is a CON of 14502230 09/30/2014 PAT 10097815

14502230 is a CON of 13376427 12/06/2011 PAT 8878905

13376427 is a 371 of PCT/DK2010/050148 06/17/2010

PCT/DK2010/050148 has PRO of 61231118 08/04/2009

PCT/DK2010/050148 has PRO of 61187744 06/17/2009

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

12/06/2021

STATE OR COUNTRY

DENMARK

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UNITED STATES

FILING FEE RECEIVED

$7,160

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	17533403
Filing Date	2021-11-23
First Named Inventor	Rune Fisker
Art Unit	2484
Examiner Name	Jose M Mesa
Attorney Docket Number	0079124-000370-T1

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.M.M/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	17533403
Filing Date	2021-11-23
First Named Inventor	Rune Fisker
Art Unit	2484
Examiner Name	Jose M Mesa
Attorney Docket Number	0079124-000370-T1

	1	WELCH et al., "High-Performance Wide-Area Optical Tracking The HiBall Tracking System", Presence: Teleoperators and Virtual Environments, Vol. 10, No. 1, February 2001, pp. 1-22.	☐
	2	WELCH et al., "Motion Tracking: No Silver Bullet, but a Respectable Arsenal", IEEE Computer Graphics and Applications, Vol. 22, No. 6, December 10, 2002, pp. 24-38.	☐
	3	WILSON et al., "Confocal Microscopy by Aperture Correlation", Optics Letters Vol. 21, Issue 23, 1996, pp. 1879-1881 (4 pages).	☐
	4	WILSON et al., "Real-Time Three-Dimensional Imaging of Macroscopic Structures", Journal of Microscopy, Vol. 191, No. 2, August 1998, pp. 116-118.	☐
	5	XIA et al., "Three-Dimensional Virtual-Reality Surgical Planning and Soft-Tissue Prediction for Orthognathic Surgery", IEEE Transactions on Information Technology in Biomedicine, Vol.5, No.2, June 2001, pp. 97-107.	☐
	6	YOSHIDA et al., "Intraoral Ultrasonic Scanning as a Diagnostic Aid", Journal of Cranio-Maxillofacial Surgery, Vol. 15, 1987, pp. 306-311.	☐
	7	ZHANG et al., "A 3-dimensional Vision System for Dental Applications", Proceedings of the 29th Annual International, August 23-26, 2007, pp. 3369-3372.	☐
	8	BOWMAN et al., "3D User Interfaces Theory and Practice § 4.1.1 "Input Device Characteristics" pp 88- 89; § 4.2.2 "2D Mice and Trackballs" pp 91-92; § 4.8.2 "Input Device Taxonomies" pp 128-132", (IPR2018-00197, Ex. 2013), 2005, 20 pages.	☐
	9	SCHENDEL et al., "3D Orthognathic Surgery Simulation Using Image Fusion", Seminars in Orthodontics, Vol 15, No 1, March 2009, pp. 48-56 (11 pages).	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/JOSE M MESA/	Date Considered	04/27/2022

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.M.M/

PE2E SEARCH - Search History (Prior Art)

There are no Prior Art searches to show.

PE2E SEARCH - Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
N14	75	(hollenbeck-karl-josef).in.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:23 PM
N15	21	(qazi-arish-a).in.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:23 PM
N16	65	(van-der-poel-mike).in.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:23 PM
N17	11	(kjaer-rasmus).in.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:24 PM
N18	61	(ojelund-henrik).in.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:24 PM
N19	203	(fisker-rune).in.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:24 PM
N20	6	(tim$5 WITH (var$4 chang$4 modif$4 alter$4) WITH (illuminat$4 light$4) WITH pattern WITH (teeth tooth)).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:24 PM
N21	7	(tim$4 near60 var$4 near60 illuminat$4 near60 line near60 pattern).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:25 PM
N22	7	(segment$4 near60 ((led) light near2 emitting near2 diode) near60 scanner).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:25 PM
N23	50	(tim$4 WITH (var$4 chang$4 modif$4 alter$4) WITH (illuminat$4 light$4) WITH pattern WITH (teeth tooth object) WITH dimensions).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:26 PM
N24	4	(tim$4 near50 (var$4 chang$4 modif$4 alter$4) near50 (illuminat$4 light$4) near50 pattern near50 (teeth tooth)).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:26 PM
N25	14	(camera near2 two near2 cameras) near50 (tooth teeth).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2022/04/27 02:27 PM

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Art Unit	2484
Examiner Name	Jose M Mesa
Attorney Docket Number	0079124-000370-T1

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Examiner Signature	/JOSE M MESA/	Date Considered	04/27/2022

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.M.M/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
	)	
Rune FISKER	)	Group Art Unit: 2484
	)	
Application No.: 17/533,403	)	Examiner: Jose M. Mesa
	)	
Filed: November 23, 2021	)	Confirmation No.: 9694
	)	
For: INTRAORAL SCANNING APPARATUS	)	
	)	
	)	
	)	

AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In response to the RCE filed on April 22, 2022, please amend the application as follows:

AMENDMENTS TO THE SPECIFICATION:

Please amend the title as follows:

~~FOCUS~~ INTRAORAL SCANNING APPARATUS

REMARKS

Should any questions arise in connection with this application, it is respectfully requested that the undersigned be contacted at the number indicated below.

Respectfully submitted,

BUCHANAN INGERSOLL & ROONEY PC

Date April 25, 2022

By: /WCRowland/
William C. Rowland
Registration No. 30,888

Customer No. 21839
703 836 6620

Electronic Acknowledgement Receipt

EFS ID:	45549086
Application Number:	17533403
International Application Number:	
Confirmation Number:	9694
Title of Invention:	FOCUS SCANNING APPARATUS
First Named Inventor/Applicant Name:	Rune FISKER
Customer Number:	21839
Filer:	William C. Rowland/Stacey Pflieger
Filer Authorized By:	William C. Rowland
Attorney Docket Number:	0079124-000370-T1
Receipt Date:	25-APR-2022
Filing Date:	23-NOV-2021
Time Stamp:	12:02:19
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		370amd.pdf	83425 dcf815e5e22fe3b08a5eeab36a2cd8b9d002222d	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Request for Reconsideration-After Non-Final Rejection	1	1
	Specification	2	2
	Applicant Arguments/Remarks Made in an Amendment	3	3
Warnings:			
Information:			
	Total Files Size (in bytes):	83425	

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

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New International Application Filed with the USPTO as a Receiving Office

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Based on USPTO Form PTO/SB/08

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	
	First Named Inventor	Rune FISKER
	Art Unit	
	Examiner Name	
	Attorney Docket Number	0079124-000370-T1

	68	8564657	B2	2013-10-22	Michalke, et al.	
	69	8743114	B2	2014-06-03	Kim, et al.	
	70	8867820	B2	2014-10-21	Peeper, et al.	
	71	3878905	B2	~~2014-11-04~~ 04/1975	~~Fisker, et al.~~ Schaumann	
	72	8897526	B2	2014-11-25	Macleod, et al.	
	73	9185388	B2	2015-11-10	Mcnamer, et al.	
	74	9208612	B2	2015-12-08	Frahm, et al.	
	75	9299192	B2	2016-03-29	Kopelman, Avi	
	76	9322646	B2	2016-04-26	Pochiraju, et al.	
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	81	10097815	B2	2018-10-09	Fisker, et al.	
	82	10326982	B2	2019-06-18	Fisker, et al.	
	83	10349041	B2	2019-07-09	Fisker, et al.	
	84	10595010	B2	2020-03-17	Fisker, et al.	
	85	11051002	B2	2021-06-29	Fisker, et al.	

Change(s) applied to document, /D.M./ 4/12/2022

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	20030096210	A1	2003-05-22	Rubbert, et al.	
	2	20030164952	A1	2003-09-04	Deichmann, et al.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.M.M/

Electronic Acknowledgement Receipt

EFS ID:	45539336
Application Number:	17533403
International Application Number:	
Confirmation Number:	9694
Title of Invention:	FOCUS SCANNING APPARATUS
First Named Inventor/Applicant Name:	Rune FISKER
Customer Number:	21839
Filer:	William C. Rowland/Stacey Pflieger
Filer Authorized By:	William C. Rowland
Attorney Docket Number:	0079124-000370-T1
Receipt Date:	22-APR-2022
Filing Date:	23-NOV-2021
Time Stamp:	15:48:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	9329675_Institution_Decision_IPR201800197.pdf	1873943 9c9c53cbf39f8963216ce4d52c79fddd04df4b38	no	32

Warnings:

Information:					
2	Non Patent Literature	9329675_Patent_Owner_Response_IPR201800197.pdf	2699092 e05db052f2c39f2cc37a382a75662ebb62db082d	no	57
Warnings:					
Information:					
3	Non Patent Literature	9329675_Patent_Owner_Submission_IPR201800197.pdf	5371777 28c9ac6fa581fc1460f8259579ad16f39fb77ccd	no	42
Warnings:					
Information:					
4	Non Patent Literature	9329675_Petitioner_Align_Technology_Inc_Reply_to_Patent_IPR201800197.pdf	1746984 3c670dbb3626fb9cb7a8e9845c27fdc6c422f535	no	35
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5	Non Patent Literature	9329675_Petitioners_Align_Technology_IPR2019800198.pdf	685196 e873890426025403bef67a758ce857ecd6ef48ed	no	14
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6	Non Patent Literature	9329675_Petitioners_Demonstratives_IPR201800197.pdf	2901043 9ce45f239fce70e22e2be29729a9f9130e50a60e	no	30
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7	Non Patent Literature	9329675_Record_of_Oral_Hearing_IPR201800197.pdf	5027184 95cb7e88f57bc7874c8344d3dc62943e0ca545c5	no	67
Warnings:					
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8	Non Patent Literature	AHN_Development_of_Three.pdf	1298514 db53ae64e9ec3f330f81dd3ac47ff4ef55ed6102	no	9
Warnings:					
Information:					

9	Non Patent Literature	BOWMAN_3D_User_Interfaces.pdf	3548416 bd8d636412f7a6f57f66d0cb018d73f054922660	no	20
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10	Non Patent Literature	BOWMAN_3D_User_Interfaces_Theory_and_Practice.pdf	1286713 9776ff93909eea8d23b3d3f5dd82463fc3a26e66	no	9
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11	Non Patent Literature	CHUA_SonoDEX.pdf	791987 cc6e5c2316a32a79f93f87c56e8866cf369957e0	no	6
Warnings:					
Information:					
12	Non Patent Literature	CN201180066956_6_CNOA_04032015.pdf	1401767 8f96ad0fbd2bd1cd52f56f7f138ddc6877eed04a	no	13
Warnings:					
Information:					
13	Non Patent Literature	RE48221_Declaration_of_Dr_Chandrajit_Bajaj_IPR2022-00145.pdf	24926371 acfb06716aecd12a7b320e8a5aad044062ed7103	no	377
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14	Non Patent Literature	9329675_File_History_Part_1.pdf	20352022 b6108e022ca704023c61edbe908b71845c30eb8f	no	300
Warnings:					
Information:					
15	Non Patent Literature	9329675_File_History_Part_2.pdf	17989355 94f5101e3fff5b9c0063dcbd21bf00130ffc5419	no	325
Warnings:					
Information:					

16	Non Patent Literature	RE48221_File_History_Part_1.pdf	21541359 196f70c6a45f011cb33273bbdac5311381f39eae	no	383
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17	Non Patent Literature	RE48221_File_History_Part_2.pdf	23379691 beb1e924bfc5b718c1b77a2612bf8ec586aa7928	no	426
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18	Non Patent Literature	RE48221_File_History_Part_3.pdf	12845863 c04a18475c8bbbdbb5a2fbdbb48c801e60a43678	no	195
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19	Non Patent Literature	Declaration_of_Dr_Chandrajit_L_Bajaj_IPR201800197.pdf	5927186 d094643aecd1dbe72fa30143b5390a8f40a5d3ed	no	142
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		Total Files Size (in bytes):	155594463		

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<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
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If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Espacenet

Bibliographic data: CN101513350 (A) — 2009-08-26

Device and method for displaying medical image and imaging system

Inventor(s): ROBERT KAGERMEIER [DE]; EIKE RIETZEL [DE]; STEFFEN SCHROETER [DE]; DIETMAR SIERK [DE] ± (KAGERMEIER ROBERT, ; RIETZEL EIKE, ; SCHROETER STEFFEN, ; SIERK DIETMAR)

Applicant(s): SIEMENS AG [DE] ± (SIEMENS AG)

Classification: - **international:** *A61B5/055; A61B6/03; A61B8/13; G06F3/033; G06F3/0346; G06F3/048; G06F3/0484; G09F9/00*
- **cooperative:** A61B6/548 (EP,US); G06F3/0346 (EP,US); G06F3/04845 (EP,US)

Application number: CN20091007572 20090223

Priority number(s): DE20081010717 20080222

Also published as: DE102008010717 (A1) US2009217207 (A1)

Abstract of CN101513350 (A)

The invention relates to a device (1) for displaying three-dimensional medical image information (B3). The device includes a processing unit (2), a display (3), a remote control (10), a communication interface, and a software module (7). The processing unit (2) is operable to process the medical image information. The display (3) is operable to display the medical image information (B3). The remote control (10) is operable to register a user movement (B) by at least one motion-sensitive sensor (11, 12). The communication interface is operable to transfer the user movement (B) to the processing unit (2). The software module (7) is associated with the processing unit (2). The software module (7) is operable to reconcile the user movement (B) with the medical image information (B3) so that the user movement (B) is reproduced as a virtual movement of the displayed medical image information (B3).

[19] 中华人民共和国国家知识产权局

[12] 发明专利申请公布说明书

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[51] Int. Cl.
A61B 6/03 (2006.01)
A61B 8/13 (2006.01)
A61B 5/055 (2006.01)
G09F 9/00 (2006.01)

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[11] 公开号 CN 101513350A

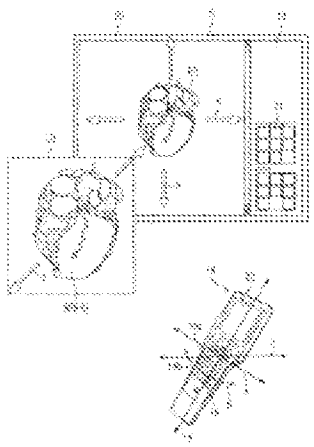
[22] 申请日 2009.2.23
[21] 申请号 200910007572.1
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[32] 2008.2.22 [33] DE [31] 102008010717.4
[71] 申请人 西门子公司
地址 德国慕尼黑
[72] 发明人 罗伯特·凯杰迈耶 艾克·里策尔
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[74] 专利代理机构 北京市柳沈律师事务所
代理人 谢 强
权利要求书 3 页 说明书 8 页 附图 4 页

[54] 发明名称

用于显示医学图像信息的装置和方法以及成像系统

[57] 摘要

本发明涉及一种用于显示三维的医学图像信息(B3)的装置(1)，包括：用于处理图像信息(B3)的处理单元(2)；用于显示图像信息(B3)的显示元件(3)；用于借助至少一个运动敏感的传感器(11，12)采集使用者移动(B)的遥控器(10)；以及将使用者移动(B)传输到处理单元(2)的通信接口。借助所述处理装置(2)配备的软件模块(7)，与图像信息(B3)一起如下计算使用者移动(B)：将使用者移动(B)理解为所显示的图像信息(B3(PI))的虚拟运动。



1. 一种用于显示三维医学图像信息（B3）的装置（1），包括：

- 用于处理图像信息（B3）的处理单元（2），

- 用于显示图像信息（B3）的显示元件（3），

- 用于借助至少一个运动敏感的传感器（11，12）采集使用者移动（B）的遥控器（10），

- 将使用者移动（B）传输到处理单元（2）的通信接口，以及

- 所述处理装置（2）配备的、用于与图像信息（B3）一起如下计算使用者移动（B）的软件模块（7）：将所述使用者移动（B）理解为所显示的图像信息（B3（PI））的虚拟运动。

2. 根据权利要求 1 所述的装置（1），其中，所述医学图像信息是三维图像信息（B3）。

3. 根据权利要求 1 或 2 所述的装置（1），其中，所述传感器是具有一个或多个测量轴线的加速度传感器（11）。

4. 根据权利要求 1 至 3 中任一项所述的装置（1），其中，所述传感器是具有一个或多个测量轴线的转动率传感器（12）。

5. 根据权利要求 1 至 4 中任一项所述的装置（1），其中，所述遥控器（10）具有至少一个加速度传感器（11）和至少一个转动率传感器（12）。

6. 根据权利要求 1 至 5 中任一项所述的装置（1），其中，作为所述通信接口（16）设置了无线电连接。

7. 根据权利要求 1 至 6 中任一项所述的装置（1），其中，所述遥控器（10）具有若干用于选择各个显示模式的显示选择转换开关（14），并且其中，根据所选择的显示模式将所述使用者移动（B）转换为虚拟运动。

8. 根据权利要求 7 所述的装置（1），其中，所述遥控器（10）至少具有一个用于医学诊断或治疗设备（4）的遥控器的操作选择转换开关（15）。

9. 根据权利要求 1 至 8 中任一项所述的装置（1），其中，在静止位置设置用于容纳所述遥控器（10）的容纳装置（17）。

10. 根据权利要求 9 所述的装置（1），其中，所述容纳装置（17）具有弹性支座（18）。

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11. 一种用于显示三维医学图像信息（B3）的方法，其中，

- 利用借助至少一个运动敏感的传感器（11，12）的遥控器（10）采集使用者移动（B），

- 将所述使用者移动（B）理解为所显示的图像信息（B3（PI））的虚拟运动。

12. 根据权利要求 11 所述的方法，其中，借助单轴的或多轴的加速度传感器（11）测量所述使用者移动（B）。

13. 根据权利要求 11 或 12 所述的方法，其中，借助单轴的或多轴的转动率传感器（12）测量所述使用者移动（B）。

14. 根据权利要求 11 至 13 中任一项所述的方法，其中，借助至少一个加速度传感器（11）和至少一个转动率传感器（12）测量所述使用者移动（B）。

15. 根据权利要求 11 至 14 中任一项所述的方法，其中，经过无线电连接进行数据的传输。

16. 根据权利要求 11 至 15 中任一项所述的方法，其中，选择显示模式，并且其中，根据所选择的显示模式将所述使用者移动（B）转换为所述虚拟运动。

17. 根据权利要求 16 所述的方法，其中，显示模式提供了，选择和在至少一个空间方向上移动放大的图像片段。

18. 根据权利要求 16 或 17 所述的方法，其中，显示模式提供了，围绕至少一个空间轴转动所显示的图像信息（B3（PI））。

19. 根据权利要求 16 至 18 中任一项所述的方法，其中，显示模式提供了，改变所显示的图像信息（B3（PI））的比例。

20. 根据权利要求 16 至 19 中任一项所述的方法，其中，显示模式提供了，改变所显示的图像信息（B3（PI））的对比度。

21. 根据权利要求 16 至 20 中任一项所述的方法，其中，显示模式共同地考虑利用加速度传感器（11）和利用转动率传感器（12）的测量，用于改变所显示的图像信息（B3（PI））。

22. 根据权利要求 16 至 21 中任一项所述的方法，其中，显示模式借助按照计算机鼠标（9）方式的使用者移动（B），允许操作作为工作位计算机运行的处理单元（2）。

23. 根据权利要求 16 至 22 中任一项所述的方法，其中，在预定的时间间

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隔上重复地采集所述使用者移动（B）。

24. 根据权利要求 16 至 23 中任一项所述的方法，其中，只有在所述使用者移动（B）超过预定的阈值时，才进行所述虚拟运动。

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DENTAL IMAGING

用于显示医学图像信息的装置和方法以及成像系统

技术领域

本发明涉及一种用于显示医学图像信息的装置和方法以及一种具有这样的装置的成像系统。

背景技术

对于医学图像信息的产生来说存在不同的成像系统。在此，例如是计算机断层成像（CT）、正电子发射断层成像（PET）、单光子发射计算机断层成像（SPECT）或者磁共振断层成像（MRT）。借助成像系统可以确定人的身体区域的图像信息。以下将医学图像信息理解为可以用成像系统采集的图像信息。这里通常是二维的（2D）、三维的（3D）或四维的（4D）图像信息。二维的图像信息包括两个空间维。三维的图像信息包括三个空间维或者两个空间维和时间。四维的图像信息包括三个空间维和时间。只有在不同的时刻采集身体区域时，时间作为维才是有意义的。在心脏学中通常是在检查患者的心脏时关于可能的缺陷功能在不同的心跳阶段采集图像信息，对这些心跳阶段的检查具有时间戳。

图像信息在显示单元上、通常是在监视器上被显示。借助所显示的图像信息可以建立医生对相应的身体区域的检查结果。此外，通过在进行医学干预期间在不同的时间用成像系统测量图像信息并接着由医生进行检查，所显示的图像信息使得可以监控医学的干预。

图像信息的准备（Aufbereitung）和显示通过成像系统配备的、通常被构造为计算机系统的处理单元来进行。借助操作元件、如计算机键盘或计算机鼠标，可以改变在显示元件上显示的图像信息。为此，设置了软件模块，该软件模块可以通过计算机键盘或计算机鼠标选择不同的功能，如图像信息的局部放大、图像信息的旋转等等。因此，借助计算机键盘的光标键或借助计算机鼠标的滚动按钮来进行显示的实际修改。对于计算机键盘或对于计算机鼠标需要桌面等作为支撑垫。由此不可能将计算机键盘或计算机鼠标安置在患者支撑装置（如

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患者卧榻，其上安置了用于医学检查或干预的患者）的直接的附属区。特别是在执行医学干预时医生由此必须不断地在患者支撑装置和计算机键盘或计算机鼠标的位置之间变换位置，以便可以仔细查看医学干预的进程。

发明内容

由此本发明要解决的技术问题是，提供一种用于显示三维医学图像信息的装置，借助该装置可以按照用户友好的简单方式修改所显示的图像信息。

按照本发明，上述技术问题的解决是通过一种用于显示三维医学图像信息的装置实现的。为此设置了用于处理图像信息的处理单元和用于显示图像信息的显示元件。在此，处理单元特别地被构造为计算机系统，为该计算机系统配备有被构造为监视器的显示元件。此外，还设置了用于借助至少一个运动敏感的传感器采集使用者移动的遥控器。另外设置了将使用者移动传输到处理单元的通信接口。为处理单元配备有用于与图像信息一起计算使用者移动的软件模块。如下进行该计算：将使用者移动理解为在显示元件上所显示的图像信息的虚拟运动。以这种方式将使用者移动按照直观方式转换为在显示元件上的图像信息的类似运动。遥控器的支撑垫（如桌面等）不再是必须的。由此医生可以随身携带遥控器并且从成像系统周围的每个位置对所显示的图像信息进行改变。尤其是在显示元件的足够大尺寸的前提条件下，医生在进行医学干预的情况下不再必须不断地改变其位置，以便根据图像信息评价医学干预的进程。这样明显更快地并且由此对患者来说更体贴地进行医学干预。

在一种优选变形中，传感器是具有一个或多个测量轴线的加速度传感器。这样的加速度传感器例如在 US5540095 中被描述过。借助加速度传感器采集遥控器的平移运动作为使用者移动。如果是具有三个测量轴线的加速度传感器，则可以在三个空间方向上的每一个上采集遥控器的运动。使用者移动被转换为在显示元件上的图像信息的相应的平移运动。

在另一种优选变形中传感器是具有一个或多个测量轴线的转动率传感器（Drehratensensor），按照专业术语也称为陀螺仪（Gyroskop），例如在 US 6505511 B1 中被描述过。借助转动率传感器可以采集遥控器的转动或旋转运动作为使用者移动，其被理解为所显示的图像信息的转动运动或旋转。如果转动率传感器是三轴的转动率传感器，则可以用它采集遥控器的任意转动作为使用者移动并且将其理解为所显示的图像信息的虚拟运动。

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在一种具有优势的扩展中，遥控器具有至少一个加速度传感器和至少一个转动率传感器。如果这两个传感器都是三轴的传感器，则借助其可以采集遥控器在空间的任意运动作为使用者移动并且将其理解为所显示的图像信息的虚拟运动。按照这种方式可以完全直观地改变在显示元件上显示的图像信息。

在一种优选扩展中，作为通信接口设置了无线电连接。由此可以将使用者移动无线传输到处理单元。换言之，检查的医生的运动自由不受任何在遥控器和处理单元之间作为通信连接的电缆连接的情况下的限制。

在一种合适的扩展中，遥控器具有若干用于选择各个显示模式的显示选择转换开关。根据所选择的显示模式将使用者移动转换为图像信息的虚拟运动。换言之，当事先操控了相应的显示选择转换开关时，才将使用者移动转换为所显示的图像信息的运动。由此可靠地避免了通过无意的遥控器运动和作为使用者移动的对运动的不期望的配准（Registrierung）引起的所显示的图像信息的错误调整。

在一种优选扩展中，遥控器至少具有一个用于医学诊断或治疗设备的遥控器的操作选择转换开关。换言之，可以借助遥控器来触发医学诊断或治疗设备的功能。例如，可以在医学信息的范围内触发对更新的图像信息的记录，以便将医学干预的进程作为图像信息变得可视。例如，在X射线治疗设备中，为了有针对地照射患者，可以开启或关闭治疗用的射线例如X射线或粒子射线。此外具有优势的是，借助遥控器来触发医学干预。在此，例如可以是注射对比剂或触发热的或电的治疗技术。可以借助遥控器来进行植入物例如近距离治疗（Brachytherapie）中的种子（Seed）、或者在对心脏的干预中的支架的放置。

在一种合适的变形中，在静止位置设置用于容纳遥控器的容纳装置。该容纳装置例如被设置在被构造为患者卧榻的患者支撑装置的扶手上。该容纳装置容纳遥控器，使得医生双手都可以自由地进行干预。因为容纳装置被设置在患者支撑装置上或者在其紧邻处，所以遥控器始终处于医生可到达的范围。

容纳装置优选地具有弹性支座。换言之，还可以（可能受限制地）移动由容纳装置容纳的遥控器。由此对于进行简单的移动不必额外地将遥控器从其容纳装置中取出。医生在进行移动之后可以立即使其双手解放，以便继续进行医学干预。

此外，本发明的技术问题还通过一种用于显示三维医学图像信息的方法解决。为此，用遥控器借助至少一个运动敏感的传感器采集使用者移动。接着借

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助通信接口将使用者移动传输到处理单元。使用者被移动理解为所显示的图像信息的虚拟运动。在此，针对用于显示三维的医学图像信息的装置的变形及其优选实施方式可以被对应地转移到所述方法。

优选地，显示模式提供了选择和在至少一个空间方向上移动图像信息的放大的图像片段。为此，合适地借助加速度传感器仅仅采集遥控器的平移运动。在此，例如借助被构造为按键的显示选择转换开关来进行显示模式的选择。在此，在激活显示模式的情况下首先放大地显示图像片段、优选地在显示元件上所显示的图像信息的中间图像片段。接着借助使用者移动可以移动该图像片段，直到图像片段中感兴趣的图像信息以放大的形式被显示。此外合适地的是，连续多次操控相应的显示选择转换开关可以逐渐地改变图像片段和逐渐放大所显示的图像信息。

此外，还可以优选地互相组合不同的功能。在二维的（2D）图像信息情况下遥控器在平面中的运动可以被理解为图像片段的改变，并且从平面出发的向上或向下运动被理解为所显示的图像信息的放大或者缩小。

合适地，显示模式提供了围绕至少一个空间轴转动所显示的图像信息。为此，合适地借助转动率传感器仅采集遥控器的旋转运动。按照这种方式可以将所显示的图像信息一直转动，直到在显示元件上感兴趣的图像信息可以被良好地看清并且由此可以检查。

优选地，显示模式提供了改变所显示的图像信息的比例。换言之，所显示的图像信息通过遥控器的平移运动或通过旋转运动被无级地放大或缩小地显示。

合适地，显示模式提供了改变所显示的图像信息的对比度。换言之，对比度通过遥控器的平移运动或通过遥控器的旋转运动被无级地增大或减小。在以灰度图表示的图像信息中无级地变换通常由255个灰度值组成的灰度级。以这种方式可以按照简单的方式对检查呈现最好可能的对比度。

在一种优选变形中，显示模式共同地考虑用加速度传感器和用转动率传感器的测量，用于改变所显示的图像信息。由此产生用于直观地改变图像信息的多种可能性。

在三维（3D）图像信息的情况下，在平移运动时可以移动所显示的图像片段，并且在遥控器转动时进行所显示的图像信息的放大或缩小。由此，例如遥控器的左旋可以导致所显示的图像的放大以及遥控器的右旋导致所显示的图像

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信息的缩小。

如果呈现一个序列的四维（4D）图像信息，则例如又可以将平移运动转换为所显示的图像片段的改变。遥控器的旋转运动可以根据旋转方向而导致选择前面的或后面的图像信息。

在一种优选变形中，显示模式借助按照计算机鼠标方式的使用者移动，使得可以操作作为工作位计算机（Arbeitsplatzrechner）运行的处理单元。为此，合适地在遥控器上附加设置一个或多个操作按键。在操控这样的按键时，特别地仿真计算机鼠标的左键或右键的操控。通过两次直接连续操控操作键模仿如通常双击鼠标左键以开始程序等等那样的双击。换言之，借助遥控器可以遥控工作位计算机，而无需为此改变其位置。

优选地，如下构造在遥控器和计算机系统之间的通信接口：使得该通信接口关于传输到计算机系统上的控制信号与计算机鼠标的标准接口相应。以这种方式可以按照通常的方式按照完全的功能范围使用在计算机系统的操作系统上安装的软件模块。由此，不需要与相应的编程成本相关的软件模块的匹配或者程序改编。

因为为显示图像信息而设置的软件模块通常是为借助计算机鼠标的操作而设置，所以优选也可以用遥控器进行软件模块的完全的操作。由此，用户通过按照计算机鼠标的方式使用遥控器，例如可以选择图像片段。接着可以用已经描述的显示模式例如通过遥控器的平移运动或通过旋转运动进行所显示的图像信息的改变。换言之，在显示元件上显示的图像信息也可以通过多个显示模式的连续切换而被改变。

合适地，在预定的时间间隔上重复地采集使用者移动并且在该时间间隔上求平均。以这种方式缓和了遥控器的突然的和剧烈的运动。

优选地，只有在使用者移动超过预定的阈值时，才将其转换为虚拟的运动。以这种方式避免了在遥控器仅仅微小偏转的情况下就立即进行所显示的图像信息的改变。

此外，本发明的技术问题还通过具有用于显示三维图像信息的装置的医学诊断或治疗设备解决。在此，针对用于显示三维的图像信息的装置的变形及其优选实施方式可以被对应地转移到所述医学诊断或治疗设备。

附图说明

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下面结合附图更详细描述本发明的实施例。在附图中：

图 1 示出了用于显示三维医学图像信息的装置的示意图，

图 2 示出了所述装置的第一运行模式，

图 3 示出了所述装置的第二运行模式，以及

图 4 示出了所述装置的第三运行模式。

具体实施方式

图 1 示出了用于显示三维医学图像信息 1 的装置，具有被构造为计算机系统的处理单元 2 和连接到处理单元上的并且被构造为监视器的显示元件 3。装置 1 与医学成像系统 4 相关联，后者例如被构造为计算机断层成像（CT）、正电子发射断层成像（PET）、单光子发射计算机断层成像（SPECT）或者磁共振断层成像（MRT）。借助医学成像系统 4 测量原始数据 R，该原始数据 R 由处理单元 2 所配备的计算单元 5 计算。在此，生成三维医学图像信息 B3 并且在显示元件 3 上显示。在计算机断层成像中作为原始数据 R 测量投影图像，该原始数据 R 由被构造为重建计算机的计算单元 5 转换为三维医学图像信息 B3。软件模块 7 用于准备图像信息 B3。计算机键盘 8 和计算机鼠标 9 作为操作元件分别借助接口 8'、9'连接到处理单元 2。借助操作元件 8、9 通过控制信号 St 访问软件模块 7 并且借助用户界面准备图像信息 B3。按照这种方式可以改变在显示器 6 上显示的图像信息 B3。因此，可以放大图像信息 B3 的一个片段并且借助计算机键盘 8 的光标键或借助计算机鼠标的滚动按钮移动该片段。以类似的方式可以旋转或倾斜（Verkippen）所显示的图像信息 B3。

此外，为装置 1 配备了遥控器 10。遥控器 10 包括三轴的加速度传感器 11 和三轴的转动率传感器 12。借助这两个传感器 11、12 可以采集遥控器 10 的任意的使用者移动 B。为此，由加速度传感器测量位置信息 PI1 并且由转动率传感器 12 测量位置信息 PI2，并且传输到处理单元 13。此外设置了多个显示选择转换开关 14，其开关状态 S1 被传输到处理单元 13。另外设置了多个操作选择转换开关 15，其开关状态 S2 同样被传输到处理单元 13。根据显示选择转换开关 14 的开关状态 S1，处理单元 13 准备由传感器 11、12 测量的位置信息 PI1、PI2 并且借助通信接口 16 将其作为位置信息 PI 传输到处理单元 2。位置信息 PI 与图像信息 B3 一起由软件模块 7 如下计算：将使用者移动 B 理解为所显示的图像信息 B3（PI）的虚拟运动。换言之，根据所显示的图像信息 B3（PI）理

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解遥控器 10 的任意的使用者移动 B。这可以非常直观地改变所显示的图像信息 B3（PI）。

操作选择转换开关 15 的开关状态 S2 借助处理单元 13 经过通信接口 16 被传输到处理单元 2 并且从那里被传输到医学成像系统 4。根据医学成像系统 4 的不同的实现，借助遥控器 10 可以远程控制设备功能。例如，借助遥控器 10 在计算机断层成像中可以触发用于产生新的原始数据 R 以及由此产生新的三维医学图像信息 B3 的扫描。如果医学成像系统是医学治疗装置的部分，则可以借助操作选择转换开关 15 开启或者关闭用于放射疗法的微粒辐射。

医学成像系统 4 配备有用于遥控器 10 的容纳装置 17。容纳装置 17 具有弹性支座 18，例如弹簧臂（Federarm）等等，遥控器 10 借助该支座被固定在成像系统 4 的组件上。在此，例如是在图 1 中未示出的患者卧榻的扶手。

总之，主治医生相应地从任意的位置既可以触发成像系统 4 的功能，也可以对所显示的图像信息 B3（PI）进行改变。由此，主治医生不必赶到处理单元 2 处并且借助计算机键盘 8 或计算机鼠标 9 在那里来触发功能。而是他可以集中精神于其医生的任务例如进行医学的干预。根据需要可以触发借助医学成像系统 4 用于产生新的图像信息 B3 的新的测量，以便监控医学干预的进程。借助遥控器修改在显示器 6 上所显示的图像信息 B3（PI），以便可得到最佳的检查结果。接着根据该检查结果继续进行医学的干预。

如果不需要遥控器 10，则将其置于容纳装置 17 中。借助容纳装置 17 的弹性支座 18，主治医生可以进行使用者移动 B，其被转换成图像信息 B3（PI）的虚拟运动，即使也许是受限的移动可能性。

图 2 示出了显示元件 3 的显示器 6，在该显示器 6 上示出了用户界面 19。该用户界面 19 具有菜单列表 20 和若干按键 21，借助其可以访问软件模块 7 的功能。在显示元件 3 的位置上的用户界面 19 的操作借助计算机键盘 8 或计算机鼠标 9，通过访问菜单列表 20 或按键 21 来进行。由此可以从计算机键盘 8 或计算机鼠标 9 的位置改变所显示的图像信息。

借助遥控器 10 进行对软件模块 7 的访问。遥控器 10 具有用于显示目前选择的运行模式的指示区域 22。通过操控显示选择转换开关 14a 可以选择第一显示模式并且在显示器 6 上显示图像信息 B3 的片段 23。此时，借助遥控器 10 的使用者移动 B 一直移动片段，直到所显示的图像信息 B3（PI）显示期望的片段 23。换言之，第一显示模式具有如下功能：仅仅分析借助加速度传感器 11 所测

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量的遥控器 10 在所有三个空间方向 x、y、z 上的平移运动并且将其转换为片段 23 在所有三个空间方向 x、y、z 上的移动以显示图像信息 B3（PI）。如果多次连续操纵了显示选择转换开关 14a，则片段 23 被逐步地放大。借助另一个显示选择转换开关 14b 又可以建立最初显示的图像信息 B3 并且再次退出第一显示模式。

图 3 如图 2 那样示出了显示元件 3 的显示器 6 和作为所显示的三维图像信息 B3 的心脏。借助遥控器 10 的显示选择转换开关 14b 可以选择遥控器 10 的第二显示模式。在所选择的第二显示模式中，仅仅分析遥控器 10 的旋转运动以及由此作为使用者移动 B 的遥控器 10 的转动率传感器 12 的测量信号，并且将其转换为所显示的图像信息 B3（PI）的转动或者说旋转。以这种方式，可以作为使用者移动 B 采集围绕空间轴 x、y、z 的任意的转动或者说旋转。换言之，随着遥控器 10 在所有三个空间方向上的转动，图像信息 B3 一直转动，直到用户感兴趣的图像信息 B3（PI）在显示器 6 上被显示。通过操控显示选择转换开关 14c 又可以显示最初的图像信息 B3 并且退出遥控器 10 的第二运行模式。

图 4 示出了处在通过操控显示选择转换开关 14d 所选择的第三显示模式之下的显示器 6。现在，在显示器 6 上不再看得见图像信息 B3，而是此时显示鼠标光标 24，借助该鼠标光标可以通过遥控器 10 在用户界面 19 上选择任意的程序功能。换言之，该第三显示模式对应于按照计算机鼠标 9 的方式操作用户界面 19。为此，如下处理利用加速度传感器 11 所测量的位置信息 PI1：仅仅分析作为使用者移动 B 的在两个空间轴 x，y 的方向上的运动并且将其转换为位置信息 PI。而对鼠标光标 24 的运动不考虑第三空间方向。在所示出的情况下所显示的图像信息 B3（PI）的虚拟运动对应于鼠标光标 24 的运动。此外，设置了两个操作按键 25，其在功能上对应于鼠标左键以及右键。由此遥控器 10 可以模仿计算机鼠标的所有功能。

通过再次操控显示选择转换开关 14d 可以再次退出第三显示模式。

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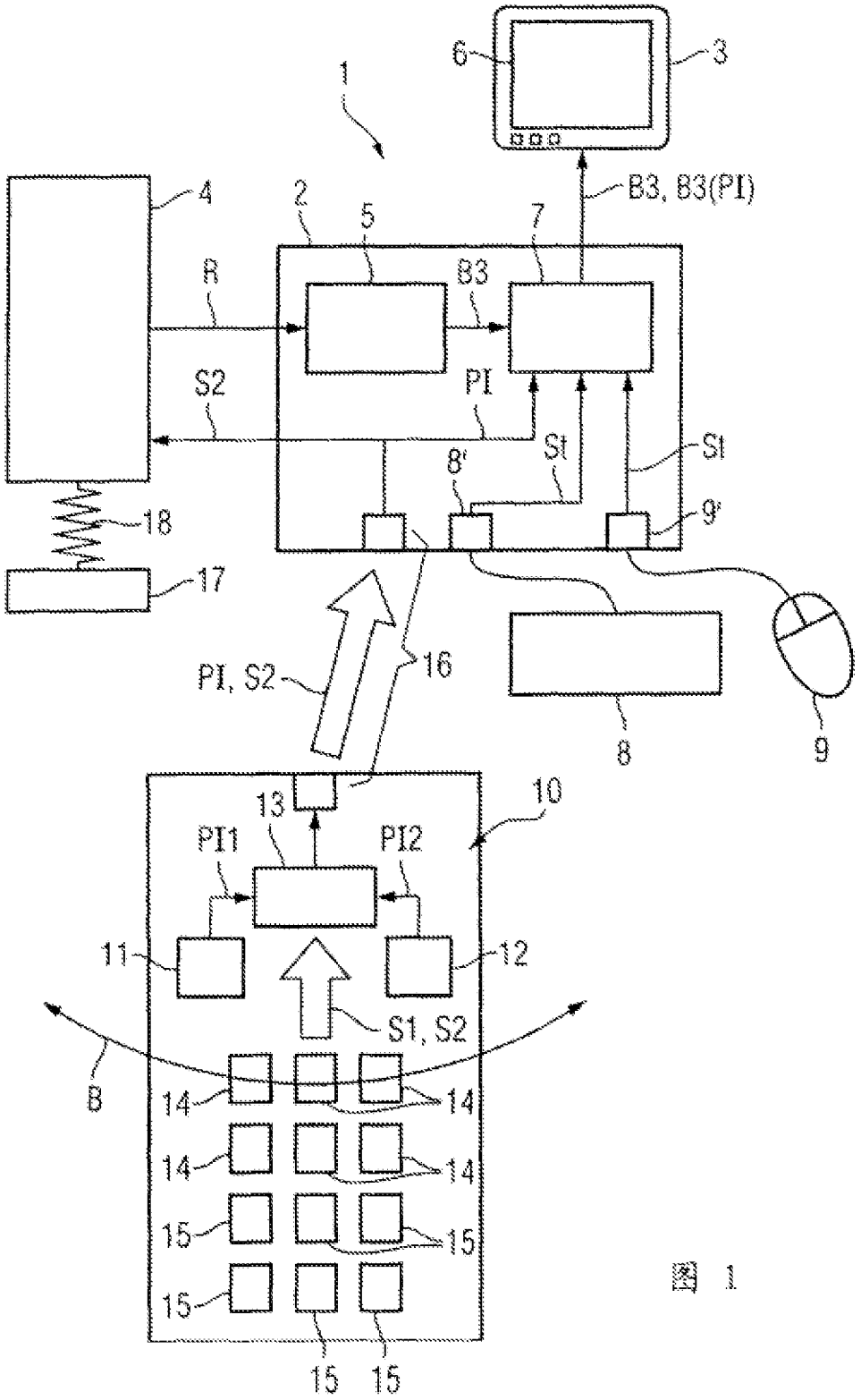


图 1

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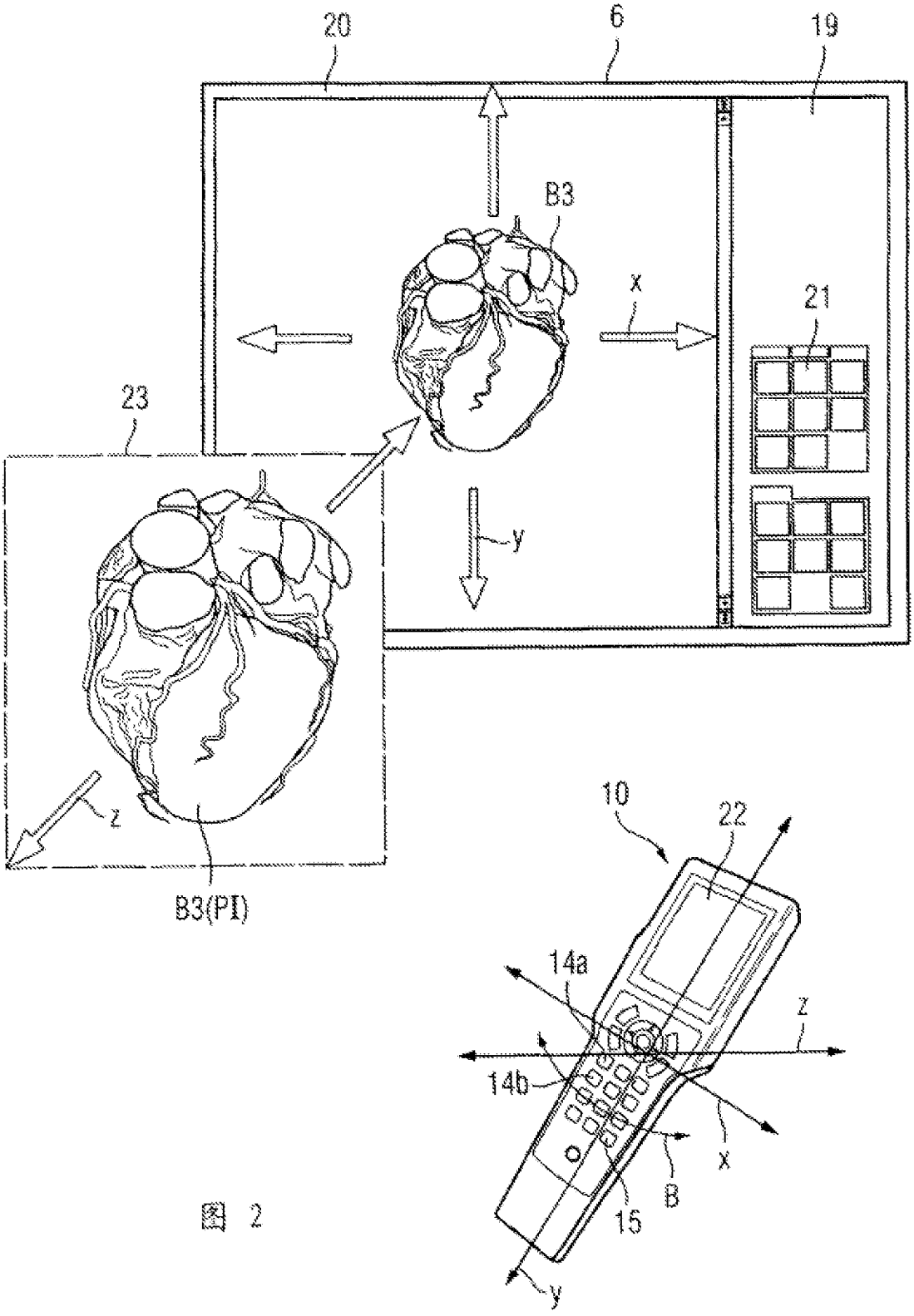
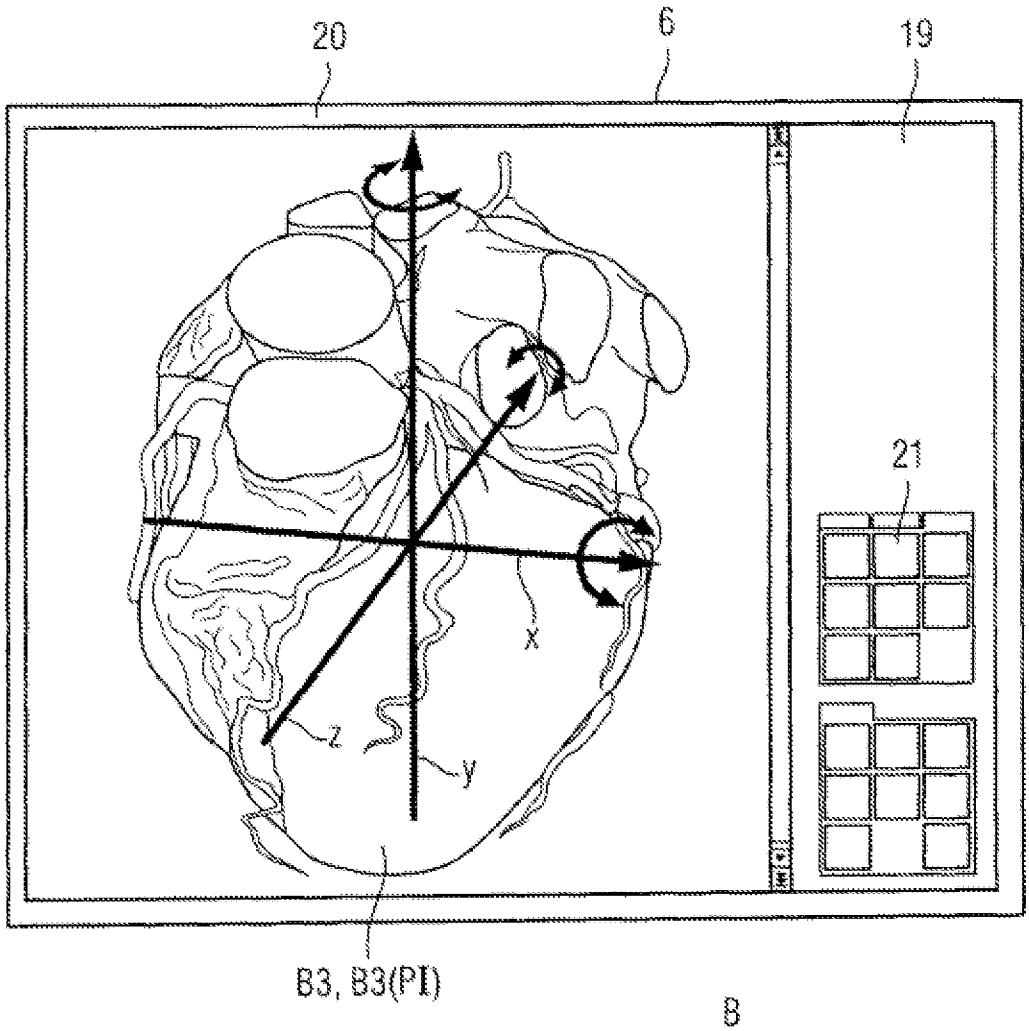


图 2

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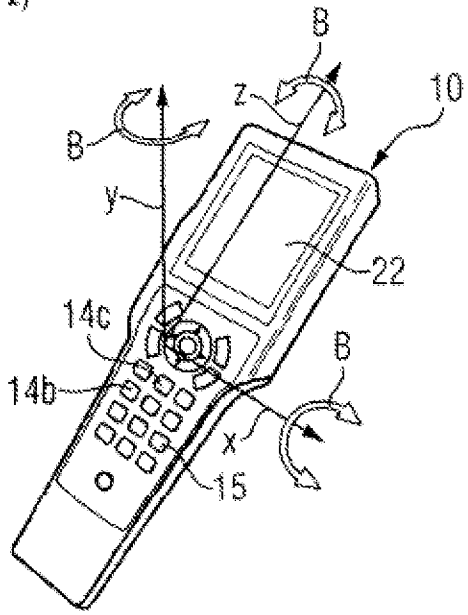
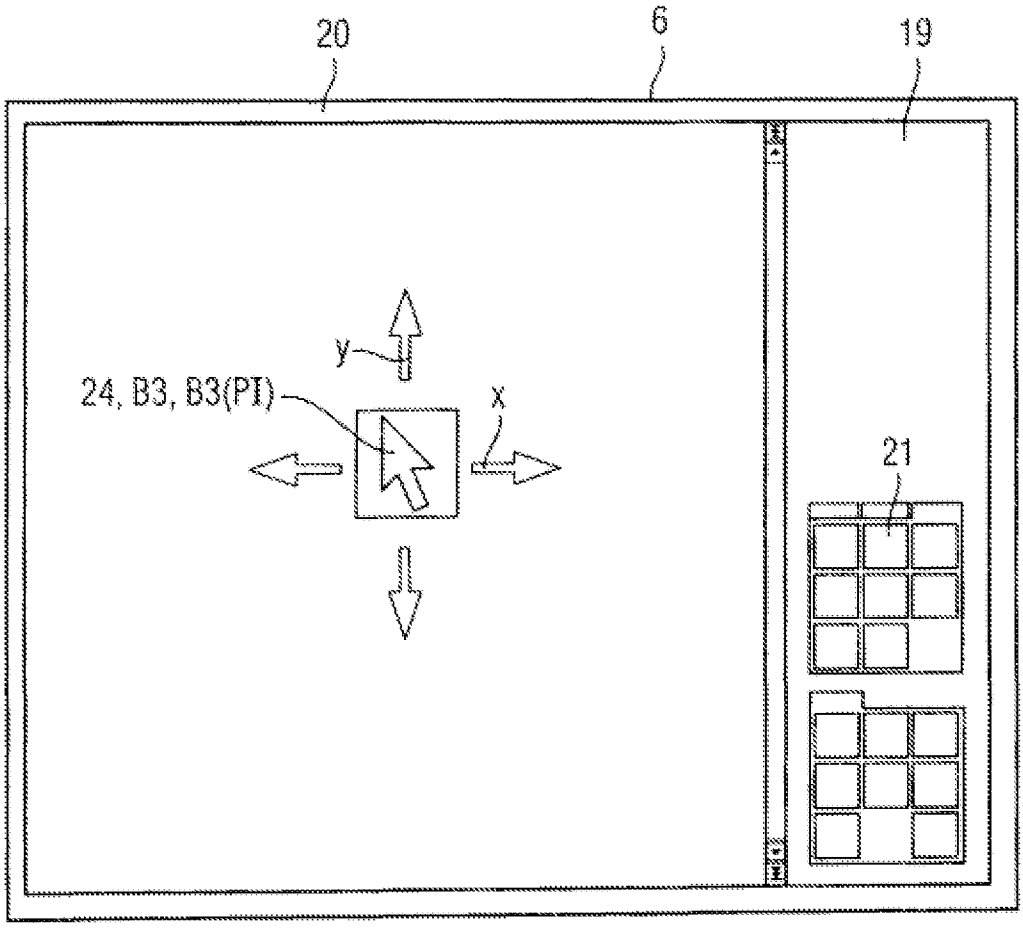


图 3

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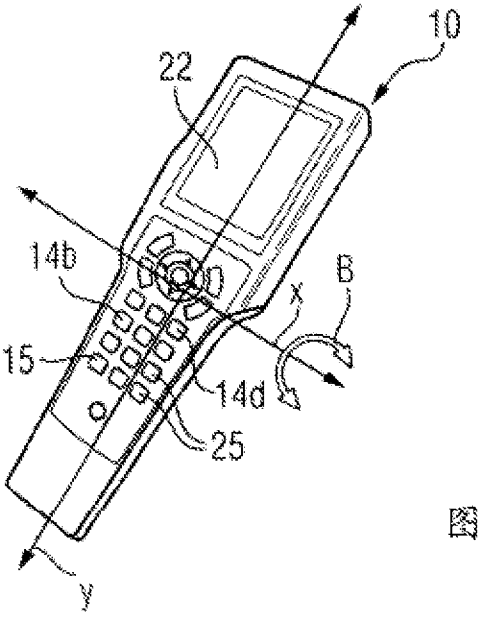


图 4

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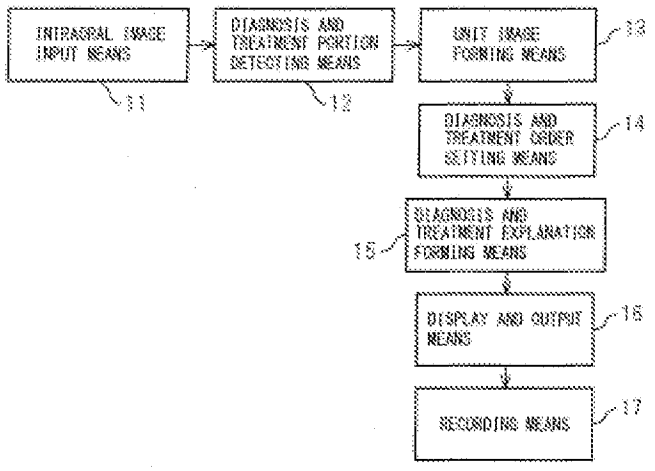
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(54) ORAL IMAGING AND DISPLAY SYSTEM

(57) A system configured provided with a continuously captured image sequence forming means for continuously capturing side surfaces of rows of teeth to form an image sequence, a side surface tooth row image forming means for combining sequences of images which were formed by the continuously captured image sequence forming means as partial tooth row images from an image forming the center of the overall composite so as to form a plurality of partial tooth row images, and a side surface tooth row image combining means for linking and combining a plurality of partial tooth row images which were formed by the side surface tooth row image forming means based on images forming the centers of the overall composite so as to form overall rows of teeth. By configuring the system in this way, it is possible to use a handheld type intraoral video camera to form a panoramic image of the side surface tooth rows for display on a computer monitor and propose a broad range of dental diagnosis and treatment to a patient and to secure participation of the patient in proactive dental diagnosis and treatment.

Fig.1A



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Fig.1B

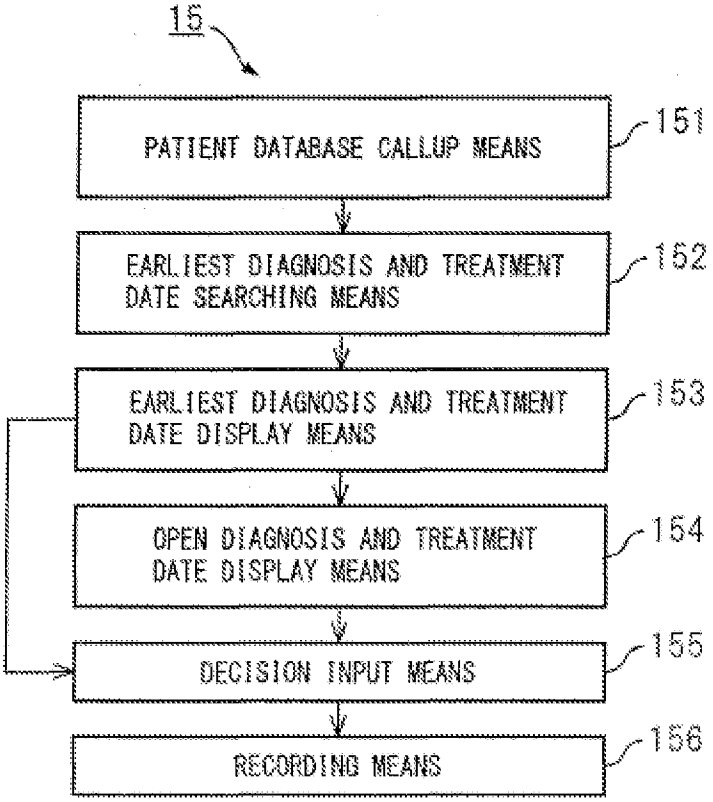


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Description

Technical Field

[0001] The present invention relates to a system which captures an image of the entire oral cavity and displays a panoramic image.

Background Art

[0002] In the treatment of tooth cavities and other intraoral diseases, when the target treatment ends, the visits to the clinic usually also end. Treatment of tooth decay usually starts when the patient becomes aware of tooth pain, discomfort, or other symptoms. When the treatment ends, the visits to the clinic also end. This is the usual pattern. Therefore, even if there is other tooth decay, if there are no noticeable symptoms, in many cases it is left alone - the clinic is visited only after the tooth decay advances. Further, with such one-time visits to the clinic, a healthy oral cavity is not secured. Staining, swelling, loss, tartar, wear, salivary calculus, mismatch, and other issues for which there are no subjective symptoms, but which can be seen from the outside after often unnoticed by the person in question.

[0003] For the business operations of a dental practice as well, one-time treatment sometimes cannot by any means be said to be good in terms of profitability, but there were no means found which were suitable for dealing with this. For example, PLT 1 discloses a configuration of an electronic patient chart in which the entire rows of teeth are displayed on a computer monitor and which the individual teeth are colored so as to enable easy viewing from the patient side. Ease of viewing the rows of teeth is a requirement which is sought in informed consent, but even if parts of the entire rows of teeth are easy to view, for use for explanations of treatment, greater enlargement and configuration for enabling understanding of the purpose of treatment are required.

[0004] Further, PLT 2 describes a configuration in which a plurality of sets of intraoral image data which is captured in advance are displayed on a monitor screen of a computer. Furthermore, PLT 3 discloses a method of presentation by display of moving images and still images using a computer to as to improve the understanding of specialized terminology etc. as a tool for obtaining informed consent. Further, it is described that such a presentation method may be used for educational purposes in elementary schools, junior high schools, various businesses, retirement homes, etc. Furthermore, PLT 4 discloses fluorescent film which enables visualization of an X-ray image and a configuration which reflects an image rendered visible by a prism for capture by a camera.

[0005] As other patent literature relating to dental medicine, for example, the following such literature may be mentioned: PLT 5: Oral Cavity Washer Fitted With Videoscope; PLT 6: Intraoral Camera Apparatus and Method; PLT 7: Handpiece for Dental Examination and Diagnosis; PLT 8: Hand Switch for Intraoral Camera, PLT 9: Intraoral Camera With Built-in Display; PLT 10: Intraoral Camera Apparatus and Dental Mirror; PLT 11: Dental Camera Apparatus; PLT 12: Instrument for Periodontal Examination Use; PLT 13: Regular Examination Method and System; PLT 14: Apparatus Used in Dental Medicine Environment; and, further, PLT 15: X-Ray Image Detection System for Medical Use.

Citations List

Patent Literature

[0006]

PLT 1: Japanese Patent Publication No. 10-97404A
PLT 2: Japanese Patent Publication No. 2005-334426A
PLT 3: Japanese Patent Publication No. 10-97405A
PLT 4: Japanese Patent Publication No. 10-201757A
PLT 5: Japanese Patent Publication No. 2001-212161A
PLT 6: Japanese Patent Publication No. 2005-144171A
PLT 7: Japanese Patent Publication No. 62-246347A
PLT 8: Japanese Patent Publication No. 2001-29315A
PLT 9: Japanese Patent Publication No. 2002-355262A
PLT 10: Japanese Patent Publication No. 2005-304600A
PLT 11: Japanese Utility Model Publication No. 5-30402U
PLT 12: Japanese Utility Model Registration No. 3131408U
PLT 13: U.S. Patent No. 5752827
PLT 14: Japanese Patent Publication No. 2009-516555A
PLT 15: Japanese Patent Publication No. 5-130991A

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Summary of Invention

Technical Problem

[0007] Numerous proposals have been made for examination of the oral cavity by using image displays. In the final analysis, these just provide information to patients by conventional one-time local treatment systems. They do not reach the level of systems designed for ensuring health of the teeth in the oral cavity as a whole.

[0008] Further, when a dentist explains treatment to a patient, sometimes he or she will use an intraoral image or X-ray image obtained by a dental camera, but the image itself is hard to interpret.

[0009] Furthermore, images and data easily understandable by the patient can be expected to help the dentist explain diagnosis and treatment to the patient, increase interest of the patient in intraoral health, and provide incentive for self health management, but such equipment, image displays, etc. fulfilling this promise have still not been proposed.

[0010] The dental practice has had to pay more attention to business operations along with the increase in the number of clinics. In order to stabilize bussness operations, entry into new dental diagnosis and treatment areas, reduction of costs, securing patients who regularly visit the clinics, and streamlining of the dental field have become necessary. For example, a handheld terminal such as described in the previously cited Japanese Utility Model Registration No. 3131408U has also been proposed.

Solution to Problem

[0011] In consideration of the above, the present invention proposes to provide a continuously captured image sequence forming means for continuously capturing side surfaces of rows of teeth to form an image sequence, a side surface tooth row image forming means for combining sequences of images which were formed by the continuously captured image sequence forming means as partial tooth row images from images forming the centers of overall composites so as to form a plurality of partial tooth row images, and a side surface tooth row image combining means for linking and combining a plurality of partial tooth row images which were formed by the side surface tooth row image forming means based on an image forming the center of the overall composite so as to form overall rows of teeth. By configuration in this way, according to the present invention, it is possible to use a handheld type of intraoral camera to form a clear panoramic image of the rows of teeth. Furthermore, it is possible to display an X-ray panoramic image of the rows of teeth and a panoramic image of the rows of teeth which have been virtual straightened or virtually beautified and colored side by side or display them superposed so as to broaden the range of diagnosis and treatment in the dental practice.

[0012] Furthermore, the present invention proposes a combination comprised of a unit image forming means for forming an image of the oral cavity for each diagnosis and treatment and care unit, a setting means for setting diagnosis and treatment and care order information for images captured by unit image formation by the unit image forming means, a display means for displaying images, with the diagnosis and treatment and care order information attached, based on the diagnosis and treatment and care order information so as to be able to be displayed in a list form, and a display medium which displays and records display information which is obtained by the display means. By configuration in this way, according to the present invention, it becomes possible to raise self awareness of the patient about treatment so as to promote intraoral health and encourage regular visits by patients and thereby realize an improvement of the efficiency of business operations of the dental field.

[0013] Furthermore, in addition, the present invention proposes preparing data for using a monitor of a computer etc. to explain details of treatment using the above-mentioned method etc. to the patient, manage attendance of dental employees, manage fees for diagnosis and treatment, and otherwise have a dental employee process data using a computer by a compact mobile terminal which is provided with a processor, memory, communicating means, inputting means, and display means. By using such a compact mobile terminal, in the present invention, greater efficiency in the dental practice is realized.

[0014] The image which is referred to in the present invention in the final analysis indicates a digital image. Either a moving image or a still image may be used. Further, the "image forming the center of the overall composite" in the present invention refers to for example an image common to two partial panoramic images when combining the two. "Overall" does not refer to only the final overall panoramic image of rows of teeth. For example, it also includes the case of a panoramic image of rows of teeth in the process of combination which is obtained by first combining two partial panoramic images of rows of teeth when forming three or more partial images of rows of teeth. "Combining ... from an image forming the center of the overall composites" means, for example, combining a plurality of still images which were obtained by continuously capturing rows of teeth in the back tooth direction from images where part of teeth at the center of the surface of the front teeth becomes the center so as to form a left side partial tooth row panoramic image and a right side partial tooth row panoramic image. "Linking and combining" means, for example, combining a left side partial tooth row panoramic image and a right side partial tooth row panoramic image at portions common to both or

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combining them by connection based on linkable portions.

[0015] The present invention sometimes sets a mark at an image including a part forming the center of combination. This "mark" indicates, for example, one which will not easily dissolve in saliva, water, etc. and which has an elongated rectangular shape or a seal which has a short rectangular shape and, for example, is coated on its back surface with a binder, adhesive, etc. and can be peeled off or another such deposit. Further, the invention is not limited to a deposit. It is also possible to draw a mark on the teeth by a pen which can give a removable color which can be clearly captured such as green, red, etc.

[0016] The portion where the mark is made is preferably arranged so as to span an upper tooth and lower tooth, but, for example, when capturing the image of only one of the upper jaw or lower jaw, it may be arranged at only the one to be captured. Further, the "predetermined position on the rows of teeth for making a mark" indicates, for example, an image becoming the center of combination at a position where a change in the capturing direction of the camera, the way it is held, etc. would cause the image capture to stop and the movement to stop.

[0017] The mark may be formed by a color (green, blue, etc.) and shape which can be easily discerned in the captured image. The material and color are suitably selected. Further, when obtaining a 3D image, it is possible to use a mark with provides a characteristic 3D property. The mark need only be one which is shown on the surface of the teeth and which clearly displays a position in the captured image, so for example it is also possible to provide a means which fires a laser sighting beam giving a shape of known dimensions on the tooth surface or to arrange a means such as a spotlight where there is correspondence between the lighting distance and area of the emitted light so as to enable light to be shone from the intraoral camera toward the teeth.

[0018] The mark need only be one enabling start of combination from the image where the mark is captured at a predetermined position. The capturing direction need not always be from the back teeth. The capturing direction and the combining direction need not be opposite. At the time of combination, sometimes the parts are combined from an image where a mark is displayed at a predetermined position to the left and right and finally the images are combined as a whole based on an image at which the mark is displayed at a predetermined position. The "predetermined position of the mark for starting combination" includes the illustrated case where, for example, the mark is at the center of the captured image, but the invention is not limited to this. It may be at any portion where combination is easy in partial combination and overall combination.

[0019] Sometimes, for example, in the case of partial combination of the three right, center, and left side surfaces of the rows of teeth such as the back side surfaces of the teeth, marks are required at the tooth between the right side surface and the center side surface and two teeth at the center side surface and right side surface, that is, sometimes a plurality of marks may be provided. The "side surface of the rows of teeth" referred to in the present invention is not limited to the front side. The back side and bite surfaces are sometimes also included. "Continuous capture" indicates automatic image capture at a rate of up to 30 images per second or less.

[0020] "Combine" is the method of combination of the panoramic images. For the method at the time of combination, existing methods may be selectively used. Simple combination, simple alignment, block matching, the Lucas-Kanade method and other optical flow estimation methods and other automatic or manual methods of combination can be utilized, but it is preferable to use an affine transform or other image adjusting means in advance and use the common parts between images as the basis to adjust the slant, magnification, etc.

[0021] The characterizing portion in the present invention is a line shape, dot shape, graphic shape, or 3D shape when combining panoramic images of partial rows of teeth, for example, when combining two side panoramic images, the center front teeth and the boundary lines of the front teeth, but the invention is not limited to this. One of the characterizing teeth of the front teeth or front end of the gums or other portions are also included.

[0022] The "oral cavity" in the unit image forming means for forming an image of the oral cavity for each unit of diagnosis and treatment and care indicates the teeth, rows of teeth, gums, alveolar bone, lips, hard palate, soft palate, uvula, and other regions.

[0023] "Diagnosis and treatment" includes diagnosis and treatment together and diagnosis by a dentist and treatment by a specialized medical institution.

[0024] The "diagnosis and treatment and care unit" indicates the range of one diagnosis and treatment procedure of tooth decay, periodontal disease, tongue cancer, gum cancer, etc. and sometimes also indicates stain removal, straightening, or other care, preventive treatment, and quasi-diagnosis and treatment.

[0025] "Care" indicates something of the extent which can be handled by brushing or application of fluorine or a mouthwash etc. and preventive care such as coating the teeth with fluorine, cleaning, coating with a preventive agent against periodontal disease, and other actions.

[0026] "Image forming" indicates conversion to image data which can be output to and displayed on a computer monitor (display) device or mobile phone display and also a state printed on paper or other state displayed two-dimensionally or three-dimensionally.

[0027] The diagnosis and treatment and care order information of the setting means for setting diagnosis and treatment and care order information for an image processed by unit image-forming by the unit image forming means includes

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symbols, codes, numerals, etc. indicating the order of diagnosis and treatment, prevention, and care and, in addition, includes the date and time of diagnosis and treatment, the state of advance of disease, predictions on the advance of disease, and other data. It need only be enough to enable determination of the order of diagnosis and treatment and care for at least a plurality of unit images. It may be content which can be directly visually confirmed and may be parameters for computation which can be confirmed after computer processing.

[0028] "Displayed in a list form" means at least a list of the order of diagnosis and treatment and care which, if in a state able to be easily viewed as a whole, is printed on several sheets of paper or is displayed as several images able to be changed by scrolling.

[0029] The "display medium" which displays and records the display information which is obtained at the display means indicates a state displayed by being printed on one or more sheets of paper or booklets or a state of image data of the JPEG, GIF, BMP, or other format displayed in a portable manner. The "display medium" includes a sheet or booklet of paper, a USB memory, SD card, memory, or other recording device provided in a display device, mobile phone, etc., but indicates at least printed matter or an electronic image etc. which a patient can carry and use to view his or her oral cavity. Alternatively, it includes the case of viewing one's own intraoral data on a homepage on the internet. Therefore, the display medium includes a desktop type or notebook type of personal computer.

[0030] The present invention utilizes a reflecting mirror, so the path of the sighting beam is relatively long. By using an LED or other sighting beam source with a spread based on the directional angle, it is possible to clarify the image capture position and the image capture range.

[0031] Further, the present invention provides an intraoral camera which utilizes a reflecting mirror wherein the dentist etc. can clearly understand the image capturing position even with an image which is captured through this reflecting mirror.

[0032] Furthermore, the present invention measures the posture of an intraoral camera which moves vertically and horizontally by a gyro sensor so as to obtain angle information of the body, derives the angle of the mirror from the angle of this body, and obtains a grasp of what kind of state the camera is in. By adjusting the posture of the image from the captured state, regardless of the state of the vertically and horizontally moving camera, it is possible to realize display of an image in a readily viewable state at all times.

[0033] In the present invention, an angular acceleration sensor (gyro sensor), acceleration sensor, or other position sensor is used. Specifically, rate gyros which output angular acceleration, rate integrating gyros which output angle, posture gyros, MEMS (micro electro mechanical systems) type and other mechanical type, optical type, and other angular acceleration sensors, piezoresistance type, electrostatic capacity type, and heat sensing type MEMS sensors, and other acceleration sensors can be mentioned.

[0034] The color of the sighting beam in the present invention may be any color which can be discriminated from the color of illumination light. If the illumination light is white, the sighting beam may be red, green, etc. Alternatively, as the timing of firing the sighting beam, a timing right before the user starts an image capture operation is preferable, but the beam may also be fired in a short time during the image capture as well in some cases.

[0035] Furthermore, the present invention provides a mobile terminal which can be worn on the body. By arranging inside it a storing means, computer, modulating and demodulating means for communication with the outside, and display means and enabling input and output for the dental practice as a whole, it is possible to manage dental employees, access electronic patient charts, calculate diagnosis and treatment fees, etc. at one's fingertips and to share, display, and synchronize this information so that even a handful of people can administer the dental office work and perform administrative processing for diagnosis and treatment in a dispersed manner. This enables the work of the dental practice to be streamlined.

[0036] The present invention preferably arranges an operating interface at a position which can be operated at the time of treatment, but depending on the operator, the method of operation will differ or the fingers will not reach the interface. Due to such physical factors, an adjusting means is provided for giving a time lag by the method of operation of the interface between operation of the operating interface and the actual operation performed in accordance with the state of inability of operation or the state of explanation to the patient (for example, when an interval is necessary between the oral explanation and screen display).

[0037] For example, when the operating interface is a switch, if the switch is successively pressed twice, the operation is performed after 2 seconds. In this way, it is possible to adjust the delay time by the number of times pressed or adjust the timing of display by the display means by the number of times pressed, the pressed time, etc. for a GUI-like operation.

[0038] Furthermore, the present invention provides a means for fetching an X-ray image and superposing it over an actual image or, for example, splicing together X-ray images for the different teeth to form a panoramic image and superposing it over an actual image obtained by capturing and combining images in the same way so as to enable a panoramic comparison from the side surfaces of the rows of teeth. By superposing, aligning, etc. this actual image and X-ray images on a display means, much greater understanding of treatment by the patient is realized.

[0039] Furthermore, the present invention forms a terminal which connects with a computer terminal wirelessly or by cable, is sometimes provided with a liquid crystal display, tenkeys, etc., and can be worn at the user arm, leg, or other

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part so as to enable input and output of patient information etc. with the computer terminal at one's fingertips, enable the dentist to obtain past data necessary for treatment and background information for when explaining treatment to individual patients in a manner not visible to the patients, and enable accurate diagnosis and treatment and explanation of treatment to the patients.

[0040] That is, a dental diagnosis and treatment system may be formed comprised of a mobile terminal which is provided with an input part for inputting dental related information and a display part for displaying dental related information, a host terminal which is provided with a recording means for temporarily or continuously recording dental related information and a processing means for processing dental related information based on a predetermined algorithm, and an information transmitting means for transmitting information between the mobile terminal and a center terminal wirelessly or by cable. In this case, the mobile terminal may be carried by being worn by the dental employee on his arm, leg, upper torso, lower torso, or other part of the body. All or part of the dental employees can therefore share the information which is displayed.

[0041] The present system may be configured to be portable as explained above and may be used as a tablet type or a desktop type PC. In this case as well, centralized management of dental information is possible.

[0042] A mobile terminal is a terminal which enables input and output and enables information processing, so enables centralized management of intraoral information, dental diagnosis and treatment information, dental office information, dental employee information, and other dental practice related information. Specifically, it displays information from corresponding software, an intraoral camera or other peripheral device, etc., adds new data, corrects data, deletes it, and otherwise processes input and stores data, shares data with other mobile terminals and host terminals and displays and processes input in synchronization with the same, but the invention is not limited to this. It is sufficient that the required dental information can be displayed, recorded, input, and processed from the mobile terminal.

[0043] On the computer monitor screen, for example, on the screen of the mobile terminal, a menu is displayed. In addition, various information is displayed by switching of the screen each time the user selects it by a mouse etc. Alternatively, a single screen displays all information of a specific patient as an individual window screen.

[0044] The user follows the displayed content of the screen to select, newly add, correct, delete, and otherwise input information. Input is performed by using the attached tenkeys or virtual tenkeys or by selecting preset input text by a mouse, tenkeys, etc.

[0045] Further, attendance of the dental employees can, for example, be input by the individual employees using their own mobile terminals and the host terminal or an attendance-keeping staff can newly add, correct, delete, or otherwise process input from his or her own mobile terminal or the host terminal. If the dental employees have their own mobile terminals and only the staff concerned should perform processing through them, it is also possible to set passwords for the staff concerned.

[0046] "Centralized management" means, for example, the case where a single terminal is used for input, output, and display of intraoral information, dental diagnosis and treatment information, dental office information, dental employee information, and other information related to the dental practice, but the invention is not limited to this. Even only part of that information is included if sufficient for the intended management.

[0047] The present invention further forms a dental treatment menu by combining partial subdivided images obtained by subdivision in advance and enables formation of still images, slide like moving images, moving images, or other explanatory images in accordance with the treatment for the individual patients.

[0048] The subdivided images are, for example, preferably images of tooth extraction, images of bridging actions of facing teeth, images explaining dental work, etc. prepared in advance as CG images and moving images. These are selected and combined by the dentist, dental hygienist, etc. based on the patient or are selected and combined by the patient from a display of a treatment menu including treatment by implants, treatment by prosthetics, etc.

[0049] The selection may be performed by selecting the individual subdivided images and running them consecutively on a computer. Further, it is also possible to prepare several existing moving images selected in advance to enable the dental employee or patient to view them as combined moving images for explanation of treatment and see the states before treatment, after treatment, and sometimes during treatment.

[0050] These linked images can be formed to content tailored to the state of treatment of the patient himself or herself, so the effect of greater understanding and promotion of efforts for prevention of tooth decay etc. can be expected. Such partial moving images and images of the patient captured by camera means may be converted to the same image format for use. A treatment system which is easy for the patient to understand and which is easy for the dentist or other user to use is therefore provided.

Advantageous Effects of Invention

[0051] The present invention enables the display of part or all of rows of teeth by a clear panoramic image using the actual image and further, sometimes, enables display of an X-ray image superposed or in parallel, so that display can be used to explain to a patient the diagnosis and treatment in an easily understandable manner.

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[0052] Further, the present invention enables the image capturing position of an intraoral camera which uses a reflecting mirror to be accurately displayed and enables the capturing posture of the camera unit being moved up and down in the oral cavity to be learned and adjusted to a state facilitating viewing of the captured image.

[0053] A patient can constantly check the situation in his or her own oral cavity and the necessity of diagnosis and treatment by a portable display means by which these are displayed on paper or in a recording medium in a list format. Due to this, the possibility of on-going diagnosis and treatment and care for maintaining intraoral health becomes higher and the profits in the dental practice can be increased and other facets of business can be improved.

[0054] The present invention further enables all processing in the dental practice to be handled using a mobile terminal able to process digital data and therefore enables rationalization of work and reduction of costs.

Brief Description of Drawings

[0055]

[FIG. 1] FIG. 1 is a block diagram for showing an embodiment of the present invention.
[FIG. 2] FIG. 2 is a schematic view for explaining an embodiment.
[FIG. 3] FIG. 3 is a schematic view for explaining an embodiment.
[FIG. 4] FIG. 4 is a schematic view for explaining an embodiment.
[FIG. 5] FIG. 5 is a block diagram for showing another embodiment of the present invention.
[FIG. 6] FIG. 6 is a schematic view for explaining an embodiment.
[FIG. 7] FIG. 7 is a schematic view for explaining an embodiment.
[FIG. 8] FIG. 8 is a schematic view for explaining an embodiment.
[FIG. 9] FIG. 9 is a schematic view for explaining an embodiment of the present invention.
[FIG. 10] FIG. 10 is a schematic view for explaining an embodiment.
[FIG. 11] FIG. 11 is a schematic view for explaining an embodiment.
[FIG. 12] FIG. 12 is a schematic view for explaining an embodiment.
[FIG. 13] FIG. 13 is a block diagram for showing another embodiment of the present invention.
[FIG. 14] FIG. 14 is a schematic view for explaining an embodiment.
[FIG. 15] FIG. 15 is a schematic view for explaining an embodiment.
[FIG. 16] FIG. 16 is a schematic view for explaining an embodiment.
[FIG. 17] FIG. 17 is a schematic view for explaining an embodiment.
[FIG. 18] FIG. 18 is a block diagram for showing an embodiment of the present invention.
[FIG. 19] FIG. 19 is a schematic view for explaining an embodiment of the present invention.
[FIG. 20] FIG. 20 is a block diagram for explaining an embodiment of the present invention.
[FIG. 21] FIG. 21 is a block diagram for explaining an embodiment of the present invention.
[FIG. 22] FIG. 22 is a schematic view for explaining an embodiment of the present invention.
[FIG. 23] FIG. 23 is a schematic view for explaining an embodiment of the present invention.
[FIG. 24] FIG. 24 is a block diagram for explaining an embodiment of the present invention.
[FIG. 25] FIG. 25 is a block diagram for explaining an embodiment of the present invention.
[FIG. 26] FIG. 26 is a block diagram for explaining an embodiment of the present invention.
[FIG. 27] FIG. 27 is a schematic view for explaining an embodiment of the present invention.
[FIG. 28] FIG. 28 is a schematic view for explaining an embodiment of the present invention.
[FIG. 29] FIG. 29 is a block diagram for explaining an embodiment of the present invention.

Description of Embodiments

[0056] Next, various aspects and embodiments for working the present invention will be explained in detail while referring to the drawings. However, the present invention is not limited to only the aspects described below. It should be understood that various changes and improvements may be made within the scope of the present invention.

[0057] The present invention continuously captures images of rows of teeth, uses panoramic image combination to form partial panoramic images, and combines these partial panoramic images to form an overall panoramic image of the rows of teeth. Preferably, marks are provided at the combined parts. By doing this, it is possible to easily form a panoramic image of rows of teeth by a handheld camera.

[0058] The present invention acquires a unit image corresponding to diagnosis and treatment or care from intraoral images which are captured at the time of dental diagnosis and treatment or examination and diagnosis by using an intraoral camera or X-ray camera system and intraoral images captured at the home. This unit image is for example shown on a computer monitor (display) device which enables viewing together with the patient. The patient views the state inside the oral cavity. While doing this, he or she works with the dentist to enter the order of diagnosis and treatment,

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the period of start of treatment, the degree of necessity of diagnosis and treatment, etc. The obtained diagnosis and treatment and care order information and unit image are printed out on a single sheet of paper or stored in a mobile phone which is provided with a storage medium and displayed on the monitor of the mobile phone. Alternatively, it is uploaded to a homepage of the dentist and displayed on an individual's own screen.

[0059] The present invention provides a portable, wearable mobile terminal which includes inside it a storing means, computer, modem means for communication with the outside, and display means so as to enable input/output and data processing for the dental practice as a whole. Using this, it is possible to manage attendance of dental employees, make entries into electronic patient charts, calculate diagnosis and treatment fees, and have dental employees perform other work at their handheld terminals and share this information. The mobile terminal is connected with a host terminal wirelessly by infrared, light, or other media or is connected by a cable. Alternatively, the mobile terminal may be connected through a wireless LAN, wired LAN, etc. to a cloud computing computer network by designing it to have computer specifications.

(First Embodiment)

[0060] FIG. 1A is a view which shows an embodiment of the present invention. In the figure, reference numeral 11 indicates an intraoral image inputting means, for example, a device which uses a camera for capturing images of all teeth of the upper jaw and lower jaw so as to obtain digital image data.

[0061] The intraoral image inputting means 11 is, for example, a reflection type of dental camera which uses a convex mirror such as shown in FIG. 3C or another camera for capturing an image of the oral cavity using a fisheye's lens and outputs a digital image of all teeth. Alternatively, as shown in FIGS. 6A and 6B, it is possible to use an ordinary intraoral camera to capture images of the individual teeth, extract contours from the individually captured images, connect the contours at the shared parts, and combine the images to obtain an overall image of the teeth.

[0062] Reference numeral 12 indicates a diagnosis and treatment portion detecting means. This, for example, is for setting a tooth for diagnosis and treatment or for care and a predetermined range of that tooth. This cuts out and extracts a tooth from a broad range intraoral image, which has been input by an intraoral image inputting means 11, by visual inspection while using graphics software. Further, it extracts and finds the contour of the tooth by software processing, assumes the extracted contour to be a circle and finds its center, and extracts an image of a radius 10% to 20% larger than the radius of the contour from that center.

[0063] Reference numeral 13 indicates a unit image forming means. This processes the image for diagnosis and treatment, which was obtained by the diagnosis and treatment portion detecting means 12, for display use. This is for forming an image with a region for entry of the diagnosis and treatment order and comments. The unit image forming means 13 automatically creates and displays templates by designation of the diagnosis and treatment portion by the above-mentioned diagnosis and treatment portion detecting means 12 by operating icons by software.

[0064] The image which is shown is sometimes just a designated range of the image which was input by the intraoral image inputting means 11. It may also be a separately prepared template for unit image display which the user himself or herself designates. The image may further be one which is displayed after being captured by a suitable camera which uses a reflecting mirror which is shown in FIG. 3 at the time when the unit image is displayed. The image may also be initially displayed as a moving image in the unit image area and then confirmed and displayed as a still image by pressing a confirmation button.

[0065] Reference numeral 14 is a diagnosis and treatment order setting means. For example, the state of advance of tooth decay or the degree of diagnosis and treatment and care may be used as the basis for the dentist to determine the order on his or her own or in consultation with the patient or by automatic measurement of the state of advance of tooth decay or degree of deformation of shape. For automatic determination of the order, it is possible to convert the difference in color of the teeth to a numerical value for comparison with a certain threshold value or determine when a degree of deformation has exceeded a basic shape of a tooth by a certain extent or more or when the size of a spectral component based on the wavelength to an illumination light source of the tooth decay detection wavelength is a predetermined value or more so as to determine the order. The order of the images may be changed on the screen of the monitor (display) device.

[0066] The above mentioned changes are talked over with the patient, then the order of treatment and diagnosis is determined, so by pushing the confirmation button after determining the order, the order of unit images which are placed on the screen is automatically changed and the result printed out for patient use, so the diagnosis and treatment time can be streamlined.

[0067] Reference numeral 15 indicates a diagnosis explanation forming means. In the same way as the diagnosis and treatment order setting means 14, this is a means for entering the time of start of diagnosis and treatment, the urgency of diagnosis and treatment, the diagnosis and treatment technique, and other content which the patient believes necessary as data. This may be entered by input from a keyboard of a computer (for example, 315 of FIG. 3), selection of set explanations by operation using a mouse (for example, 316 of FIG. 3), or input by connecting operating buttons

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of the intraoral camera which is shown in FIG. 3 with the input interface of the computer and in that state operating the buttons attached to the camera body.

[0068] The diagnosis explanation forming means 15 has the date of start of diagnosis and treatment or scheduled date of diagnosis and treatment entered from the cells 21b to 23b which are shown in FIG. 2C to FIG. 2E, but it is also possible that the earliest date enabling diagnosis and treatment be automatically displayed for that date.

[0069] The earliest date enabling start of diagnosis and treatment may also be set by a function of calling up the diagnosis and treatment scheduled start date entry fields from the database of patients recorded and stored in the recording means 17 and displaying the earliest date among the dates with no entries.

[0070] The specific configuration is shown in FIG. 1B. This is part of the configuration of the diagnosis explanation forming means. The rest is omitted. Reference numeral 151 indicates a patient database callup means. This is a database in which the image data which is shown in FIG. 2, the order data, data on the date of start of treatment (including time), and explanatory data are recorded. This is managed as is general practice, so related data is recorded in a temporary recording region. This may be configured so that when the stored data is voluminous, data is called up to the database for each examination.

[0071] The earliest diagnosis and treatment date searching means 152 calls up the diagnosis and treatment start date data from this and searches for a date where no diagnosis and treatment start date is entered from this starting from the search start date. When there is data which does not match it, this is output as the earliest diagnosis and treatment date.

[0072] Reference numeral 153 indicates an earliest diagnosis and treatment date display means which displays a date searched for and detected by the earliest diagnosis and treatment date searching means 152 on the display part of the unit image.

[0073] Reference numeral 154 indicates an open diagnosis and treatment date display means which displays the open dates and times of diagnosis and treatment in an easily understandable format. For example, an analog clock and calendar can be schematically displayed or otherwise a computer monitor can be made to display units of months, units of several months, or units of years.

[0074] Reference numeral 155 indicates a decision input means for input of the consent of the patient and recordal of it in the database.

[0075] Reference numeral 156 is a recording means for recording to a database. This recording means 156 is the same as the recording means 17. Input may be recorded as finalized in the recording means 17, but the date and time of diagnosis and treatment have to be quickly recorded in the database since there is a possibility of another dentist simultaneously setting up a schedule like that of the patient. Therefore, as soon as the decision is made, it is preferably recorded in the database.

[0076] Returning again to FIG. 1A, 16 is a display and output means for editing and displaying images comprised of unit images, diagnosis and treatment orders, and diagnosis and treatment explanations on a screen of a computer monitor (display) device or using a printer (for example, 317 of FIG. 3) to print edited images on paper.

[0077] Reference numeral 17 is a recording means for recording the edited image data. It records it as part of an electronic patient chart stored by the dentist or records it in a patient mobile phone or computer through a storage medium. The recording means 17 includes a database which stores data of all of the patients from data of the individual patients.

[0078] Next, one example of an intraoral camera will be shown by FIG. 3 and explained.

[0079] Reference numeral 301 is a housing for holding use. It is shaped as a tube so as to form a pencil type intraoral camera. Inside, a circuit board, a USB connection circuit for connection with the outside, and a USB socket are contained.

[0080] At the front end, a camera unit 309 is integrally connected. For example, as shown in FIG. 3E, the camera unit 309 has for example a CCD camera arranged at its center and has white LEDs and other color LEDs and other illumination devices 312 arranged around it in a concentric circle at equal intervals.

[0081] Reference numeral 302 is a reflecting mirror unit. At its front end, a flat mirror 303 which is arranged at a for example 45 degree angle is connected. At its back end, a tubular part 305 is formed in a state enabling insertion into the outer circumference of the camera unit 309 and enabling replacement. The outer shape of the camera unit 309 and the inner shape of the tubular part 305 of the reflecting mirror unit 302 are preferably made elliptical so that the parts will not rotate when fastened by insertion with each other.

[0082] The reflecting mirror unit 302 can be suitably replaced. FIG. 3B shows the state where a reflecting mirror unit provided with a flat mirror 303 is attached, while FIG. 3C shows the state where a reflecting mirror unit 310 where a spherical surface shape convex mirror 308 is attached is inserted into and joined with the camera unit 309.

[0083] When capturing all of the teeth in this way, the reflecting mirror unit 310 which has the convex mirror 308 of FIG. 3C connected to it is used. The convex reflected video of the convex mirror 308 is captured by the camera 313 of the camera unit 309. The output light of the illumination device 312 is reflected through the convex mirror 308 to light up the observed portion of the oral cavity. The camera 313 is illustrated as a CCD type, C-MOS type, etc. For the resolution, a higher image quality is preferable, but when mainly capturing a moving image, the image quality may be kept low in use.

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[0084] In the case of normal image capture, the tubular part 305 of the reflecting mirror unit to which the flat mirror 303 which is shown in FIG. 3B is attached is inserted into the outer circumference of the camera unit 309 to join it for use.

[0085] Reference numeral 304 is a lead line such as a dedicated electrical lead line or a general use USB cable etc.

[0086] Reference numerals 306 and 307 are operating buttons. These are one or more push type, rotary type, composite type, or other buttons. In the present embodiment, two are shown. In addition to turning the power on or off or otherwise operating the camera, sometimes a selection and operation use display window which is displayed on a monitor 314A of a computer 314 which is connected through a lead line 304 is operated by pressing this operating button 307 in a GUI (graphical unit interface) function. For example, the operating buttons 306 and 307 can be operated when automatically rearranging the unit images in order after the order has been determined.

[0087] For example, reference numeral 306 may be made a button corresponding to the left click function of a mouse and 307 may be made a button corresponding to the right click function.

[0088] Reference numeral 314 indicates a computer which is formed integrally with a monitor (display) 314A as one example. In addition, it may also be combined as a dedicated device.

[0089] Reference numeral 315 indicates a keyboard, while 316 indicates a mouse for a computer. Both are used for operating the computer. Furthermore, they may also double as switches for operating the intraoral camera.

[0090] Reference numeral 317 indicates a printer. It is formed by an ink jet type or laser type color printer etc. and is used when printing out a patient's own intraoral image to give to the patient.

[0091] FIG. 3D shows a reflecting mirror unit 318 which uses a concave mirror 311 as a reflecting mirror. For example, this is used when an enlarged image is required. Alternatively, in the case of an oral cavity, when capturing enlarged only the inside of the rows of teeth, sometimes the curvature of the concave mirror 311 is adjusted to a direction close to a flat mirror and the rows of teeth are captured from a location somewhat separated from it so as to obtain a wide range image shown in the present invention.

[0092] In the present invention, sometimes not just the rows of teeth but also the tongue, lips, gums, etc. included in a wide range image are handled as a unit image. For example, the present invention can be suitably utilized in the case of displaying a polyp, which can be a manifestation of tongue cancer, as a unit image and explaining diagnosis and treatment.

[0093] Next, the present invention will be explained while referring to FIG. 6 which shows one example for forming an overall tooth image. The camera which is used is one using the reflecting mirror unit 302 using a flat mirror 303 such as shown in FIG. 3B. Alternatively, the image may be captured as a still digital or may be captured as a digital moving image. Furthermore, when obtaining a plurality of still images from a digital moving image, since this is for capturing a moving image, the number of pixels becomes relatively small, therefore it is preferable to capture still images by an auto catcher while moving.

[0094] All of the teeth of the lower jaw 600 which is shown in FIG. 6A are captured while making the flat mirror 303 of the reflecting mirror unit 302 move in the direction from the capture planes 601 to 612. When capturing a digital moving image, the result is similar to the case of inputting still images at a rate of about 30/sec, so if the reflecting mirror part of an intraoral camera for capturing a digital moving image is made to move along a path from the image capture planes 601 to 612 of FIG. 6A, a large number of still images can be found. Further, continuous capture of still images gives a greater number of pixels and a higher resolution than acquisition of still images by capture of a moving image, so this is a preferable mode when acquiring images of individual teeth from this overall tooth image.

[0095] FIG. 6B shows parts of the individual images when performing a capture operation which is shown in FIG. 6A. Reference numeral 613 indicates an image of a common part of the images 601 and 602, 614 indicates an image of a common part of the images 602 and 603, and 615 indicates an image of a common part of the images 603 and 604. In addition, the capture operation is performed so that images of common parts are obtained for 604 and 605, 605 and 606, 606 and 607, 607 and 608, 608 and 609, 609 and 610, 610 and 611, and 611 and 612.

[0096] For example, these images are digitalized to obtain the contours, then are superposed so that the contours of the common parts match between images. Furthermore, the images 605, 606, 607, 608, 609, 610, 611, and 612 are successively captured and these images are linked based on their mutually common parts to obtain an overall tooth image. A panoramic type image of the bite plane can be formed by known panoramic image combining software, but when there is the effect of shaking due to holding the camera by the hand, the images are corrected before combination, so sometimes processing by affine transformation is preferable.

[0097] Next, the operation of the above embodiment will be explained in detail while referring to FIG. 2.

[0098] The intraoral image inputting means 11 is used to capture an image of for example the entire teeth of the upper jaw in the oral cavity. The position of the captured image is shown in FIG. 2A. The intraoral image inputting means 11 need only obtain an image which includes the tooth which the dentist is diagnosing and treating and which enables to which part in the oral cavity this corresponds to be understood.

[0099] The image which is shown in FIG. 2A, for example, is captured by the intraoral camera unit which is shown in FIG. 3C which is shown in FIG. 3C. Furthermore, it is possible to calibrate this so as to correct for distortion. Alternatively, the intraoral image inputting means 11 does not necessarily capture all of the teeth. It may also capture part of the teeth

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or a single tooth. FIG. 2A shows the upper jaw 20 and captures all of the teeth and the hard palate part. This portion is sometimes both diagnosed and treated.

[0100] Next, the diagnosis and treatment portion detecting means 12 is used to automatically or manually extract a portion requiring diagnosis and treatment or care. If extracting it manually, in the same way as graphic software, a mouse is used to designate this portion by a circle or square, then the portion is copied, cut, etc. and furthermore pasted. In FIG. 2A, 20a, 20b, and 20c indicate the state of using graphic software to manually or automatically designate and display a tooth to be covered by a conspicuous color circle.

[0101] "Manually designate and display" is to operate a mouse or keyboard which is for example attached to a computer so as to draw a circle, square, or other contour etc. and process the inside, while "automatically designate and display" is to for example use a mouse to move a point to a designated portion on the screen and press a button so as to display a circle of a predetermined radius or a square of a predetermined area and process the inside.

[0102] Next, the unit image forming means 13 adjusts the designated tooth 20a which is shown in FIG. 2C to a unit image 21. At that time, for example, an order field 21a in which the order of treatment is entered after the order is determined, a diagnosis and treatment start date field 21b in which for example the start of treatment is entered after it is determined, and an explanatory field 21c in which what kind of diagnosis and treatment are to be performed is entered are additionally set. This earliest diagnosis and treatment date is, for example, displayed in the diagnosis and treatment start date field 21b of the unit image earliest in order in FIG. 2. If the patient consents to this date, the operation shifts to the decision input means 155 which decides on this date and records it in the patient database by the recording means 156.

[0103] If the patient does not consent, the open diagnosis and treatment date display means 154 displays the open diagnosis and treatment dates in a 2D form like a calendar format. This display may be of a list type, a page flipping type, or other type employing display of a schedule. It is sufficient that it at least be a display which the patient can easily understand.

[0104] Note that, not only the date, but also the time is required, so the time is also preferably displayed simultaneously. If agreement is reached on the date of start of diagnosis and treatment based on this display, the decision input means 155 is used to input that date and time and the recording means 156 is used to record them in the database.

[0105] The next unit image in order is shifted to and a similar date of start of diagnosis and treatment is decided and entered.

[0106] This scheduling operation of the diagnosis and treatment date is effective for clarification of the schedule since when the present invention sets a plurality of scheduled diagnosis and treatment dates, it is necessary to avoid conflicts with schedules of other patients - which does not occur with singe-instance diagnosis and treatment.

[0107] Note that, the ID number may be entered in any field for each tooth. This field is for example an input use box display used in the database. The diagnosis and treatment date can be automatically determined as a date which is open in view of the diagnosis and treatment schedules of other patients, so when a unit image is displayed, the open time slots may also be displayed from the data of patients. The content which is displayed in a window may be the image before treatment with fields in which at least the order of treatment is displayed or in which ID codes are attached.

[0108] FIG. 2D shows a unit image 22 which shows a tooth 20b for diagnosis and treatment of FIG. 2A, while FIG. 2E shows a unit image 23 which shows a tooth 20c for diagnosis and treatment of FIG. 2A.

[0109] The unit image 22 displays an order field 22a, diagnosis and treatment start date field 22b, and explanation field 22c all together. FIG. 2E similarly shows a unit image 23 which shows an order field 23a, diagnosis and treatment start date field 23b, and explanation field 23c all together. Note that, when finalized, a confirm button (including a virtual button which is displayed on the screen) is pressed. By pressing the confirm button, the display may be rearranged along the numbers in the order entry fields. By automating this work, in the final analysis, the time for preparing the paperwork to be handed over to the patient can be shortened.

[0110] The view which is shown in FIG. 2 sometimes is shown in its entirety on a single computer monitor. In this case, this sometimes doubles as the operating range of the display and output means 16.

[0111] In the diagnosis and treatment order setting means 14, the order in the order field 22a is determined and entered by the dentist alone or by the dentist and patient in consultation. Similarly, the diagnosis explanation forming means 15 is used to make entries into the diagnosis and treatment start date field 22b and the explanation field 22c. These entries include considerable specialized matter, so sometimes are made by the dentist alone in advance.

[0112] The display and output means 16 forms and displays on the computer screen the finalized plurality of unit images and state including all tooth images. The display and output means 16 preferably displays any dental diagnosis and treatment which are performed on the same screen when they are performed.

[0113] However, when there are many unit images, they may be displayed by scrolling or may, if necessary, be reduced in size or shown by thumbnails. Furthermore, the finalized image at the display and output means 16 may be printed by a printer on paper to be given to the patient. The patient can keep the image of his or her own oral cavity. This is expected to lead to regular visits to the clinic to maintain oral cavity health. Further, after diagnosis and treatment end, the image of the oral cavity is again captured as shown in FIG. 1.

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[0114] The tooth 20a of the same portion is displayed as a unit image 24 as shown in FIG. 2B. Reference numeral 24d indicates the diagnosis and treatment portion, while 24a displays the order when, for example, the diagnosis and treatment order setting means 14 is used to search for the same image data from image data for which the diagnosis and treatment order has been set in advance and that order is shown. For example, the diagnosis explanation forming means 15 is used to describe the recorded matter etc. in advance at the time of diagnosis and treatment.

[0115] Further, the unit images after diagnosis and treatment which are shown in FIG. 2A can be displayed at locations adjoining the same unit images before diagnosis and treatment so as to increase the trust in the dentist and keep the patient aware of the timing for visits to the clinic for maintenance of the diagnosed and treated teeth. Reference numeral 24c indicates the explanation field for example after diagnosis and treatment. This is more preferably an explanatory field for consultation with the patient over the start of the next diagnosis and treatment.

[0116] Further, the display and output means 16 uses a printer to print out on a single sheet of paper for example the four images which are shown in 400 of FIG. 4. This is handled to the patient to impress on the patient the need for continuous diagnosis and treatment. Note that, 400 does not show the intraoral wide range image which is shown in FIG. 2A, but preferably shows the wide range image so as to clarify the diagnosis and treatment portion and thereby obtain the further understanding of the patient.

[0117] The display fields of FIG. 2 and FIG. 4 are an example. The number of display fields per unit image and the displayed content are suitably selected in accordance with the purpose of the treatment, schedule, etc.

(Second Embodiment)

[0118] Next, another embodiment will be shown in FIG. 5 and explained. In the figure, reference numeral 51 indicates a wide range image inputting means. This is a means for capturing an image of all teeth of the upper jaw and all teeth of the lower jaw of the oral cavity. For example, it is possible to capture all teeth which are reflected in the convex mirror which is shown in FIG. 3C by a camera so as to obtain a wide range image or to continuously capture images shown in FIG. 6 and combine common parts from the still images forming the digital moving image so as to form a complete tooth image.

[0119] Reference numeral 52 indicates a tooth detecting means which extracts image data of respective teeth from the rows of teeth obtained by the wide range image inputting means 51. The extraction may, for example, be performed by a means using a contour extraction program to extract the peripheral sides in just a predetermined range to form an image of a single tooth and also by a means which uses the flat mirror which is shown in FIG. 3B to capture the individual teeth and form a single image, but the method of cutting out unit images from the overall tooth image and intraoral wide range image so as to form images of single teeth is both rational and preferable in some cases.

[0120] Reference numeral 53 indicates a unit image forming means which adds to the individual images obtained by the tooth detecting means 52 the respective order entry fields, diagnosis and treatment explanation entry fields, etc. to form the display use images. Furthermore, it is preferable to form a tooth database and attach unique codes to manage the teeth.

[0121] Reference numeral 54 indicates a diagnosis and treatment image selecting means for selecting a tooth for diagnosis and treatment of tooth decay, loss, etc. The dentist can visually, or through a comparison with previously registered data which is read out, select a tooth for diagnosis and treatment based on the differences in color, shape, etc.

[0122] Reference numeral 55 indicates a diagnosis and treatment order setting means by which the dentist decides on the order of the teeth for diagnosis and treatment on his or her own or by which the dentist and patient decide on this by discussion based on images displayed on a computer monitor (for example, monitor 314A of FIG. 3A) or printed images.

[0123] Reference numeral 56 indicates a diagnosis explanation forming means by which the period of diagnosis and treatment, date of start, and details of the diagnosis and treatment and the necessity of care etc. may be entered by the dentist alone or by consultation with the patient and by which explanations recorded in advance based on comparison with previous data may be displayed according to the magnitude of the differences.

[0124] Reference numeral 57 indicates a display and output means by which the display image for diagnosis and treatment may be displayed on a single sheet of paper or may be displayed on a computer monitor (for example, 314A of FIG. 3A) for use for explanations for obtaining patient consent and understanding. Alternatively, an image which is printed out on paper may be provided to the patient and used for scheduling future diagnosis and treatment so as to realize on-going dental diagnosis and treatment.

[0125] Reference numeral 58 indicates a recording means by which information may be recorded as a patient chart or database or by which information is uploaded to a storage area exclusively for the patient in a server. Tooth image data may also be recorded at the recording part of a mobile phone of a patient.

[0126] Next, the operation of the embodiment which is shown in FIG. 5 will be explained with reference to FIG. 7. In the present embodiment, a wide range image inputting means 51 is used to capture an image of all of the teeth from the oral cavity of a patient so as to form image data 700 of all teeth comprised of a single or multiple images (see FIG. 7A). The image data 700 which shows all teeth can be formed by linking the still images which are shown in FIG. 6 as

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one example. From the obtained wide range image data 700, the tooth detecting means 52 manually or automatically forms tooth images.

[0127] As the technique for automatically detecting teeth, the intraoral image data may be processed by a contour extraction program to extract contours and detect the contours of the teeth. In this case, if the contours are incomplete, several points are detected and a virtual circle which passes through these points is formed. This virtual circle can be deemed as the position of one tooth, so the radius from the envisioned center can be enlarged by exactly a predetermined value and a square surface can be extracted as an image of one tooth.

[0128] The extracted images become, for example, as shown in FIG. 7B, the tooth image 701 for the tooth 71, the tooth image 702 for the tooth 72, and the tooth image 703 for the tooth 73.

[0129] Next, the unit image forming means 53 is used to link the images of these teeth with identifiers and other patient information for unit image forstion (see FIG. 7C). A unit image 74 includes a tooth image 701 and a display field 704 for entering the diagnosis and treatment order etc. The unit image 75 includes a tooth image 702 and a display field 705, while the unit image 76 includes a tooth image 703 and a display field 706. These unit images are recorded in a preset patient database and form an upper and lower intraoral data list of the patient.

[0130] The diagnosis and treatment image selecting means 54 visually or automatically extracts from the unit images a unit image 77 which shows an image of a tooth for diagnosis and treatment or care (see FIG. 7D).

[0131] In the diagnosis and treatment order setting means 55 and diagnosis explanation forming means 56, which have configurations similar to FIG. 1 and perform similar operations, the dentist enters the diagnosis and treatment order etc. alone or preferably while viewing the unit tooth images displayed on a computer monitor together with the patient.

[0132] Further, when the diagnosis and treatment order has been determined and the date of start of diagnosis and treatment etc. has been entered, the display and output means 57 may also display on the computer monitor 78, for example, an array of unit images displayed in sequence as shown in FIG. 7E or, as shown in FIG. 7F, a wide range image further included in an edited state. It is therefore possible to create a situation where the patient confirms diagnosis and treatment and gives consent for on-going diagnosis and treatment.

[0133] The unit images 707, 708, 709, and 710 are preferably arranged in order of start of treatment. FIG. 7F shows, for example, a screen display including the entire tooth image data 711 or tooth data 79 printed out to enable the patient to carry it.

[0134] The recording means 58 records these unit images in the database and is suitably used for adjusting the schedule with other patients.

[0135] Further, the present invention may form a single image by combining the technique of using a convex mirror shown in FIG. 3 when obtaining a wide area image or the technique of making the reflecting mirror move along the rows of teeth and combining the still images. That is, by making only the rows of teeth a still image, capturing the tongue portion by using a convex reflecting mirror, and combining the images, an intraoral wide area image provided with distortion-free rows of teeth is obtained.

[0136] Furthermore, one example of a panoramic tooth row image forming technique which combines panoramic images of rows of teeth in a state with the teeth engaged so as to form a clear image is shown from FIG. 8 to FIG. 12.

[0137] As shown in FIG. 8, the technique is adopted of using a camera to capture images from the left back up to near the center, then changing the orientation of the intraoral camera to then capture images from the right back to near the center. In this case, the direction of the camera is changed once, so the capture operation is interrupted. Therefore, the left and right tooth row images often cannot be accurately combined and end up deviating from each other.

[0138] Further, when manually moving and operating a camera, for example, when capturing an image of the back teeth, the intraoral camera is made to move in a state arranged between the cheek at the inside of the oral cavity and the side surfaces of the teeth and pushing aside the cheek or a state of contact is formed with the side surfaces of the teeth. Therefore, the cheek and the side surfaces of the teeth are in a state where they support the reflecting mirror of the intraoral camera or the image capturing portion of the camera, but if the intraoral camera is made to move in the direction of the front teeth, the camera is released from the pinched state with the cheek etc. and becomes held only by the hand whereby the operating camera becomes unstable in position and the images easily become disturbed. In particular, the distance between the camera and the captured object, that is, the side surfaces of the teeth, fluctuates and shaking occurs in the image capturing direction whereby the captured objects, that is, the teeth, fluctuate in size or the images become distorted.

[0139] The intraoral camera 901 which uses the reflecting mirror which is shown in FIG. 8 is configured as shown in FIG. 3 as one example, that is, is configured by a modular CCD camera or CMOS camera around which a plurality of light source LEDs are arranged. The oral cavity is lighted by the light source LEDs through the reflecting mirror and images of the rows of teeth in the oral cavity etc. are continuously captured. Stable capture is possible from the back teeth, but the invention is not limited to this. It may also use a camera for direct image capture not using a reflecting mirror in some cases.

[0140] The intraoral camera 901 which is used here is illustrated as one which is configured with a reflecting mirror unit 903 (302 of FIG. 3) which is provided with a flat type reflecting mirror 902 (303 of FIG. 3) attached interchangeably

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at the front end of a body 904 (301 of FIG. 3). The body 904 is provided at its front end with a camera unit 905 (309 of FIG. 3) which combines a CCD camera, CMOS camera, or other camera and four to eight light emitting diodes arranged around the camera.

[0141] The camera unit 905 is illustrated as one which outputs still digital images by using the continuous capture technique so as to obtain a range of for example 10 to 30 still images per second.

[0142] Before starting the continuous capture, first a mark ML is attached near the center of the rows of teeth 900a in the state with the upper and lower teeth engaged with each other. The mark ML is preferably made by temporary adhesion of a colored seal, marking by a colored pen giving a color that can be removed, or use of another means giving a mark which can be clearly displayed in the image captured by the camera. "Near the center" when attaching the mark ML for example near the center of the rows of teeth indicates a location serving as a reference when continuously capturing the left and right tooth rows, then combining the images. In addition, it is also possible to detect a characterizing portion in image processing near the center of a captured image and set that portion as the mark in the image. The mark ML is preferably arranged so as to span an upper tooth and lower tooth.

[0143] This continuous capture operation is performed from the back tooth position, for example, the state of 906a, along the tooth surfaces like 906b and 906c, preferably separated by the same distance from the surfaces of the rows of teeth, while the body 904 is held by the hand and the reflecting mirror 902 is moved.

[0144] "IG" indicates a correction use indicator. This is comprised of an adhesive member which is attached to a tooth surface in a manner enabling it to be peeled off later. On this, a graphic for image correction use such as a box, square, triangle, or checkerboard may be displayed to enable correction of distortion of the image or correction of the relative size of images based on the distance between the camera and tooth side surfaces. Alternatively, the correction use indicator IG may be colored green or another color which can be discerned in image processing, but it is not limited to green.

[0145] This adhesive member may be attached at the center of a tooth such as shown in, for example, FIG. 8 and FIG. 10, at the surface of the tooth where the mark ML is made. Alternatively, the tooth attached to is not limited to a single tooth. A plurality of teeth may have the adhesive member attached for image capture. The adhesive member may sometimes also be attached to another tooth in the oral cavity where the teeth are to be captured by hand with no other support.

[0146] The means for attaching the correction use indicator IG to a tooth surface may utilize a similar technique to that of the mark ML. An indicator which will not dissolve and will not run in saliva etc. may be used as an example. This is preferable when correcting for distortion and size of and combining a partial panoramic image of the left rows of teeth and a partial panoramic image of the right rows of teeth based on the correction use indicator IG which is captured in common to the two. Note that, when combining three partial panoramic images of the left rows of teeth, the center rows of teeth, and the right rows of teeth, the teeth common to the partial panoramic images may be provided with auxiliary use indicators IG.

[0147] Individual captured still images may also be corrected. For example, based on a reference auxiliary use indicator IG in the continuously obtained images or using as a reference one of the auxiliary use indicators IG captured in a group of images and detected by the block matching method or the template matching method etc., the auxiliary use indicator IG captured in another image is detected, then compared with the reference image to detect distortion, tilt, and differences in size, then correction is performed using affine transformation which performs enlargement, reduction, rotation, and adjustment of movement. At the time of image capture by hand where shaking is unavoidable, the auxiliary use indicator IG may be attached to a tooth so as to enable stable combination for forming a panoramic tooth row image.

[0148] The above-mentioned such correction of an image using the correction use indicator IG may, for example, be performed by the method of Zhang (IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(11); 1330-1334, 2000) and other techniques used in calibration of camera images. Further, the correction use indicator IG sometimes is not essential depending on the captured state, affine transformation, or other processing.

[0149] FIG. 8B schematically shows one image capture range when continuously capturing images from the back teeth. The reflecting mirror part of the intraoral camera is made to move along with the elapse of time such as by 906a→906b→906c→906d→906e→906f→906g while obtaining continuously captured images as still images.

[0150] The intraoral camera 901 is configured provided with a reflecting mirror 902 at the front end at a predetermined angle, so if capturing the surfaces of the row of teeth from the left back teeth in the figure, the direction of the body 904 is changed near the center and then the surfaces are captured in order from the right back teeth in the figure. Therefore, the surfaces of 906e to 906g shown in FIG. 8 are captured, then the intraoral camera 901 is reversed and starts to capture images from the right back teeth.

[0151] The speed of continuous capture is made capture of a slightly great 20 to 30 images per second since the body 904 is moved by hand and therefore the effects of hand shaking and other shaking should be considered. Continuous capture with enough extra leeway to delete images which are out of focus due to hand shaking is preferable.

[0152] This continuous capture is preferably performed until the mark ML reaches the center of the capture screen or the reflecting mirror, but sometimes it is performed until a portion exceeding that by a certain extent. After that, the captured images may be picked and discarded.

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[0153] Since the camera is operated manually, before combination, sometimes, the common portions of the images are used as the basis for affine transformation so as to match the images in state. For example, using the image first becoming the center of combination as a reference, block matching is performed with a comparative image to detect a plurality of common points. Based on this plurality of common points, the next image is processed by affine transformation. For example, a plurality of pixel coordinates (xb, yb) of the next image corresponding to the pixel coordinates (xa, ya) of the reference image at the common part are selected and entered into the following formula to obtain the coefficient values "a" to "f". In the state entering the coefficient values into the following formula, the next image is processed by affine transformation to straighten out the images or the images are straightened out while combining panoramic images.

[0154]

[Formula 1]

$$\begin{pmatrix} x_a \\ y_a \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} x_b \\ y_b \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix}$$

[0155] Part of the images which are obtained by continuous capture from the left back to near the front surface in the figure in the rows of teeth 900a are shown in FIG. 9. Jointly using FIG. 8, the capture operation of an intraoral camera based on this embodiment will be explained.

[0156] FIG. 9A to FIG. 9E show one example of the sequence of captured image data when performing continuous capture near the centers 907c to 907e in the captured image data of the rows of teeth which are shown in FIG. 8B. Note that, the intraoral camera utilizes the reflecting mirror 902 to obtain a tooth row image, so the captured image is inverted left to right, but is shown in FIG. 9 and FIG. 11 in a non-inverted state so as to facilitate understanding.

[0157] FIG. 9A is an image which captures the area near 906c of FIG. 8B, FIG. 9B is an image which captures the area near 906d, FIG. 9C is an image which captures the area near 906e, FIG. 9D is an image which captures the area near 906f, and further FIG. 9E is an image which captures the area near 906g. Note that, since the capture is performed manually, the captured images often cannot be captured in the same state at all times. Therefore, when the images are tilted etc., it is preferable to perform correction for matching states using affine transformation at parts for example overlapping with the states of other teeth. FIG. 9 shows the view after correction. At the time of correction, as portions serving as reference, in addition to the mark ML, the vertical centerline CL and horizontal centerline HL which are set in advance at the reflecting mirror surface at which the reflecting mirror 902 is captured may be used.

[0158] The vertical centerline CL and the horizontal centerline HL are not necessarily displayed at the image. Further, at the edges of the reflecting mirror, it is also possible to provide projections or other marks at portions corresponding to the starting points and end points of the vertical centerline and horizontal centerline. These marks are sometimes used as the basis for virtual display.

[0159] Further, it is also possible to simultaneously perform processing for correcting distortion caused by a CCD camera lens by software.

[0160] RM is the contour of a mirror. The actually captured image becomes a circular image in the contour RM, but is displayed as a square image so as to facilitate the explanation of the range.

[0161] The captured image sometimes differs in the distance between the teeth and camera since the camera is held by the hand. In this case, an image where the mark ML and the vertical centerline CL approximately match may be used as a reference to correct the size of another captured image. Note that, sometimes the front end of the reflecting mirror 902 is made to lightly contact the tooth surface while continuously capturing images so it is possible to stabilize the obtained images.

[0162] As shown in FIG. 8, the reflecting mirror 902 of the body 904 is arranged from the front surface to the back teeth of the left side and then is made to move in the direction of the front surface for continuous capture so as to obtain, for example, the images of FIG. 9A to FIG. 9E. In this case, the images which are obtained by capture at timings where the mark ML matches the vertical centerline (CL) of the reflecting mirror 902 (up to FIG. 9C) are supposedly employed as images for combination. If using FIG. 9D on, at the time of combination, sometimes these will cause deviation, so it is preferable not to use these for combination.

[0163] The image which is shown in FIG. 9C is corrected for tilt of the image etc. in accordance with need with reference to the mark ML used as the reference image. That is, the image may be corrected based on the long sides and short

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sides of the mark ML to obtain the reference image. One example of the combination operation will be explained below.

[0164] The images which are used for combination are shown in FIG. 9F on. FIG. 9F corresponds to the image which is shown in FIG. 9C, FIG. 9G corresponds to FIG. 9B, and FIG. 9E corresponds to FIG. 9A.

[0165] The image 906e which is shown in FIG. 9F and the image 906d which is shown in FIG. 9G are combined by superposition based on common parts where the shape of the image of the image 906d matches or approximates the image 906e as a reference.

[0166] The part which sticks out in the left direction of FIG. 9G when superposed based on FIG. 9F is shown by 1001a. 1001a becomes the image in the back tooth direction.

[0167] Next, the combined image which is shown in FIG. 9G and the image 906c which is shown in FIG. 9A are superposed visually or by an image processing technique at parts of common shape etc. with reference to the combined image of FIG. 9G. In the superposed image, the part protruding in the left direction from FIG. 9G is indicated by 1001b. 1001b is an image in the back tooth direction.

[0168] The above operation is next performed between the next adjoining images. Furthermore, the next adjoining images are superposed at the common part. Due to this, the images from the image where the mark is at a predetermined position to the deep tooth direction are combined panoramically to form the left side rows of teeth.

[0169] In addition, the technique of splicing together the parts 1001a, 1001b... which protrude from the center image shown in FIG. 9F to form a left half panoramic image may be illustrated.

[0170] Further, the protruding parts are detected by, for example, extracting the protruding parts between 906e of FIG. 9C and 906d of FIG. 9B, extracting the protruding parts between 906d of FIG. 9B and 906c of FIG. 9A, furthermore collecting the protruding parts between the next adjoining images, and finally making the reference image the image shown in FIG. 9F and splicing together the protruding parts to form a panoramic image. The images of the protruding parts are sometimes preferably obtained by using an image from the center as a reference and superposing the adjoining images from it.

[0171] Note that, even when not completely superposed and matching or approximate, if the marker part is present in common, that part may be superposed for similar combination. Further, since the operation is manual, there is a proximity feeling in the obtained still images and the tilt sometimes differs. In this case, it is preferable to use affine transformation etc. for automatic correction to enlarge or reduce the image for adjustment.

[0172] The combined state is shown in FIG. 12A. As shown in FIG. 12A, it is possible to form the left half of the panoramic image of the rows of teeth.

[0173] Next, as shown in FIG. 10A, the reflecting mirror 104 of the body 103d is arranged at the right back of the rows of teeth 900a in the state with the top and bottom engaged. In that state, while holding a certain distance from the surface of the rows of teeth 900a as much as possible, continuous capture is performed by still images at 1101a→1101b→1101c in a direction approaching the center. FIG. 10B schematically shows the positional relationship between the captured still images and the rows of teeth 900a.

[0174] The user holds the intraoral camera 901 in his or her hand while making it move in the direction of 1102a→1102b→1102c→1102d→1102e→1102f to capture images and obtain continuously captured still images. The present example is of a handheld type, so the captured image will tilt or shift to the left or right and in the back direction, but a step may be provided which utilizes affine transformation to rotate or move the image based on the common parts present between adjoining images obtained by continuous capture so as to adjust the image.

[0175] The intraoral camera 901 which is shown in FIG. 10A is the one of FIG. 8 used as it is, so the same reference notations are assigned and explanations are omitted.

[0176] In FIG. 11A to FIG. 11E, typical images are shown in the range of 1102a to 1102f of FIG. 10B. Configurations which are common to FIG. 11 and FIG. 9 are assigned the same the same reference numerals as the reference numerals which are shown in FIG. 9.

[0177] In FIGS. 11, FIG. 11A shows the area near the image of 1102d of FIG. 10B, FIG. 11B shows the area near the image of 1102e of FIG. 10B, and FIG. 11C shows the area near the image of 1102f of FIG. 10B. Further, FIG. 11D shows the area near the image of 1102g of FIG. 10B, and FIG. 11E shows the area near the image of 1102h of FIG. 10B.

[0178] Note that, FIG. 11D and FIG. 11E are images of photos when the vertical centerline CL and the mark ML match, then the reflecting mirror 104 is made to move further in the left direction. If employing these images, the superposed parts of the images captured from the left and right directions will become greater and the images will deviate, so these are not employed. FIG. 11A to FIG. 11C are employed.

[0179] In the above images, the one using the image where the mark ML and the vertical centerline CL match (1102f of FIG. 11C) as a reference is shown in FIG. 11F. Next, the common portions of the images 1102e and 1102f shown in FIG. 11B are superposed.

[0180] In the state where the image 1102f is used as a reference and the image 1102e is superposed from above in a matching or similar range of shape, the protruding part is 1201a.

[0181] Next, this superposed image and the image 1201b which is shown in FIG. 11B are superposed with reference to the superposed image using pattern matching etc. at portions matching or substantially matching in shape.

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[0182] The part which protrudes in the superposed state is 1201b. In this way, the adjoining images are superposed to form the right side rows of teeth. As another method of combination, the reference image 906e and images 1201a and 1201b may be combined as shown in FIG. 12B in some cases. Note that, when superposing front and back images, if there is some deviation, it is sometimes also possible to delete one of the superposed locations.

[0183] By using the above routine to combine continuously captured still images and superposing the center image 906e when combining the images of the left rows of teeth and the center image 1102f when combining the images of the right rows of teeth to make them match or substantially match, the panoramic image of the rows of teeth which is shown in FIG. 12C is formed.

[0184] The superposition is, for example, preferably performed by connecting and combining the left and right panoramic images of the rows of teeth based on the boundary part (KL) of teeth at the center. Note that, to deal with the case where the boundaries of teeth differ between the upper jaw and the lower jaw, the boundary part of teeth of the upper jaw or lower jaw may be used as the boundary for the combination. The combination at that time may also consist of respectively combining the panoramic image of the row of teeth of only the upper jaw and the panoramic image of the row of teeth of the lower jaw and finally combining the upper jaw and the lower jaw. At this time as well, when there is some deviation between the center images, it is also possible to delete one of the images in the superposed range.

[0185] Further, it is not necessarily required to superpose the center image 906e and the center image 1102f in advance. In some cases it is possible to employ one of the center images 1301. In this case, when for example employing the center image 906e, sometimes the sizes of 1201a and 1201b are corrected somewhat. When employing the center image 1102f, sometimes the sizes of 1001a and 1001b are corrected. In this way, in addition to the technique of splicing together the protruding parts between images, when not extracting the protruding parts and superposing images as they are at the common parts, sometimes the center images are superposed while adjusting them in size.

[0186] By, in this way, combining the left and right rows of teeth from the center images to form left side combined rows of teeth and right side combined rows of teeth and combining these based on their respective center images, it is possible to form a panoramic image of rows of teeth kept down in deviation.

[0187] For combination based on the center images, for example, it is preferable to use the contact line (edge) between teeth at the center so as to combine the left side combined rows of teeth and the right side combined rows of teeth. Furthermore, the mark does not necessarily have to be provided at the center teeth. It may sometimes be a portion of a tooth which is captured at a timing when changing the direction of the camera at the time of capture. In addition, the position of the mark is suitably selected based on the objective etc.

[0188] The characterizing portion is also not particularly limited so long as a portion which, in the same way as a mark, enables positioning at the time of combining images. Further, by applying a mark to the rows of teeth being captured in advance or providing a portion corresponding to a mark from the images, more accurate combination becomes possible.

[0189] Note that, the above explanation of operation is for the case of using graphic software to perform operations on a plurality of images which are displayed on a computer monitor such as copying and pasting them, dragging and dropping them, enlarging or reducing images, or correcting tilt visually and by mouse operation. Sometimes the known automatic panoramic image photo composing software such as Photoshop Elements 7® (made by Adobe), Photo Stitch® (made by Canon), etc. may be utilized.

[Preparation of 3D Panoramic Tooth Row Image]

[0190] A row of teeth is shaped bent into a bow in the bite plane. When trying to obtain a realistic grasp of it as a whole, with a 2D panoramic image display, the state of the individual teeth can be understood, but since the teeth are displayed in a state arranged in a flat shape, they are insufficiently grasped in three dimensions. Therefore, a technique able to display them in three dimensions is preferable.

[0191] The technique for obtaining a panoramic image by the actual image of an oral cavity, as described in for example WO2007/063980, is to form a frame which has a shape approximating an imaginary curve resembling the outline of an arch form of a row of teeth, arrange the camera device at its side surface, capture the rows of teeth as a whole, and convert the result to a 3D format so as to obtain a 3D panoramic image. True, it is possible to capture an image of rows of teeth in a 3D state, but it is hard to say this is a simple measurement technique due to the need for forming a frame provided with an imaginary curve resembling the outline of an arch form.

[0192] Next, an example of forming a 3D panoramic image by actual images will be explained with reference to FIG. 13. FIG. 13 is a block diagram for explaining a 3D panoramic tooth row image forming means.

[0193] Reference numeral 1401 indicates a camera data input means. This connects a stereo image capturing camera which is provided with a plurality of cameras such as shown in FIG. 14 and simultaneously forms the same number of images as the number of cameras.

[0194] The camera data inputting means 1401 is of a type where the shutter is operated for each image or a type where the shutter is operated once to enable continuous capture of a plurality of photographs. Sometimes a plurality of pairs of still images are continuously output.

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[0195] Reference numeral 1402 indicates a calibrating means. This corrects distortion due to the lens shape, hand-shaking, etc. and corrects the perspective distance etc. It is configured using the known technique of calibration.

[0196] The calibrating means 1402 calibrates the simultaneously captured images and deletes the peripheral parts where distortion is large.

[0197] Reference numeral 1403 indicates a common point detecting means. This for example detects common points of a pair of images. The common point detecting means 1403 uses the luminance of one pixel or one group of pixels of one image as the reference luminance, uses the luminance of one pixel or one group of pixels of the other image to obtain, for example, the sum of absolute difference (SAD) of luminance and the sum of squared difference (SSD) of luminance, and outputs the parts which match by the minimum values or maximum values or the parts estimated by subpixel estimation as common points.

[0198] More specifically, for example, it is possible to utilize the configuration shown by Motoki Arai et al., Optimization of Correlation Functions and Subpixel Designation Formula in Block Matching of Images, Research Reports of Information Processing Society of Japan, 2004, P33-40 and other known techniques.

[0199] Reference numeral 1404 indicates a world coordinate converting means. This converts the coordinates of images of the common points obtained to 3D coordinates common to them all.

[0200] The world coordinate converting means 1404, for example, performs computer processing by the triangle method, 8-point algorithm method, triangulation method, or other arithmetic technique. It forms and outputs parallax values from coordinate values of photographic images of common points obtained by the common point detecting means 1403 and world coordinates (X, Y, Z) from characteristics of the camera (internal parameters of focal distance of lens, image center, and pixel size and external parameters of positions and postures of two cameras).

[0201] For example, the world coordinates (X, Y, Z) are found based on the generally known following formula (1) from the perspective projection matrixes P1 and P2 comprised of the internal parameters and external parameters of the different cameras and the local coordinates (u1, v1) and (u2, v2) of the common points M of the captured images:

[0202]

[Formula 2]

$$\omega i \begin{bmatrix} ui \\ vi \\ 1 \end{bmatrix} = Pi \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} (i = 1, 2) \cdots\cdots (1)$$

[0203] For the method of using the internal parameters and external parameters of the cameras to find perspective projection matrixes or finding the perspective projection matrixes P_1, P_2 and $\omega 1$, $\omega 2$ from the local coordinates of a plurality of common points obtained from still images and obtaining world coordinates based on the above formula (1), for example, the technique described in the Journal of the IEICE, Vol. 92, No. 6, 2009, 463-468 and other known techniques may be suitably used.

[0204] Another technique for obtaining 3D coordinates is described together with the closeup technique in, for example, Dental Materials and Equipment, Vol. 19, No. 3, 333-338 (2000) etc., but the invention is not limited to this. Other general techniques can be employed.

[0205] Reference numeral 1405 indicates a 3D image forming means which, for example, can display this world coordinate data in a 3D coordinate space virtually formed on a computer and connect this coordinate data by lines or curves to form a wire frame model and which, furthermore, can attach virtual surface data to parts surrounded by the lines so as to obtain more realistic panoramic 3D data. By making the 3D panoramic tooth row data three-dimensional on 3D coordinates, curved rows of teeth can be displayed.

[0206] Reference numeral 1406 indicates a display means which may be formed by a computer monitor, printer, etc. and may display a virtual 3D image on a usual computer monitor. Furthermore, it may display a curved panoramic tooth row image by projection to two dimensions.

[0207] FIG. 14 shows one example of a probe-shaped 3D measurement probe 1500 which is provided with two cameras at its tip end. Reference numeral 1501 indicates a camera part A. This has a lens 1501a at its center and has the form of a so-called "camera module". Reference numeral 1502 indicates a camera part B. This has a lens 1503a at its center and has the form of a so-called "camera module".

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[0208] Reference numeral 1503 indicates a lighting beam emitter. This is preferably provided around the camera part A1501 and the camera part B1502. Light which is emitted by the light emitting means 1505 which is formed inside of the support member 1506 is guided through the light guide 1504 and fired from the lighting beam emitter 1503 to the surface of the tooth being captured. The lighting beam emitter 1503 is preferably shaped so that more uniform lighting is performed. It is not specified as being the shape which is shown in FIG. 14.

[0209] Reference numeral 1503a indicates a light source for instruction use and shows the captured surface. It provides output in a spotlight like manner. Red, blue, white, and other LEDs covered around them by a black tube are used. Since the light is of a spotlight nature, the area of the surface struck will differ depending on the distance. Therefore, the probe 1500 can be moved while maintaining this constant.

[0210] Reference numeral 1504 indicates a light guide which is formed inside of the support member 1506 and is preferably covered at its surface by a light reflecting member made of aluminum, silver, or other thin film. The light guide 1504 is connected with a lighting beam emitter 1503.

[0211] Reference numeral 1505 indicates a light emitting means which is attached inside of the support member 1506. A white LED or other light source may be illustrated. In the present embodiment, an intermittent flash drive like a strobe or continuous illumination drive etc. may also be used.

[0212] Reference numeral 1506 indicates a support member which, for example, is molded from a light weight, hard plastic material, has a camera part etc. at its front end, is rod shaped, and has a shape enabling it to be easily inserted to the back of the oral cavity.

[0213] Reference numeral 1507 indicates an operating switch which performs a shutter operation etc. The switches may be freely set in number in accordance with the operating specifications and objectives and may be configured in any way. A specification may also be employed where, when used as a shutter, the shutter is driven continuously at predetermined intervals while pressed.

[0214] Reference numeral 1508 indicates a holding part which is preferably configured integrally with the support member 1506 and is molded by a light weight, tough plastic material.

[0215] Reference numeral 1509 indicates an electric lead line which is connected to an outside power supply and connects with an outside data processing system etc. A cable utilizing a USB connector may be utilized. Note that, when the light source is a strobe-type light emitter and the continuous shooting data can be temporarily stored inside of the camera, if Zigbee® wireless communication front end circuit is used for wireless connection etc., sometimes a connecting means becomes unnecessary.

[0216] Next, the operation of the present embodiment which is shown in FIG. 13 and FIG. 14 will be explained.

[0217] In the camera data inputting means 1401 of FIG. 13, the user holds the holding part 1508 shown in FIG. 14 and, in the state such as shown in FIG. 8 where the upper and lower teeth are engaged with each other, brings the camera part A1501 and the camera part B1502 at the front end of the support member 1506 close to the captured portion, and, while viewing the size and position of the spotlight emitted by the instruction use light source 1503a, presses the operating switch 1507 to start the continuous capture operation.

[0218] Sometimes rather than a continuous capture operation, it is better to press the shutter use operating switch 1507 for every capture operation, but to prevent hand shaking etc., continuous capture where the number of times the switch is depressed is reduced is preferable. In this pressed state, images are captured up to the same position as in FIG. 8A, then images are captured up to the same position in the same state as FIG. 10A.

[0219] FIG. 15 shows images forming pairs in the group of images which were obtained by a single continuous image capture operation. Note that, when more precisely measuring the surface shapes of the teeth in the oral cavity, it is preferable to capture the images in the proximity state. The focal distance of the camera is also preferably set at a state which enables close-up photography. These captured images are calibrated against distortion due to the curvature of the lens, tilt, etc. by the calibrating means 1402 of FIG. 13 and are output to the common point detecting means 1403.

[0220] At the time of 3D processing, as shown in FIG. 9 and FIG. 11, the combination is preferably performed from the center in consideration of the combination from near the center to the left-right direction, but the invention is not particularly limited to this technique.

[0221] FIG. 15A is a front view of teeth and shows an image capturing a location near the center. This is also data which is obtained by capture by the camera data inputting means 1401 which has the probe 1500 of FIG. 14 as a constituent requirement.

[0222] Reference numeral 1701a indicates the image of the camera part B1502, while 1701b indicates the image of the camera part A1501. These images are assigned coordinates having center points of the same part. For example, any point A (x1, y1) of the image 1701a of FIG. 15A captured by the camera part B1502 is set and the point A' (x2, y2) showing the same position as this is searched for. The average luminance is found using the point A as for example one pixel block. From near the position envisioned as the point A' of the image data 1702a of FIG. 15A, a pixel block of the same size as the point A is found. The sum of the difference of luminance of the two or the squared sum is obtained and gradually similar operations are performed in the direction of the point A' along with movement to form a match evaluation curve.

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[0223] The subpixel estimation technique which sets the part where the sum of the differences or the squared sum of the differences becomes the smallest or becomes the largest on the match evaluation curve as the point A' is preferable, but the invention is not particularly limited to this so long as a technique obtaining common points.

[0224] Next, a similar operation is performed on the pixel block next to the point A of 1701a to detect the common points from the image 1702a. This operation is performed repeatedly to find the coordinates of common points in the common range 1703a minus the range of occlusion of the images 1701a and 1702a. In this case as well, formation of common point coordinates centered at the position of the newly added mark ML enables high precision common points to be obtained. Further, by making this block smaller, common points can be detected in a state of a high precision, but the processing time becomes long, so the size of the block etc. are suitably selected.

[0225] Next, the world coordinate converting means 1404 of FIG. 13 converts, for example, the coordinate values measured by taking several of the above-mentioned common points to a 3D word coordinate system based on the parallax, focal distance, and other parameters inherent to the camera and formula 1. For this specific technique, the usual methods shown in the above-mentioned literature etc. may be suitably employed.

[0226] It finds the common points from a pair of images of FIG. 15A, then uses the image pair 1701b and 1702b shown in the next FIG. 15B to convert the common range 1703b minus the range of occlusion to 3D world coordinates A (X, Y, Z). In the state of 3D world coordinates, it prepares, for example, an image formed into the wire frame shown in FIG. 15D.

[0227] Furthermore, it finds the 3D world coordinates of common points of the common range 1703c minus the range of occlusion of the image pair 1701c and 1702c shown in FIG. 15C.

[0228] Next, the 3D image forming means 1405 which is shown in FIG. 13 superposes the 3D coordinates which were converted to world coordinates and found from FIG. 15A with FIG. 15B not by planar superposition, but in a virtual 3D coordinate space. It further superposes the 3D world coordinates shown in FIG. 15C with this superposed image. If this superposition is superposition in a virtual 3D space, it is possible to use the data converted to 3D world coordinates as the basis to virtually display wire frame like rows of teeth such as for example shown in FIG. 15D on a computer monitor and possible to try to superpose them visually while operating a mouse or other computer interface, but to raise the precision of the superposition, sometimes it is preferable to use either of the 3D values for comparison as a reference and use differential comparison etc. so that the difference becomes the smallest in the combination. The subpixel estimation technique using block matching may also be used to obtain common points.

[0229] FIG. 15A to FIG. 15C show the formation of rows of teeth based on data obtained by converting the right side rows of teeth to 3D world coordinates toward the front surface, but next the left side rows of teeth are converted to 3D world coordinates. The conversion to world coordinates may be performed using the above-mentioned known technique. For example, it is possible to obtain 3D coordinates based on the two images, the convert them to common coordinates, that is, world coordinates.

[0230] After obtaining the 3D world coordinates of the left and right rows of teeth, it is sometimes sufficient to combine the rows by 3D virtual display on a computer or by approximate match by numerical superposition of the coordinate values. In this case, it is preferable to superpose them based on the 3D coordinate data of the mark part. According to this technique, not only with 2D, but also with 3D coordinates, panoramic display of the rows of teeth without offset becomes possible by the display means 1406 shown in FIG. 13.

[0231] The superposition is performed by the technique of superposing numerical values of data of the same shape parts and, when they do not match, taking the average of two coordinate values while performing superposition, the method of superposing images on the screen by the manual technique of dragging and dropping them while operating the computer mouse, then finding the coordinate values, etc.

[0232] Note that, even if images which have mutually common portions, if images with poor degrees of superposition due to the image capture circumstances even after calibration, it is sometimes sufficient to select one of the common images. Sometimes it is possible to use the image of the not superposed part as required for preparing the panoramic image.

[0233] By combination by conversion to three dimensions based on world coordinates, it boomes possible for the entire rows of teeth to be displayed in a so-called "denture" state.

[0234] A 2D display of a panoramic digital image of the side surfaces of the teeth and a 3D display of a panoramic digital image of the side surfaces of the teeth enable a patient to easily understand the state of his or her entire rows of teeth, so, for example, the 2D panoramic image tooth row data and 3D panoramic image tooth row data may respectively be processed for simulation of straightening and virtual whitening to as to form virtual rows of teeth. The image of this state may be displayed together on the computer monitor to form a state impressing upon the patient the effect of treatment etc.

[0235] "Simulation of straightening" indicates for example, in the case of a 2D panoramic tooth row image, preparing a database of various shapes of single teeth in advance in accordance with the portion, processing the images of the teeth on the 2D panoramic tooth row image by having an orthodontist operate a computer mouse in graphic software to copy and paste images, and thereby forming a virtual straightened panoramic image of the rows of teeth.

[0236] In the case of a panoramic 3D tooth row image, since the 3D coordinates have already been set, existing CAD

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software may be used by an orthodontist etc. to adjust the 3D coordinates of the panoramic 3D tooth row image so as to form a virtual straightened 3D panoramic image of the rows of teeth. The technique of displaying such a straightened panoramic image is an illustration. Other techniques may also be employed.

[0237] A virtual display after virtual whitening of one's own panoramic 2D and 3D tooth row images or display of these images after being adjusted in color by the dentist in graphic software are also possible alongside. By providing a display of a panoramic image of a patient's own rows of teeth after treatment for virtual straightening and virtual coloring in this way alongside on the screen, it is possible to increase the depth of the patient's understanding of treatment.

[Means for Firing Sighting Beam]

[0238] FIG. 16 is a view which shows one embodiment of the present invention. In the figure, A10 indicates a reflecting mirror unit. This is formed by a hard plastic etc. At the front end, a reflecting mirror A10K set at a predetermined angle (for example 45 degrees) is provided. At the back end, a tubular mounting part A10S able to be connected to the outer circumference of the camera unit A14 is formed. The shape between them is opened.

[0239] The mounting part A10S and the camera unit A14 are connected by being shaped to allow one to be pushed into the other. They can be detached by just pulling them apart as well. To prevent rotation, the two may be provided with relief shapes or may be formed in elliptical shapes or other asymmetric shapes.

[0240] A11 indicates a housing. This is formed by a plastic or resin and is shaped as a tube like a ball pen which has a large caliber and is easy to grip by the hand. At the front end, the camera unit A14 is arranged sticking out. At the back end, a cable A15 for connection with an outside processing system is connected.

[0241] A12 is the direction of observation when a dentist, dental hygienist, etc. directly views the reflecting mirror A10K which is arranged at the front end of the reflecting mirror unit A10 at a predetermined angle.

[0242] A13 indicates a surface struck by the sighting beam. This is one example of the surface struck by the sighting beam when the sighting beam which is output from the sighting use light source A142 is reflected at the reflecting mirror A10K and strikes the tooth surface.

[0243] The sighting use light source A142 (see FIG. 16C) may be positioned at any location. So long as a position enabling the range of the captured image to be determined, it may be another position as well. That portion may be, for example, the front end of the reflecting mirror unit A10 at a portion lighting up the image capture range. In this case, the light path becomes short, so sometimes even if the directional angle is somewhat wide, the range of the captured image can be lighted up.

[0244] FIG. 16C shows the state of the camera unit A14 enlarged. In the figure, A141 is the illumination use light source. An LED with a wide directional angle or a combination of a lens and an LED may be illustrated as an example. A plurality of illumination use light sources A141 are arranged in the vicinity of the camera member A143.

[0245] A142 indicates a sighting use light source. An LED with a small directional angle or a combination of a lens and an LED may be used to output light to give a predetermined spread on the illuminated surface as an example. Alternatively, in the case of a light source with a small directional angle, arrangement of a plurality at predetermined intervals is preferable.

[0246] A143 indicates a camera member. This is formed by a CCD or CMOS camera. One with a larger number of pixels is preferable.

[0247] Returning again to FIG. 16A, A15 indicates a cable for connection with an external image display device. It may be formed by a general use cable such as a USB cable or also by a dedicated cable.

[0248] A16a and A16b respectively indicate operating buttons A and B. These are configured by push types, pull types, turn types, etc. If pushing the operating button A16a among these buttons, the sighting use light source A142 emits light for a predetermined time and lights up important parts for exactly a certain time through the reflecting mirror A10K. The "certain time" is at least the time by which the user can recognize the sighting beam as it strikes a key part in the oral cavity and is preferably until the timing of image capture, for example, when the operating button A16a is pressed.

[0249] At the time of image capture, a lighted part with a different color arrangement is formed in the still image. This is not preferable from the viewpoint of obstructing observation. If not obstructing observation, there is no particular need to erase the sighting beam. This may also be turned on and off to draw the attention of the user.

[0250] Next, the operation of the embodiment which is shown in FIG. 16 will be explained.

[0251] The light output of the illumination use light source A141 which is attached around the camera member A143 of the camera unit A14 lights up the tooth AH1 of the oral cavity through the reflecting mirror A10K. A14L is the light path of the sighting beam. In addition, the illumination use light source also emits light through the reflecting mirror A10K. In this state, the surface A13 struck by the sighting beam is formed in part of the surface which is lighted up.

[0252] The camera member A143 captures the portion of the oral cavity which is lighted up through the reflecting mirror A10K and displays it through the cable A15 at an external monitor device.

[0253] The dentist or other user can obtain a grasp of the image capturing position by the image which is displayed

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on an external monitor device, but when shortening the diagnosis and treatment time, when treatment is included, etc., this is often used in the same way as a dental mirror. Sometimes the observation direction differs from the captured image such as shown by A12. At this time, for example, the operating button A16a is pressed. If the operating button A16a is pressed, the sighting use light source A142 emits light. The light is emitted for a predetermined time, preferably until before starting to capture the image, and is of an extent enabling the observer to confirm the observed position and image capturing position. The observer moves the reflecting mirror A10K to match the capture position and the observation position and again presses the operating button A16a so as to adjust the capture position and the observation position.

[0254] When the positioning ends, the operating button A16a or operating button B16b is depressed again to record the still image or moving image. The contents of the operations of the above-mentioned operating button A16a and operating button B16b are illustrations and are suitably selected according to the case. One example is shown in FIG. 16B.

[0255] A17 indicates an example of an image. A tooth AH1 targeted for capture is captured. The range of firing of the sighting beam is the range of the circle shown by the surface A13 struck by the sighting beam. Almost the entirety of the key part targeted for capture is included.

[0256] The range of the surface A13 struck by the sighting beam changes depending on movement of the combination of the housing A11 and reflecting mirror unit A10 up and down with respect to the tooth H1, so the user may adjust this by moving the housing A11 and reflecting mirror unit A10 up and down. The surface becomes larger than or smaller than the image capture range, but never becomes offset from the key part of the image capture range. Further, the key part of the image capture range is sufficiently shown compared with a point light source.

[0257] Due to the above operation, the captured surface and the observed surface are adjusted and an accurate still image or moving image is recorded.

[0258] The housing A11 which is shown in FIG. 16A is held and the reflecting mirror A10K is made to move up and down with respect to the observed portion of the oral cavity so as to observe and capture the target portion.

[0259] The intraoral camera is inserted to the narrow back portion of the upper jaw or lower jaw of the oral cavity. The image capture range of the reflecting mirror extends over a wide range. At the same time, the oral cavity can be captured with the reflecting mirror in the inverted state. Capture is also possible in the tilted state or laid flat state etc. Therefore, the captured image also becomes tilted or inverted. Accordingly, the present invention is provided with an image correcting means for detecting the image capture state by position sensors and correcting images in an up-down inverted state or tilted state to a horizontal state.

[Means for Correcting Captured Image]

[0260] FIG. 17 shows an example of an intraoral camera which is used for explaining one embodiment of the present invention. It is shown as a partial cross-sectional view. In the figure, A21 indicates a housing for holding use. This has a cylindrical shape which is provided with an internal space. At the front end, an elliptical tubular shaped camera unit A23 which is comprised of a camera and illumination use light sources formed around the camera is connected in a state sticking out from the housing A21. At the back end, a cable A26 for connection with an external display device is connected.

[0261] One example of the illumination unit is shown in FIG. 17. In the figure, A22 indicates a reflecting mirror unit. At its front end, a reflecting mirror A22H which is arranged at a predetermined angle is attached. At the back end, a tubular mounting part A22S which can be attached to cover the circumference of the camera unit A23 is formed. The rest is open in state.

[0262] A24 indicates a circuit board. This is mounted inside of the housing A21 and mounts an image processing use IC etc. A25a and A25b indicate position sensors. These have IC chips etc. which are mounted on the circuit board. The numbers and mounting portions of the position sensors are examples. Depending on the types of the sensors, they are sometimes not mounted.

[0263] The position sensors A25a and A25b employed are acceleration sensors, angular acceleration sensors, or other sensor devices which can sense the state of movement of the intraoral camera over a wide range and therefore will not be disabled from measurement due to the angle. The number of the position sensors is shown here as two, but this is an illustration. The number of chips changes depending on the number of axes. If a unit for three axes, sometimes a single one is sufficient. The acceleration sensors and angular acceleration sensors are illustrated as three-axis sensors. The number of the position sensors also may be adjusted by the number of axes. The x-axis, y-axis, and z-axis of the position sensors A25a, A25b... are for example the axes which are shown in FIG. 19.

[0264] When the position sensors A25a and A25b are made angular acceleration sensors (gyro sensors), the angular acceleration sensors, for example, respectively output the amount of change of the angle due to movement about the x-axis, the amount of change of the angle due to movement about the y-axis, and the amount of change of the angle due to movement about the z-axis. In the case of angular acceleration sensors, the initial states of the x-axis, y-axis, and z-axis are freely set, then the amounts of change along these axes are added to thereby detect the image capture

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state of the camera.

[0265] As opposed to this, the acceleration sensors respectively output the x-axis direction acceleration component, y-axis direction acceleration component, and z-axis direction acceleration component. Furthermore, the combined vector of these acceleration components gives a posture vector. In the still state, the respective gravity acceleration vectors are shown. The image capturing state of the camera can be obtained from this posture vector.

[0266] For example, an acceleration sensor outputs the state of the gravity acceleration vector A451 as the posture vector when still, so it is possible to use the x-axis direction, y-axis direction, and z-axis direction vectors in this state as the reference posture and then use the angular acceleration sensors to add the amounts of change by rotation of these axes and perform other operations, so

[0267] it is also possible to combine both acceleration sensors and angular acceleration sensors to detect various states of a camera.

[0268] FIG. 18 is a block diagram which shows an example of means for using position sensors to correct the image display state. The configuration which is shown by the block diagram may have parts which are realizable by a program if involving computer processing. In the figure, A31 indicates a camera means which uses a camera which is arranged at the center of the camera unit A23 of FIG. 17 to capture a moving image or still image.

[0269] A32 indicates an image correcting means which is comprised of an image recording memory, CPU, etc. It temporarily records an image which is obtained by the camera means A31 and uses the camera angle information of the position detecting means A34 as the basis to rotate the image and form image data in a state which can be easily viewed.

[0270] For example, when the camera unit A23 captures an image, the reference posture of the image displayed on the monitor is determined, the housing is moved with respect to that reference posture, and thereby the reference posture image rotates, for example, the angular acceleration sensors etc. detect the amounts of change of the rotational angles from the angular accelerations of the respective axes to enable display of the images rotated by exactly the angles minus the amounts of change of the rotational angles whereby an easily viewable image can be formed.

[0271] Note that, sometimes the image can be corrected by just rotation about the y-axis which is shown in FIG. 19. When capturing an image of the oral cavity which is reflected by the reflecting mirror, since the camera of the camera unit A23 is constantly facing the reflecting mirror direction, the image rotates mainly due to rotation accompanying rotation of the housing about the y-axis coordinate shown in FIG. 19. Therefore, at the very least, in the state where the housing A11 and reflecting mirror unit A10 are changed in the x-axis, y-axis, and z-axis directions, it is sometimes preferable that the image which is displayed at the xz plane be corrected to a state facing a certain direction at the image display unit.

[0272] Reference numeral 33 indicates an image display means. This shows a computer monitor or other dedicated monitor. It is sufficient that it be one which displays the output image of the image correcting means A32.

[0273] Reference numeral 34 indicates a position detecting means. This is comprised of the position sensors A25a, A25b, etc. of FIG. 17. Specifically, rate gyros which output angular acceleration, rate integrating gyros which output angle, posture gyros, MEMS type and other mechanical type, optical type, and other angular acceleration sensors, piezoresistance type, electrostatic capacity type, and heat sensing type MEMS sensors, and other acceleration sensors can be utilized.

[0274] Next, the operation of FIG. 18 will be explained with reference to FIG. 17 and FIG. 19.

[0275] The coordinate axes which are shown in FIG. 19 indicate the case where a single position sensor deals with three axes. When the position sensors respectively deal with single axes, two axes, etc., coordinate axes are set corresponding to the individual portions of the position sensors.

[0276] The housing A21 which is shown in FIG. 17 is held and the reflecting mirror A22H is inserted into the oral cavity to capture an image of the target portion. At this time, a switch which is attached on the housing A21 is operated to record the initial posture state. One example of the coordinates at the initial posture state is shown by A410 of FIG. 19.

[0277] By installing the position sensors, coordinate axes are formed. In the present embodiment, A421 is designated as the x-axis, A431 as the y-axis, and A441 as the z-axis. Note that, A451 indicates a gravity acceleration vector. This is one example of a posture vector obtained by combination when the acceleration sensor is stationary. Therefore, the gravity acceleration vector sometimes cannot be utilized when not using an acceleration sensor.

[0278] The coordinates are shown in a state where the intraoral camera is in a state close to vertical for capturing the side surfaces of for example the back teeth. A422 is the x-axis, A432 is the y-axis, and A442 is the z-axis. When using an acceleration sensor, A452 can indicate a gravity acceleration vector.

[0279] The reflecting mirror 22H is made to move the target portion of the oral cavity. One example of the method of movement is shown in FIG. 19. The intraoral camera which is comprised of the reflecting mirror 22H and the housing is moved to the positions such as shown by A411, A412, and A413. The camera means A31 captures the intraoral images in those states as still images or moving images and outputs them to the image correcting means A32.

[0280] The position detecting means A34, for example, outputs the initial posture information to the image correcting means A32 for the x-, y-, and z-directions. Further, when, as in the present embodiment, configuring the system to display the image of the reflecting mirror, the camera faces the reflecting mirror direction, so the camera image inverts

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and becomes hard to view in state usually due to rotation about the y-axis, so sometimes it is also possible to use only single-axis type position sensors. The image correcting means A32 links this initial posture information and image for output to and display at the image display means A33.

[0281] As shown in FIG. 19, when moving the intraoral camera like A411, A412, and A413 to capture an image of the oral cavity, the camera means A31 outputs images corresponding to those postures. If the camera rotates about the y-axis, the image is captured upside down and an image corresponding to the captured state is output.

[0282] The position detecting means A34 detects the angular accelerations about the x-axis, y-axis, and z-axis from the position sensors A25a and A25b (for example in the case of gyro sensors) and detects the amount of change of the angle about the x-axis ($\Delta\theta yz$), the amount of change of the angle about the y-axis ($\Delta\theta xz$), and the amount of change of the angle about the z-axis ($\Delta\theta xy$) from the angular accelerations.

[0283] These amounts of change are output to the image correcting means A32. The image correcting means A32 uses the image data which was input from the camera means A31 and the position information which was output from the position detecting means 34 as the basis, for example, uses the amounts of change of the angles as the basis, to make the image rotate and return it to the initial state of the image.

[0284] Therefore, in the image display means A33, even if capturing the same intraoral object as a moving image or still images while rotating the camera, images can constantly be displayed as in the initial set state with the images of the displayed content changed.

[0285] Note that, when using a convex mirror to capture all teeth of the upper jaw and lower jaw, it is also possible to use the fisheye lens correcting means of the technique described in the Literature (Design Wave Magazine, 2008 December, P113-115).

[Means for Adjusting Capture Operation Timing]

[0286] The present invention adjusts the time until the actual capture operation by the method of pressing the switch which is operated when obtaining an actual image, for example, by the number of times pressed in a certain time like the "double click" performed when operating a computer, and therefore help stabilize camera operation when the dentist performs treatment, performs diagnosis, or provides an explanation to the patient. Alternatively, it is possible to adjust the capture operation timing by operating a camera switch on the monitor image and designating an icon showing the timing of display (for example, for two operations in two seconds and then continuous capture of several images) so as to determine the timing.

[0287] Further, when displaying coordinates etc. on the screen, by adjusting the number of times the operating button is depressed, the way it is depressed, etc., it is possible to adjust the timing of the display and therefore provide an explanation while inserting the camera into the oral cavity or otherwise adjust the timing of display of the image. The specifications of the specific timing may be input and adjusted from the screen of a mobile terminal.

[0288] One example of the timing adjusting means will be explained in detail with reference to FIG. 20. In FIG. 20, B7001 indicates an inputting means. For example, it shows pushbuttons 101d and 101e forming the operating interface of FIG. 1.

[0289] B7002 indicates an input count detecting means. This is comprised of a counter, flipflop, etc. and counts the number of times a pushbutton is depressed. This count is preferably counted within a predetermined time interval.

[0290] B7003 indicates a delaying means. This is for setting a delay time by multiplying the number of times the pushbutton is depressed with the delay time for each time. After the elapse of the delay time, a single pulse is output.

[0291] B7004 is an image capture output setting means. At the rising and trailing edges of the delay pulse of the delaying means B7003, a signal for starting the capture operation is output to the camera means B7005.

[0292] The camera means B7005 uses the signal of the start of capture as the basis to continuously capture several to several dozen still images or capture a moving image. The images obtained by this capture operation are input to the image inputting means B7006. Furthermore, the image selecting means B7007 selects the focused images and stores them at the storage and display means B7008 or displays them on the display 104 shown in FIG. 1.

[0293] The image inputting means B7006 is for fetching an image obtained by the camera means B7005 as digital data and outputting it to the image selecting means B7007. Further, the image selecting means B7007 is, for example, a means for selecting only focused images.

[0294] B7009 indicates a display means which shows the time from when a button of the inputting means B7001 is pressed to when the operation is performed in a visual manner while changing the position of blinking. The display means B7009 is set at a location highly visible to the dentist at time of treatment and shows how many seconds after the operating button is pressed the operation will be started. It is sometimes displayed on the monitor of a computer constituting one of the display means B7009.

[0295] Further, by providing an LED which gives off a red color during the delay time and which changes to a white color when the delay time ends or a light source which continuously emits light or intermittently emits light only during the delay time or other indicator by which the user can discern that the delay time is in progress, relaxed button operation

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becomes possible and the extent of intraoral work can be expanded.

[Means for Capturing X-Ray Image]

[0296] FIG. 21A is a block diagram which shows an embodiment of the present invention. In the figure, B8011 indicates an X-ray image capturing means. A combination of an X-ray output device and an X-ray CCD sensor or a combination of an X-ray output device and X-ray phosphor plate and CMOS or CCD camera are illustrated. Specifically, FIG. 21B shows one example.

[0297] The X-ray image capturing means B8011 includes the existing panoramic image X-ray camera device, X-ray CT, digital X-ray device, etc. It is sufficient that it enable data to be displayed on a computer monitor. When X-ray image data cannot be directly obtained, it is also possible to obtain visualized data of the X-ray image on the computer, hard copy data of the screen, data in a shared state on the monitor screen, data obtained by capturing an X-ray image on the monitor by an intraoral camera, or other X-ray image data. Furthermore, sometimes the configuration of FIG. 21B is also included.

[0298] B8012 indicates an actual image capturing means. For example, a reflection type intraoral camera is preferably used. The actual image capturing means B8012 sometimes further includes the configuration which is shown in FIG. 21C.

[0299] B8013 is a comparison portion extracting means. It is formed by the block matching technique and subpixel estimation technique and extracts parts matching with the image captured by the X-ray image capturing means B8011 and extracts comparison portions. For example, it extracts contours of the captured image, extracts a plurality of pixel values, and outputs the X-ray image extracted data.

[0300] B8014 indicates a comparison portion extracting means. It is formed by the block matching technique, subpixel estimation technique, etc. and extracts parts matching with the image captured by the actual image capturing means B8012 and extracts comparison portions. For example, it extracts contours of the captured image, extracts a plurality of pixel values, and outputs the actual extracted data.

[0301] B8015 indicates a comparing means. It compares extracted data which is output from the comparison portion extracting means and outputs portions which match, substantially match, or are estimated as matching as matched parts. At the time of comparison, the images are sometimes enlarged or reduced, but for example the actual image and X-ray image data need only be enlarged or reduced by general use graphic software after conversion to the BMP, JPEG, GIF, or other general formats.

[0302] B8016 indicates a matched part recording means. This records the matched portions, substantially matched portions, or estimated matched portions and transmits them to the display means B8017.

[0303] The display means B8017 may be a computer monitor (display) device, mobile phone display part, etc., but it is sufficient if it be of a size of an extent enabling side-by-side display of an X-ray image and an actual image and superposed display and have a resolution of an extent whereby the X-ray image can be displayed clearly.

[0304] The present embodiment is realized by computer software, but may also be formed by hardware.

[0305] The X-ray camera means and the actual image capturing means may be separate devices, but preferably they are a single device with parts changed and shared.

[0306] Next, the operation of the present embodiment will be explained.

[0307] The X-ray camera means B8011 is used to capture a measured portion by a moving image or still images. The portion which is measured by the X-ray camera means B8011 may be selected as a single tooth, a plurality of teeth, or all teeth of the upper jaw and lower jaw.

[0308] Next, the actual image capturing means B8012 is used to capture the portion captured by the X-ray camera means B8011 as a moving image or still images. In capture, the same portion may be accurately positioned to for capture, but it may also be used as a general measure for capture.

[0309] Distortion of the image obtained from the two is corrected. As the technique for the correction, for example, the calibration technique may be used. A grid serving as a reference is captured in advance to calculate the distortion value due to the lens and to correct the data.

[0310] Next, the comparison portion extracting means B8013 and B8014 calculate the characterizing portions. The characterizing portions are, for example, contours. Part or all of the contours of teeth in the case of X-rays and the contours of teeth in the case of actual images are extracted.

[0311] Next, the contours of the two are compared. At that time, the X-ray image and the actual image have parts of the contours matched in state or substantially matched in state and the superposed portions of the two images are taken out.

[0312] The comparing means B8015 outputs the two superposed images to the matching part recording means B8016, whereupon the matching part recording means B8016 records the two images. The display means B8017 displays the two images in accordance with the selection of the user to superpose them in a transparent state or place them side by side.

[0313] FIG. 23 shows one example of images captured by the X-ray image capturing means and the actual image capturing means. FIG. 23A indicates an X-ray image which shows a tooth b101 captured by X-rays. FIG. 23B shows

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an actual image of a tooth b101 captured at the same portion as FIG. 23A. FIG. 23C shows a superposed image b103 displaying these superposed. The comparison of the X-ray image and the actual image can be used to facilitate understanding of the X-ray image. In particular, the display of the actual image enables the color and any swelling or inflammation of the gums to be displayed, so comparison with the X-ray image enables the degree of advance of any periodontal disease or tooth decay to be displayed in a manner easily understandable by the patient.

[0314] Next, a specific example of the X-ray camera means will be shown in FIG. 22 and explained in detail. In FIG. 22, B9101 indicates a housing for gripping use. This is preferably molded from a plastic material etc. containing lead to make it impenetrable to X-rays.

[0315] B9102 indicates an X-ray output device. An existing device of a portable type for general dental use is preferable, but the invention is not particularly limited to this. Any X-ray output device which is used in dental diagnosis and treatment can be used if sufficient functionally, but a portable type is effective for home diagnosis and treatment etc. as well and is suitable for use for X-ray images used with actual images. Even if a portable type, use mounted on a stand is possible.

[0316] B9103 indicates an electrical lead line. A general use USB cable may be used. In addition, a dedicated cable etc. may be utilized.

[0317] B9104 indicates an X-ray phosphor member. One comprised of a glass substrate which is coated with a crystal of a phosphor material such as CsI, CaWO, $Gd_2O_2S:Tb^{3+}$, 549nm(f-f), and (Zn, Cd)s:Ag is used.

[0318] B9105 indicates a member passing visible light. This is formed by a transparent member which contains lead and passes only visible light.

[0319] B9106 indicates a camera unit. In this case, this need only be a camera. A higher resolution one is preferably used.

[0320] B9107 indicates a support member for X-ray capture. This is formed by a member including lead and impenetrable by X-rays. At the front end, a reflecting mirror B9108, an X-ray phosphor member B9104, etc. are mounted. The other end is formed into an open tubular shape which is inserted over the camera unit B9106 for fastening.

[0321] The reflecting mirror B9108 is, for example, formed in a state tilted 45 degrees. It is formed by a flat type mirror. It is for reflecting a visualized image after removing the X-rays and transferring it to the camera unit B9106.

[0322] In FIG. 22A, the X-rays which are output from the X-ray output device are converted to visible light by the X-ray phosphor member B9104, then the X-ray component is removed, then the light is reflected at the reflecting mirror B9108, then input to the camera unit. B9109 is a schematic view of a row of teeth in the oral cavity at the portion captured.

[0323] FIG. 22B shows an example of combination of an X-ray photographic image which is obtained by an X-ray sensor and an actual image which is obtained by a reflecting mirror. B9110 is a support member for capturing X-rays and is formed by an X-ray impermeable member in the same way as the support member B9107 for capturing X-rays which is shown in FIG. 2A.

[0324] B9111 indicates a visible light passing member which is comprised of a filter which is formed from a light transmitting member containing lead, which removes X-rays, and which transmits the visible light to the camera unit B9106.

[0325] B9112 indicates a reflecting mirror comprised of a flat mirror, while B9113 is an X-ray sensor which is formed by an existing X-ray CCD (CMOS) sensor or imaging plate. B9114 is a lead line which transmits a sensor signal of the X-ray sensor to the outside. This is also preferably covered by a resin containing lead.

[0326] The present embodiment is configured to use only an X-ray sensor B9113 and also jointly use a combination of a reflecting mirror unit and a camera unit B9106 so as to output an X-ray visible image and an actual image at the same timing.

[0327] The configuration combining the reflecting mirror B9112 and the X-ray sensor B9113 enables the actual image to show the back side of the teeth, but comparison against an image separately capturing the front of the teeth becomes easy. The same portion can be simultaneously obtained at the actual image and the X-ray image, so this is preferable from the viewpoint of easy acquisition without image processing for finding the range of match.

[0328] An X-ray image of the oral cavity is difficult for a patient to understand, but displaying the actual image of the same captured portion on a computer monitor, paper, etc. side-by-side or superposed transparently enables the X-ray image to be more easily understood and facilitates the explanation to the patient.

[0329] In an X-ray image, in the case of a dental X-ray, several teeth are captured as a single image or single set of data by a single shot. In this case, X-ray sensor and the X-ray output device are shifted while for example continuously capturing images so as to obtain a plurality of X-ray images of the entire jaw, then the contours are extracted as digital data. Further, it is possible to detect the common parts of the images with little distortion at the adjoining X-ray images, detect the points of match and estimated match by the block matching method or superposition, and form a panoramic image. Furthermore, a panoramic image is formed in the same way by the actual images. These images can be displayed on the monitor screen or printed out on paper to form data easy for comparison.

[0330] One example of the data is shown in FIG. 23D and FIG. 23E. FIG. 23D shows the state where the actual image data is spliced together by digital processing. b104 is the upper jaw data, while b105 is the lower jaw data. The upper jaw data b104 is obtained, for example, by continuous capture by the intraoral camera which is shown in FIG. 1 while

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shifting the position bit by bit and splicing together the common parts of the images by superposition. The lower jaw data b105 is also similarly prepared. The method of forming a single image is shown, but it is also possible to simultaneously capture the upper jaw and lower jaw and splice the common parts together by superposition. With continuous capture, the images are displayed continuously. They are also continuous in terms of size. Therefore, it is easy to find the connecting portions. Sometimes, little size adjustment is required.

[0331] When obtaining such a panoramic actual image, the intermediate luminance method, block matching method, optical flow method, etc. may be used.

[0332] FIG. 23E shows the upper jaw X-ray data b106 and the lower jaw X-ray data b107 which are prepared by splicing together X-ray images in the same way, Furthermore, at the lower jaw, lower jaw data b108 obtained from the actual image is superposed to facilitate viewing by the patient.

[0333] The present embodiment enables comparison of the intraoral actual image, X-ray image Y, virtual corrected panoramic tooth row image, virtual colored panoramic tooth row image, etc. by display on a computer monitor or printing on paper to make the oral cavity "visible" to the patient and therefore promote on-going treatment, effective preventive care, and proactive treatment for increasing the ratio of care at the patient's own cost.

[0334] Further, it is possible to display portions at the gums and jawbone where care is required by X-ray and actual images and combine the state of the jawbones as conditions for implanting an artificial root and the state of a virtual prosthetic shown by actual image based on the X-ray image and possible to display areas for regeneration by bone regenerating means.

[0335] An actual image, X-ray image, and microscope image can be summarized for easy viewing in a multiperspective image list. By editing this and displaying or printing out the result, it is possible to show the patient the order of treatment and prevention based on the intraoral situation in an easily understandable manner.

[0336] An actual image can be captured by, for example, coloring the plaque by phloxine etc. to enable the state of deposition of plaque to be visually observed, then forming the image shown in FIG. 23D, recording it at the recording device, then observing the state of deposition of plaque and state of the gums. Furthermore, based on the state of the gums, the plaque may be sampled and a microscope used to form an image of periodontal bacteria and edit the image in a state related to the sampled portion.

[0337] Furthermore, together with use of the X-ray image, an intraoral map which easily shows the state of periodontal disease in five rankings may be formed as image data and print data to enable suitable prevention of periodontal disease and prevention of tooth decay.

[0338] By using an actual image forming means which obtains a photographic image of all or part of the teeth by the above-mentioned panoramic image specification, it is possible to use a red color dye to show the plaque in the image data obtained.

[0339] The degree of depth of the red color of this image data is detected as a depth value by a software-based detecting means using for example the luminance detection technique. When this depth value exceeds a certain value, for example, when the value of the deepness based on the thickness in the state where the plaque has accumulated to an extent where periodontal bacteria can easily proliferate exceeds a value converted to luminance, a caution mark (symbol formed on the screen etc.) is attached to that portion of the image data. By providing this means, if outputting the image after dyeing the oral cavity to a computer monitor or printer, the parts with large amounts of deposition of plaque can be automatically displayed. This output display and the state of the gums can be viewed from the images and therefore periodontal disease can be efficiently discovered, prevented, and treated.

[Virtual Prosthesis Treatment Display of Oral Cavity]

[0340] The present invention can combine an X-ray image and an actual image side by side to form an easily understandable image, but it is further possible to superpose the virtual shape or color information of a prosthesis on this image and display the virtual state after treatment in a readily understandable form.

[0341] As one example, the X-ray camera means B8011 which is shown in FIG. 21A is given a means for displaying in combination the virtual shape which is shown in FIG. 21B, while the actual image capturing means B8012 which is shown in FIG. 21A is given a means for displaying in combination the virtual shape which is shown in FIG. 21C.

[0342] Furthermore, it is preferable to provide a virtual shape etc. storing means B8022 for storing virtual shapes in advance to enable them to be called up for use when displaying the virtual shapes in combination. As the virtual shapes etc., shape information of dentures, bridges, clasps, nonclasps, implants, inlays, crowns, and other prosthetic and orthodontic devices are included. Further, the virtual shapes include color information. For example, shade guides comprised of color samples providing a large number of tooth shapes used when deciding on the hue are stored in advance or converted to data at the time of use. Ones storing color information of all teeth or single teeth are also included. This data may be successively stored when taking X-ray images or actual images of the oral cavities of patients while adding corrective and management data to the images as required.

[0343] In FIG. 21B, B8018 indicates a virtual shape adjusting means for X-ray image use. In the X-ray image capturing

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means B8011, this adjusts the virtual shape which is called up from the virtual shape etc. storing means B8022 by designation by the user or automatically to the size of the X-ray image captured or adjusts it to a color which is easily recognizable on the X-ray image but not disturbing so as to adjust it to a state enabling combination. B8019 indicates a combined display means for the X-ray image which combines the X-ray image and virtual state for display on the monitor screen.

[0344] FIG. 21B and FIG. 21C added virtual combined display means as ancillary members to the respective camera means, but these are not limited to ancillary members. They may also be set as main components in accordance with the objective. Alternatively, it is not necessary to superpose the actual image and X-ray image of FIG. 21. It is also possible to combine respectively independent virtual displays of the actual image and X-ray image. This combination may be performed by converting the images to the BMP, JPEG, GIF, or other general format and, in the same way as a grid display etc., using the superimposition technique or using the transparency technique or superposition technique used in general graphic software.

[0345] In FIG. 21C, B8020 is a virtual shape adjusting means for real image use. This has a configuration the same as the virtual shape adjusting means for X-ray image use. B8021 indicates a combined display means. This has a function and configuration similar to the combined display means for X-ray image use.

[0346] Next, the configuration for combination of virtual displays shown in FIG. 21 will be explained in detail.

[0347] In FIG. 21A, the X-ray camera means B8011 captures and forms a full tooth X-ray image b201 shown in FIG. 28A. This is, for example, a panoramic image which is obtained from an existing X-ray panoramic image camera system or all teeth captured several at a time by X-rays to obtain images, converting these to digital images, then processing these images to for example extract contours, then detect the common parts.

[0348] It is also possible to connect individual images at common parts to form a panoramic image of all teeth. Similarly, the actual image capturing means B8012 forms a panoramic actual image b202 of all teeth shown in FIG. 28B. Further, this full tooth image is not limited to this technique. It is also possible to use the technique of continuously capturing images then selecting and splicing together suitable images.

[0349] The treatment portions are found from the image. For example, in the image b201, there are a lost back tooth part b219a and lost back tooth part b219b and a lost part b219c of the front teeth and a gap b219d of the front teeth. The same is true in the panoramic actual image b202.

[0350] Each lost part is studied as to what kind of prosthetic is necessary. For example, if a front tooth prosthetic, the virtual shape adjusting means B8018 searches through the virtual shape etc. storing means B8022 to select a candidate for the front tooth of a shape enabling prosthesis. After selection, the selected image is read out and is displayed on the display monitor combined at the combined display means B8019 while selecting the size and color on the screen. FIG. 28C shows the image b203 which is obtained by for example combining virtual configurations. In the combined image b203, when artificial roots are deemed suitable for the lost back tooth parts b291a and b219b of the back tooth lower jaw, if bridging several artificial tooth roots b213 and superstructures b215, the bridge use implant b212 and bridge superstructure b214 are selected from the virtual shape etc. storing means B8022. The virtual shape adjusting means B8018 adjusts the size and color and combines the images at the combined display means B8019 for display on the monitor screen or mobile terminal monitor screen.

[0351] In the same way for the panoramic actual image b202 which is obtained by the actual image capturing means, the actual image use prosthetic teeth, inlay data, etc. are called up from the virtual shape etc. storing means B8022. The virtual shape adjusting means B8020 adjusts the size and color for display at the combined display means B8021.

[0352] In FIG. 28, b216 indicates the bridge superstructure b214 of FIG. 28C, while b219 indicates the superstructure b215 of FIG. 28C. b217 indicates a crown for a front tooth and corresponds to b210 of FIG. 28C. b218 indicates a gap prosthetic part b211 of FIG. 28C.

[0353] For formation of the gap prosthetic part b211, for example, if the teeth are crowns, formation is possible by enlarging the sizes of the crowns and making the two crowns contact in state. In the case of natural teeth, the technique is shown of grinding away some of the two teeth for insertion of the prosthetic.

[0354] In the combined images b203 and b204, the prosthetics are shown by hatching. For example, in the bridge use implant b212 and bridge use superstructure b214 in the combined image b203, when strength etc. is not preferable, three artificial roots and superstructures similar to the lower jaw right side are read out from the virtual shape etc. storing means B8022 and displayed replaced to allow adjustment of the state of the one at the lost part and the possible range of an implant while viewing the image.

[0355] Further, it is possible to call up tooth color data from the virtual shape etc. storing means and compare and adjust the relationship of color with the adjoining teeth to make a decision. For example, for the front tooth prosthetic b210, it is possible to refer to general use models and adjust the shape and color with the adjoining teeth for combination and decision.

[0356] As the method of treating a gap b219d as well, it is possible to select the type of prosthetic which can be used, such as an inlay, crown, etc., from the virtual shape etc. storing means B8022, apply it to the image while adjusting it by the virtual shape adjusting means B8018, view the extent of combination by the combined display means B8019,

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and study the virtual shape as well. When this virtual shape is formed as a 3D shape, the virtual shape is made to rotate on the screen and a more realistic combined image can be obtained even with a planar intraoral image.

[0357] There is sufficient information for study even in the state giving the images of FIG. 28C and FIG. 28D, but the comparison portion detecting means B8013 of FIG. 21A designates a characterizing portion in the portions before combination out of the combined image shown in FIG. 28C, the comparison portion extracting means B8014 designates a characterizing portion in the portions before combination out of the image shown in FIG. 28D, and the comparing means B8015 compares the two comparison portions and temporarily records and displays the matched state.

[0358] An image showing this displayed state is shown in FIG. 28E. The combined image b205 consists of the actual image and the X-ray image superposed. The number is the prosthetic state shown by the combined images b203 and b204. An X-ray image is hard to view. In particular, the gum portion is hard to view, but with such a combined image, the gum part of the X-ray image is displayed in an easily understandable manner. Further, the superstructures or teeth and the balance of the root parts can be displayed to be easily understood.

[0359] By virtually attaching the prosthetic on the screen, it is possible to display to the patient the oral cavity in a manner enabling the actual results of treatment to be imagined. Alternatively, it is attempted to realize a prosthesis suitable for the patient by presenting the patient with a virtual lineup of suitable colored or silver teeth or ceramic or other teeth. At the time of treatment, the virtual attachment to the X-ray image also becomes of reference in treatment to the dentist. For the virtual data, it is possible to use already available data as it is or enlarged or reduced for combination. In addition, after combination, it is possible to convert the actual distance to prosthetic data and obtain color information and whitening and corrective data.

[0360] By combining a virtual shape with a prosthetic portion, it is possible to find part of the size of the actual prosthetic, so the virtual shape or other data can sometimes be used as is as data for prosthetic production.

[0361] Further, this technique is performed by a computer. Part of the size of an actual prosthetic is quickly learned. This can sometimes be used as production data as is for the prosthetic.

[Mobile Terminal Type Information Inputting/Outputting Means]

[0362] Next, an embodiment of the present invention will be explained in detail with reference to FIG. 24. In the figure, 1a01 indicates a small sized battery of a button type, tube type, sheet type, pin type, etc. Further, either a primary cell or a secondary cell may be used. 1a02 indicates a voltage boosting means such as a DC-DC converter, chopper, or switching regulator which, for example, has the function of boosting a voltage of 1.5V to around 3V. 1a03 indicates a control means such as a one-chip type computer or ASIC or other control chip. 1a04 indicates a display means formed by a liquid crystal panel etc. which can display a 2D image.

[0363] 1a05 indicates a terminal side communicating means which is suitably provided by the type of the wireless medium 1a0C. If a radio wave, a circuit which includes a carrier wave output means for use up to several GHz, an FM, AM, PCM, or other modulating means, and a transmission and reception antenna is used. If light, a combination of an LED, laser, and CDS or other light receiving element is used. Among these, Zigbee Module (brand name) using radio waves etc. can be suitably used. In addition, sometimes a USB connection or other general use cable, dedicated cable, or other cable communicating means is also possible.

[0364] 1a06 indicates an inputting means such as a keypad, touchpad, or other means which is depressed, touched, etc. to convert the portion intended by the user to an electrical signal. Sometimes a liquid crystal panel which has a touch panel function or other device which doubles as the display means 1a04 and the inputting means 1a06 is used.

[0365] 1a07 indicates a storing means which stores a program for editing patient data and displaying it on a display. The patient data is mainly recorded at the host device side, so temporary storage is also possible. It need only be stored up to the capacity. 1a08 indicates an electrical line which directly connects the inputting means 1a06 and the terminal side communicating means 1a05. This exhibits the function of direct transmission of a signal through the terminal side communicating means 1a05 if a key is pushed and may be configured in the same way as a circuit line between a keyboard and computer. When a control means 1a03 acts in its stead, it is sometimes unnecessary.

[0366] 1a0B indicates a host device which is configured by a combination of a recording means 1a11 which stores patient data, patient intraoral data, patient health data, attendance records and other dental employee related data, dental diagnosis and treatment data, electronic patient chart data, patient reservation data, etc. in a database and all other data relating to the dental practice, a host computer 1a10, and a communicating means 1a09.

[0367] 1a09 indicates a host side communicating means which is configured paired with the mobile terminal side terminal side communicating means 1a05. It is not uncommon for a plurality of mobile terminals to be utilized for a plurality of patients, so the mobile terminals or communicating means 1a09 preferably can be set to multiple channels and input from only specific mobile terminals can be made to be accepted.

[0368] 1a10 indicates a host computer which is configured by a combination of a display device for display use, a keyboard, mouse, printer, and other peripheral devices. 1a11 indicates a recording means such as a hard disk, SD, DVD, USB memory, or other recording medium which can be housed in the host computer 1a10. The communicating

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means 1a09 may be similarly connected at the outside and may be built in. 1a12 indicates a communication network such as the Internet, an in-house LAN, Intranet, etc. 1a13 indicates another host device which is configured in the same way as the host computer 1a10 of the host device 1a0B and may store patient data etc. which the host device 1a0B does not hold. Further, for example, by sending treatment data from a distant location to a mobile terminal, it becomes possible to assist the diagnosis and treatment of a dentist operating it.

[0369] Next, the operation of the embodiment which is shown in FIG. 24 will be explained.

[0370] The voltage of the battery 1a01 is boosted by the voltage boosting means 1a02 and supplied to the different means. This voltage boosting means 1a02 is used to, for example, boost the battery voltage of 1.5V to 3V or more to enable the C-MOS control device etc. to be driven.

[0371] The control means 1a03 may call up, run, and display on the display means 1a04 a diagnostic data processing program at the time of dental diagnosis and treatment from the storing means 1a07. Otherwise, data which is sent from the host computer 1a10 may be displayed as it is on the display means 1a04.

[0372] Since a wireless communicating means is used, first, or in the middle of operation, the state of communications is examined and the communication situation is confirmed. Further, even if the wireless connection is broken in the middle, the control means 1a03 may be configured to enable provisional input and output while it is broken.

[0373] In accordance with the display of the display means 1a04, the operator pushes, touches, or otherwise operates the input buttons of the inputting means 1a06. In this case, for example, if pushing the key "1" of the inputting means 1a06, "1" is output and displayed through the control means 1a03 on the display means 1a04 and is sent through the terminal side communicating means 1a05, wireless medium 1a0C, and communicating means 1a09 to the host computer 1a10. If the executed button signals reach the host computer 1a10, for example, when the patient name is sent from the inputting means 1a06 to the host computer 1a10, a search is conducted in the database in the host computer 1a10 receiving it and the data is sent to the mobile terminal 1a0A. The sent data is adjusted for display use at the control means 1a03 through the terminal side communicating means 1a05 and is displayed at the display means 1a04.

[0374] Further, the system may be configured so that the data which is transmitted from the host computer 1a10 to the mobile terminal is displayed as is at the display means 1a04 of the mobile terminal 1a0A. Alternatively, the controlling means 1a03 may call up and run a program from the storing means 1a07, process data which is sent from the host computer 1a10 by the program, and display the results on the display means 1a04.

[0375] As the data which is transferred by a wire communication means, sign data, numeric data, symbol data, and other text data and image data are sent. When the host computer 1a10 does not have the required content, sometimes the data is acquired from another host device 1a13 through the communication network 1a12.

[0376] The input from the inputting means 1a06 is further recorded at a host device side recording means 1a11. For example, when a periodontal pocket depth value is obtained and is manually input from the inputting means 1a06, it is recorded as is through the host computer 1a10 in the recording means 1a11, but to confirm the input value, the display means 1a04 may also be provided with a circuit for displaying it.

[0377] Next, the operation of an embodiment of the present invention will be explained in more detail while referring to FIG. 24 and FIG. 25.

[0378] At the time of start of use, as shown by step 1b01 shown in FIG. 25, an automatic communication test is run. If the communication test fails (NO) (step 1b02 shown in FIG. 25), an error message is displayed (step 1b03 shown in FIG. 25) and an automatic communication test is run again at step 1b01 shown in FIG. 25.

[0379] If the automatic communication test succeeds (YES), the host computer 1a10 which is shown in FIG. 24 outputs the patient selection menu display data through the communicating means 1a09, wireless medium 1a0C, and terminal side communicating means 1a05 to the control means 1a03. The control means 1a03 to which this data is input outputs this to the display means 1a04. In this case, what the host computer 1a10 outputs is display use data. When displaying this display use data at the display means 1a04, a display use program which is read out from the storing means 1a07 is run by the control means 1a03 to form this in this illustration.

[0380] Note that, the patient selection menu may also be recorded as a program in the storing means 1a07 of the mobile terminal. Alternatively, the data may sometimes be directly displayed at the display means 1a04 without going through the control means 1a03.

[0381] The display means 1a04 shown in FIG. 24 displays the patient/user selection menu (step 1b04 shown in FIG. 25).

[0382] The case where, at step 1b05 shown in FIG. 25, the patient selection menu number is input by depressing the keypad (yes) will be explained. If something else is selected (no), the operation shifts to the terminal 1b05a. There, a similar operation is repeated, so illustration and explanation will be omitted.

[0383] The patient selection (for example, depression of "1" on the keypad) and the signal of "1" are sent as they are through the wireless communicating means to the host computer 1a10 where a program operates which displays a patient name input box on the display means 1a04. At step 1b06 shown in FIG. 25, if a patient name or patient code is input by depressing the keypad, each time depressed, a code and text data corresponding to the depressed key of the keypad are sent to the host computer 1a10. If the enter key is depressed, the stored data in the recording means 1a11 of the host computer 1a10 is searched.

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[0384] For this search, in addition to a full match search for the entire name, a partial match search where only the surname and first name are input etc. may be utilized, so a list of patients obtained in the case of a partial match search is displayed.

[0385] Whether or not there is a patient candidate is displayed. If there is, a key showing that there is is pressed. The pressed information is sent directly to the host computer 1a10. The host computer 1a10 then calls up the patient data from the database and sends it to the mobile terminal 1a0A.

[0386] This patient data is displayed on the display means 1a04. In this case, the control means 1a03 lists the data for display as it is for each paragraph code.

[0387] Furthermore, when displaying patient data, the control means 1a03 may read out a display use program from the storing means 1a07 and run it so that the display means 1a04 displays an array in accordance with the program.

[0388] If there is a patient candidate (yes) at step 1b07 shown in FIG. 25, the host computer 1a10 shown in FIG. 24 sends the patient data to the mobile terminal 1a0A (step 1b08 shown in FIG. 25). If there is no patient candidate (no) at step 1b07 which is shown in FIG. 25, the patient is registered as new or a search is conducted again, but display of the routine for the repeated search is omitted. Only the step for new registration of a patient (step 1b09 shown in FIG. 25) is shown.

[0389] In the case of new patient registration, if operating the keypad of the inputting means 1a06 to input data, the keypad input is sent as is to the host computer 1a10 where it is registered in the database of the recording means 1a11. Further, in the case of registering a new patient, in addition to input from the inputting means 1a06, input from the host computer 1a10 is also possible. Whatever the input, the patient is newly added to the patient information which is recorded in the recording means 1a11 of the host computer 1a10 (step 1b09 shown in FIG. 25).

[0390] If the patient is identified and the records are displayed, next, at step 1b10 which is shown in FIG. 25, a menu for examination is displayed at the display means 1a04 of the mobile terminal 1a0A. This menu display shows the data which the host computer 1a10 outputs and displays or the data which is processed by running a program which is called up from the storing means 1a07 and is displayed by the display means 1a04 by the control means 1a03 as an example.

[0391] When the examination menu related information is displayed as text sentences, it is displayed from host device 1a0B through the wireless medium 1a0C and the control means 1a03 as is. In the case of a display having a pattern of arrangement distinctive to the database, an application program may be read out from the storing means 1a07 and run (step 1b10 shown in FIG. 25).

[0392] FIG. 25 shows the case where plaque examination is designated. Other options (1b11a) are omitted. If designating plaque examination at step 1b11 which is shown in FIG. 25, the signal which is obtained by pressing the inputting means 1a06 to designate input is directly sent to the host computer 1a10. The host computer then outputs the past plaque data.

[0393] The past plaque data which the host computer 1a10 calls up from the recording means 1a11 and outputs to the mobile terminal 1a0A is data of numerical values, symbols, text, moving images, still images, etc. The control means 1a03 runs a plaque display program which was called up from the storing means 1a07 and uses the data which is output from the host computer 1a10 as the basis for display.

[0394] Data as what stage of plaque to add at what side surface of what tooth is sent to the host computer 1a10 shown in FIG. 24 by operation of the keypad at the mobile terminal side. The host computer 1a10 records data to this effect in the recording means 1a11.

[0395] If, at step 1b12 shown in FIG. 25, the plaque of the patient is displayed, the routine proceeds to step 1b13 shown in FIG. 25 for determination of whether to make corrections or additions to the same. If making corrections or additions, the above-mentioned corrections or additions (step 1b14 shown in FIG. 25) are performed.

[0396] When the modifications and corrections or additions are completed, at step 1b15 shown in FIG. 25, it is judged whether to perform another examination. If performing another examination, an examination menu of step 1b10 shown in FIG. 25 is displayed. If not performing another examination, whether to return to the initial menu is displayed (step 1b16 shown in FIG. 25). If returning to the initial menu, the patient and user selection menu of step 1b04 shown in FIG. 25 is displayed and the processing is continued. If not returning to the initial menu, for example, the routine may be ended.

[0397] Note that the above configuration is only one example. For example, smart phones and mobile phones may sometimes also be used as they are as mobile terminals for managing dental information. At the very least, the dental employee can carry the device and operate it to input, display, and record intraoral information, dental office information, dental employee information, and other related information. If necessary, he or she can read out information from the host terminal and record information there. The devices need only be ones by which dental employees can display and input necessary information in a shared manner. They may be configured in accordance with the purpose of use.

[0398] The above operation enables wireless communication of keypad codes and numerical values, text, symbols, text data, images, moving images, and other data. Real time display is possible, so even if using the terminal at the same time as diagnosis and treatment, stress-free use is possible. Alternatively, when wearing the host device on the waist or back or when there is no problem even if connecting the host device and the mobile terminal by cables, sometimes wireless communication is not necessary and communication by cables is possible.

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[0399] The present invention enables centralized management of dental information by the above-mentioned mobile terminal. As the information to be managed, for example, dental office information, patient information, patient chart information, account information, diagnosis and treatment fee information, etc. handled by reservation management systems for dental diagnosis/treatment, electronic patient chart systems, reception computer systems for preparing reception data from accounting information and diagnosis and treatment information, recall management systems relating to repeat patients, etc. can be input. For example, dental office information which is handled by a business management system which is provided with the function of preparing and displaying graphed reports, digital X-ray information, dental microscope information, dental CT information, intraoral camera and other examination information, treatment use dental unit information, patient chair and other data information, probes for periodontal pocket examination use, and intraoral information from other devices, and attendance and other information on dental employees such as dentists, dental hygienists, dental staff, reception and administration staff, dental technicians, and other employees may be shown. In addition, toothpaste information, plaque related information , periodontal bacteria information, etc., preventive information, lifestyle disease related information, and other such information which is not limited to the oral cavity, but relates to diseases relating to periodontal diseases and other indirect diseases, for example, blood pressure and blood information etc. is sometimes also included.

[0400] Further, useful information about the clinic, useful information about the patients, questionnaire information, business information, etc. may be centrally managed, but the centralized management may not only cover all information related to the dental practice, but also just the required part of the information.

[0401] For example, when, like in the case of an analog X-ray camera device, data can only be obtained by analog photographs or images or in the case of handwritten data, an image scanner, digital camera, hard copy of the computer screen, or other digital converting means is preferably used to convert this to a digital signal for management.

[0402] The data may be centrally managed by the above mobile terminal, but a tablet type, notebook type, desktop type, or other dental computer may also be used for centralized management. In particular, a network specification terminal used primarily for the Internet or a mobile terminal may be utilized. A mobile terminal which is connected to the Internet by a wireless LAN may also be utilized.

[0403] Further, the present invention can provided centralized information and can provide data processing etc. using the cloud computing technique. For example, a mobile terminal or host terminal may use application software which is provided by one or more center organizations through the Internet and input and output data by dedicated or general use browser software at the terminal side. The terminal side need not install the centralized management application software. By just installing Internet Explorer®, Firefox®, or other browser software and using this browser software to run software for centralized management of dental information of a center, it can input and output data. It is therefore possible not to worry about the capacity of the recording device at the terminal side and provide both small size and simple design.

[0404] Note that, rather than a general use browser, it is also possible to use dedicated software for starting up software for centralized management of dental information. Further, the terminal side may sometimes store all information at the cloud side resources and sometimes store part of the information requiring secure management such as personal information at the terminal side.

[0405] As the type of the cloud, for example, a system which is constructed as a private cloud of just an in-house system, just a center organization, or a group of participating dentists where leakage of information would be a problem is preferred, but so long as security is reliable, it may be configured by a public cloud which is constructed by outside computer information service organizations. Sometimes, the entire part may be made a private cloud or a public cloud.

[0406] This mobile terminal may be carried for use by not only dentists, but also dental hygienists, dental reception and administrative staff, dental technicians, and other related staff and sometimes patients. Data can therefore be shared with other staff. Alternatively, by providing a function of switching IC cards or other carriers for identifying individuals, a single terminal may be alternately used exclusively.

[0407] For centralized management of the data, it is preferable that there be compatibility between the data which the different systems handle, but compatibility is not necessarily required. For example, when using hard copy data of the screen etc., it is sufficient that the data be displayed on the mobile terminal and be able to be operated there.

[0408] In the present embodiment, use in real time where the server provided with the external database and mobile terminal can communicate is preferable, but the invention is not limited to this. The operation may be temporarily recorded in the mobile terminal and, when communication with the server is enabled, the temporarily recorded data may be automatically transferred to the database by the batch method.

[0409] For example, when operating a patient reservation system on a mobile terminal, when determining the schedule of visits to the clinic for patient treatment and preventive care, if inputting a candidate reservation date from the terminal, the reservation status data is read out from the database and compared. It is possible to display overlapping scheduled dates on the screen of the mobile terminal and prompt change. Alternatively, it becomes possible to enter the schedule into a plurality of treatment and preventive care screens in an input display field of the mobile terminal screen and send a print command from the mobile terminal so as to print out the schedule of treatment and preventive care by a related

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printer. This can be then given to the patient.

[0410] The mobile terminal may be connected with a host device wirelessly or by cable and also may be connected with an intraoral camera by cable or wirelessly. In this case, it is possible to perform suitable positioning for capturing a tooth or tooth surroundings which require treatment or preventive care.

[0411] Not only is it possible to centralize information between a mobile terminal and host terminal, but also when using a host terminal as a server when providing each dental diagnosis and treatment chair with a terminal as a dental computer, it is possible to achieve centralized management of information between the host terminal and the computers of the individual chairs.

[0412] For input of data to the mobile terminal, in the above-mentioned way, use may be made of operating buttons or rotary dials of the pressing type, sliding type, or type which are operated by bringing a finger or pen or other such object into contact with screen. In addition, virtual buttons or virtual keyboards on the screen and, when an intraoral camera or other peripheral device, is connected, the above mentioned buttons or dials on the peripheral devices may be used. In addition, audio input and recording by an integrally provided microphone or a scanning and recording function by a camera which is integrally or separately provided may be provided to facilitate free input. Further, the scanning and recording function may use a dental camera to record a photographic image.

[0413] When inputting text or a handwriting image by an electromagnetic induction type pen or resistance film pen when inputting information onto the screen of a tablet type computer, mobile terminal, etc., it is also possible to fetch handwritten input data. For example, when providing an explanation to the patient, when explaining a treatment technique to a dental hygienist, and when otherwise display on the screen by handwriting is suitable, if inputting information directly from a mobile terminal by handwriting, it is possible to have this displayed as it is or have it displayed synchronously on the monitor screen of the host terminal to allow explanation to the patient or explanation to another employee or to have it recorded as is and used later. In particular, when entering information into the intraoral image by handwriting, the information can be used as is as patient data.

[0414] Furthermore, it is also possible to input and output audio data to obtain an accurate grasp of the intraoral situation. With the audio data, for example, when talking with a user of another mobile terminal, it is possible to designate a window on the mobile terminal screen and simultaneously display the audio and image. Alternatively, the audio data is converted as is to text data or the handwriting text is converted to text data so as to reduce the required storage capacity. In particular, when diagnosing the oral cavity, specialized terms relating to the state of tooth decay etc. can be recorded in advance as audio data and compared against audio which is input through the mobile terminal for conversion to text data. This enables data which had been previously entered to automatically be made electronic data.

[0415] By recording prerecorded audio samples and text data of specialized terms as tables in a recording device, comparing the input audio data and audio sample data, and converting the matching or substantially matching audio sample data to corresponding text data, it is possible to record accurate dental information.

[0416] The present embodiment enables input of electronic patient charts and other patient information, input of diagnosis and treatment fee information, and input and output of information relating to other dental administration under centralized management, but in this case, the host terminal and the mobile terminal may be synchronized in at least the input state. That is, if there is input from the host terminal, that input is displayed on the mobile terminal. The output display is also performed synchronously in the same way. The screen synchronization software can be run by a mobile terminal which has a built-in general use computer by utilizing the commercially available software Sync+®. Alternatively, the mobile terminal is one shown in a state which utilizes a function built in in advance or connects with a USB terminal which is provided with a LAN function to as to be able to utilize a wireless LAN. This enables sharing not only between the host terminal and mobile terminal but also with another mobile terminal through the host terminal or direct sharing between host terminals. The "direct sharing" may be sharing utilizing electromagnetic waves, infrared rays, and other wireless media and also through relay terminals.

[0417] In the case of home dental treatment, if the storage capacity and processing ability of the mobile terminal are low and data cannot be recorded, it is also possible to use a separate storage device or e-mail etc. to clean up the part which cannot be stored as data and use a dedicated or public line to transmit it to the host terminal sequentially or every certain stored amount.

[0418] Such synchronization of display between terminals enables input from a host terminal provided with a keyboard, mouse, or other input interface and thereby enables quick input since when dental diagnosis and treatment is for example performed on a common room, complicated input from the mobile terminals takes time.

[0419] Further, in centralized management of dental information using a mobile terminal or other terminal, it is also possible to automatically process time series data. For example, the date and time of the end of treatment or suspension of treatment of a patient after treatment is read out from a database and compared with the current date and time. When a preset time period has elapsed after treatment, that fact is displayed on the mobile terminal or host terminal. Alternatively, it is also possible to automatically print out e-mails directly.

[0420] The host terminal may automatically notify the mobile terminal when the time for preparing diagnosis and treatment fees and may automatically notify and adjust attendance figures for days where there are no reports etc.

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[0421] The mobile terminal may connect with an X-ray image capturing system, intraoral camera, microscope, or other peripheral devices directly or through a host terminal so as to, for example, display the camera outputs by these peripheral devices in real time on the mobile terminal and record them in patient data folders identified by the patient names etc. These peripheral devices and dental chairs, lighting equipment, etc. may also be controlled in operation from the mobile terminal. At that time, records of the control operation may be logged into the patient chart.

[0422] The patient data folder is preferably recorded mainly in the host terminal in a nonredundant state and can be read by a search from individual terminals. There may be several copies of patient data folders such as at the individual terminals in the case of temporary use, but when recording it continuously, presence in a single storage area is preferable. This storage area may be not only the host terminal, but also a distant location through a network.

[0423] The mobile terminal may further be able to swap audio, image, or text information with the patient. In particular, as use of mobile terminals becomes generalized, the patient may also carry such a mobile terminal. If the patient carries one, preferably he or she can only view information required for himself or herself as a patient. This is because, for example, if developing application software for using smart phones and other mobile phones as the above-mentioned dental management terminal, a patient need only install a specialized application to enable such use.

[Dental Explaining Means]

[0424] The present embodiment explains dental diagnosis and treatment by for example displaying a panoramic image of the entire row of teeth of a patient and an image of the treatment portion on a computer monitor (display) screen and combines subdivided moving images in accordance with the objective for reproduction as a combined moving image so as to enable individual patients to easily understand explanations of treatment. The dentist may use an existing sequence of moving images obtained by combining the subdivided moving images in advance or may select, edit, and combine images in advance.

[0425] For the technique by which the dentist selects and edits images in advance, a semicustom or existing combined moving image sequence is selected for use, but an example of combining all explanatory data to prepare at least one moving image sequence will be explained in detail with reference to FIG. 26.

[0426] FIG. 26 is a view for explaining the operation in the case where the dentist sets one combined moving image in advance. In the figure, 1c01 is the display of the initial menu. A list which shows the existing moving image sequences, a list enabling semicustom connection and editing, and a list of individually subdivided moving images are displayed and are selected in accordance with the objective.

[0427] 1c02 is the step of selecting one of the initial menu displays.

[0428] 1c03 is the step where the steps to be executed are branched according to which is selected. In the case of NO, the routine proceeds to selection of another combined moving image (not shown) through the terminal 1c03a. In the case of YES, the routine proceeds to the step (1c04) of judging whether an image is already registered among the combined moving images by the technique of searching through the names of moving images or searching for combinations of distinctive codes assigned to the subdivided moving image data. If provisionally registered (YES), the routine proceeds to selection of another combined moving image through the terminal 1c03a.

[0429] When not registered, a list of the subdivided data is displayed and furthermore editing regions are displayed. The list of the subdivided data may be broken down by objectives or may be formed into an array or formed into a tree.

[0430] In the selection 1c05 of the subdivided moving image data, the data is moved from the list to the editing region by the copy and paste or drag and drop technique to edit the time-series explanatory data.

[0431] In FIG. 26, when selection of the subdivided moving images has ended (1c06), the selected combined moving image sequence is reproduced on a test basis (1c07).

[0432] FIG. 27 shows an example of combination of the combined moving image. In the figure, 1d01 indicates a moving image of recovery of the gums after tooth extraction, 1d02 indicates a slanted moving image of the adjoining teeth, 1d03 indicates a moving image of elongation of a facing tooth, 1d04 indicates a moving image of formation of a support tooth, and 1d05 indicates a moving image explaining the dental work shown in FIG. 1 and a moving image showing the setting of the dental work. These individual moving images are preferably not single, but a plurality of moving images.

[0433] The series of moving images from 1d01 to 1d05 are made the combined moving image 1d00 which is named and is recorded in a recording device. Code sequences assigned to the individual subdivided moving image data in advance are recorded by the recording device, then the combined moving image 1d00 is displayed on the computer screen as a single icon.

[0434] The combined moving image 1d00 is comprised of moving images which are successively combined to form one moving image which can be continuously reproduced. The individual moving images are subdivided. They are preferably respectively set with patient capacities and dentist capacities. The individual moving images are, for example, the WMV, AVI, or MPEG format. They may be selected and successively combined by existing moving image editing software.

[0435] Furthermore, at step 1c08, the dentist side data and patient side data are displayed, and the time and cost are

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displayed. Preferably, the use of another technique for lower cost, shorter time, and higher profit is explained in the display as an alternative.

[0436] At step 1c09, even if the combined moving image has already been prepared, if desiring to reselect it, the routine is made to proceed to selection of the subdivided moving image data. 1c10 is the step of selecting whether to store this menu list. If storing it (YES), at step 1c11, the name of the combined moving image is input and registered for storage. When not storing it, the routine returns to the end step it is selected whether to perform editing or to end the routine as it is (1c12).

[0437] FIG. 26 explains the operation when a dentist prepares a combined moving image, but there is a large number of actual subdivided data, so depending on the selected data, sometimes time is taken. Therefore, it is also possible to form samples in the manner of an editing box for each type of explanation in advance. This embodiment may further register the intraoral image of the patient itself in the subdivided moving image for utilization as part of an explanation of treatment, prevention, etc. unique to the patient.

[0438] The present embodiment is mainly utilized for obtaining informed consent. From the viewpoint of shortening the treatment time for the patient and for making the explanation more efficient, more efficient viewing is preferable, but in this case, subdivided moving images of durations of several seconds to several minutes are presented by the dentist while explaining them to the patient. An auxiliary screen which explains terms used by the dentist may also be displayed to make the explanation easier for the patient to understand.

[0439] For example, a list of the subdivided data is displayed on a computer screen by icons, tables, etc. The data is given simple titles easy for the patient to understand. This list is edited by displaying it on the above-mentioned mobile terminal and having the dentist select from it. The selected state is displayed on the screen which is viewed by the patient.

[0440] Further, it is also possible to discuss treatment with a patient while using a simple mobile terminal to prepare a combined sequence of moving images selected for the patient and display this to the patient on an immediate basis. That is, a mobile terminal provided with a display unit and input interface which is mainly carried by a dental employee and a terminal provided with a display monitor by which a patient or person desiring preventive treatment (referred to as "patient etc.") can view the information is used by the dental employee to search for and edit moving images, subdivided moving images, or combined moving images which include content to be informed to the patient etc. on the mobile terminal. When the editing ends, the image is transmitted to the patient viewing terminal. Further, in this case, moving image data may also be transmitted, but it is also possible to transmit identification data attached to the moving image data, have the terminal for patient viewing receive this identification data, and process the moving image based on this identification data sequence in real time for display on a screen.

[0441] Furthermore, the dentist etc. can carry a mobile terminal and in that state play back a moving image on the screen display of the terminal which the patient etc. views, stop it, display or not display the patient data, and perform other remote operations.

[0442] Further, the image and data which the patient is viewing can be synchronously displayed on a mobile terminal which a dental employee carries. In particular, when using the intraoral camera which is shown in FIG. 1 to display and explain the oral cavity of a patient, the explanation and case studies match and become easier to understand.

[0443] Furthermore, in the present embodiment, the mobile terminal which is shown in FIG. 24 may be used to edit the moving image data and to output and display the edited image on a computer monitor which the patient can view.

[0444] Further, the mobile terminal may be used to enable operation of display of a moving image on a monitor which is connected to a dental computer which a patient can view.

[Gum and Tooth Boundary Detecting Means]

[0445] The present invention includes a configuration for enabling the boundary between teeth and the gums to be clearly set.

[0446] The image of an intraoral camera is usually captured while lighting up a dark narrow space, so, for example, in the means for forming a panoramic image by computer image processing which is shown in FIG. 8 and FIG. 10, if detecting the common parts between images, when explaining dental treatment to the patient, etc., it is sometimes difficult to discern the boundary between the gums and teeth and the like due to the close color and the effects of saliva etc.

[0447] Therefore, a combination configuration which is comprised of a contour extracting means for extracting contours of teeth in an actual image, a color component image converting means for converting an actual image to component colors to clarify the shapes of the teeth and the gums, and a combined image forming means for combining the image which was converted by the color component image converting means and the contour extracted image is used to enable extraction of the contours of the teeth and gums even at locations of staining of the teeth or poor illumination.

[0448] The contour extracting means is for example comprised of a means for applying a 3D Fourier transform to an image and a means for detecting only a phase signal in a frequency region which shows changes in contrast of a image after the Fourier transform and applying an inverse Fourier transform. In addition, a Z-transform system and Laplace transform system etc. may also be utilized in some cases.

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[0449] The color component image converting means, for example, is a means for forming images broken down into component colors shown by the RGB color system, La*b* color system, HSV color system, XYZ color system, xyY color system, L*u*v* color system, Munsell color system, Ostwald color system, NCS (Natural Color System), DIN color system, or other color system, selecting from among these a component color by which the shape can be clearly seen, and forming an image based on this component color or a means for combining component colors without regard to the color system to form a component color by which the shape can be more clearly seen and form an image based on that component color. This selection is preferably performed by measuring and determining a component color suitable for the intraoral image, but, for example, combination of any one of the L component image, a* component image, or b* component image of the La*b* color system and any one of the H (hue) component image, S (saturation chroma) component image, and V (brightness lightness value) component image of the HSV color system is shown. Combination of component colors of different color systems is sometimes preferable. The component colors need only be selected and combined for conversion to a component color by which the shape can be clearly seen or for combination of a plurality of component colors. Further, a "component image" includes an image which enhances the component obtained by adjusting the values showing the component values in for example a program.

[0450] Further, in addition to selecting a component image by which the shape can be clearly recognized, a combination of colors by which a person can recognize the boundaries more is used for coloring. For example, application of a R (red) component image to the gums and application of a G (green) component image to the teeth is shown.

[0451] Further, the component colors which are shown here not only include ones which are detected from an image, but also ones obtained by newly coloring while using colors which clarify the boundaries.

[0452] Further, the combined image forming means combines the contour image which was obtained by the contour extracting means and the image which was obtained by the color component image converting means and, for example, like the chroma key technique, makes the parts of the contour image other than the contour part the same color system and makes the color component image transparent etc. for combination. Alternatively, after that combination, to further enhance the color component image, means may be employed to change the color of the gum parts or more deeply enhance them to a red color system and to change the color of the teeth or more deeply enhance them to green so that the boundaries become more differentiated visually to people or mechanically. Further, depending on the color component, if converting the gum color to red and the tooth color to green, those color component images may be converted to. These means are preferably all realized by computer software, but sometimes are comprised of gate arrays and PLD (Programmable Logic Devices) and other custom and semicustom ICs.

[0453] Next, the embodiment which is shown in FIG. 29 will be explained. In the figure, reference numeral 2901 is an image inputting means. For example, it is a means for inputting a still image which was captured by an intraoral camera. The still image which was input by the image inputting means is output to a filtering means 2902. The filtering means 2902 is shown as an unsharp filter or other edge enhancement filter, but in addition sometimes a filter which enhances the contrast of the image may also be used.

[0454] The image which is filtered by the filtering means 2902 is output to the contour extracting means 2903 and the component color image converting means 2904. The contour extracting means 2903 is a comprised of a 2D Fourier transform means, a phase signal detecting means, and an inverse Fourier transform means, but these means are for example realized by combining program modules in a software library such as the "open-CV" (made by Intel).

[0455] Reference numeral 2904 is a component color image converting means. In the same way as explained above, it is comprised of a means for forming an image which is converted to the a* component color or b* component color or the H component color, S component color, or V component color of the La*b* color system or the HSV color system and a component color combining means for combining these component colors. The colors change, but an image with clear shapes of the teeth and the gums is formed. Furthermore, the changes in the color sometimes allow staining of teeth and tooth cavities to be found.

[0456] The contour image which is obtained by the contour extracting means 2903 and the images converted to component color images by the component color image converting means 2904 are output to the combined display means 2905. The combined display means 2905 combines the contour image which was output from the contour extracting means 2903 and the component color images which were output from the component color image converting means. This combination, for example, makes parts of the image other than the contours the same color system, makes the system of color transparent, and combines this with the component color image forming the background image. The combined image is displayed on a computer monitor.

[0457] Sometimes this series of processing for composition can give an image with a clear boundary between the gums and teeth. Alternatively, the present embodiment is suitably used when detecting the boundary KL of two teeth at for example the center as a general measure for when combining images (for example, image 906e and image 1102f) where the mark ML becomes the center of the image in the left and right rows of teeth shown in FIG. 12. Alternatively, a contour image which is obtained by detecting the phase signal by a Fourier transform and the actual image can be combined as they are. Further, even if using only component color images, images of clear shapes can be obtained, so even with only the images obtained by the component color image detecting means, an image with a clear boundary of

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the gums and teeth is obtained. Such an image with a clear boundary between the teeth and the gums can be utilized as mark for various types of combining operations or may be used for explanations to the patient and for dental treatment.

Industrial Applicability

[0458] The present invention provides a dental system which promote intraoral health in dental diagnosis and treatment by providing a patient with intraoral information in a readily understandable format and thereby enabling patient intraoral information to be refreshed. It is effectively utilized in the field of dental medicine.

Reference Notations List

[0459]

11 intraoral image inputting means
12 diagnosis and treatment portion detecting means
13 unit image forming means
14 diagnosis and treatment order setting means
15 diagnosis explanation forming means
16 display and output means
17 recording means

Claims

1. An intraoral video camera and display system which is provided with a continuously captured image sequence forming means for continuously capturing side surfaces of rows of teeth to form an image sequence, a side surface tooth row image forming means for combining sequences of images which were formed by the continuously captured image sequence forming means as partial tooth row images from an image forming the center of the overall composite so as to form a plurality of partial tooth row images, and a side surface tooth row image combining means for linking and combining a plurality of partial tooth row images which were formed by the side surface tooth row image forming means based on images forming the centers of the overall composite so as to form overall rows of teeth.

2. The intraoral video camera and display system as set forth in claim 1, further provided with
a mark setting means for setting a mark which is recognizable on the captured image at a predetermined position on rows of teeth,
a continuously captured image sequence forming means for forming continuously captured image sequences for one side surface and another side surface of the rows of teeth,
a side surface tooth row image forming means for combining the continuously captured image sequence of said one side surface and the continuously captured image sequence of said other side surface from images with marks at the predetermined positions so as to form one side surface tooth row image and another side surface tooth row image, and
a side surface tooth row image combining means for linking and combining said one side surface tooth row image and said other side surface tooth row image based on characterizing portions on the rows of teeth in still images where said marks are at the predetermined positions.

3. The intraoral video camera and display system as set forth in claim 1, further having X-ray image display means for displaying X-ray images of teeth corresponding to said side surface tooth row images and a virtual tooth row display means for displaying rows of teeth obtained by virtually correcting or virtually beautifying and coloring teeth corresponding to said side surface tooth row images.

4. The intraoral video camera and display system as set forth in claim 1, comprising a tooth row display means for displaying a tooth row image which is obtained by said side tooth row image combining means, a unit image forming means for forming an image of the oral cavity for each unit of diagnosis and treatment or care, a setting means for setting diagnosis and treatment and care order information for images formed by unit image formation by said unit image forming means, a display means for displaying images, with said diagnosis and treatment and care order information attached, based on said diagnosis and treatment and care order information so as to be able to be displayed in a list form, and a display medium which displays and records display information which is obtained by said display means.

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5. The intraoral video camera and display system as set forth in claim 1, further provided with a small sized portable data processing terminal which has an input part enabling input and adjustment of data relating to the dental practice, a communicating means which can communicate data with an external data processing terminal and a server which manages work attendance or dental diagnosis and treatment, and a display means for displaying a tooth row image combined by said side surface tooth row image combining means and said data relating to the dental practice.

6. The intraoral video camera and display system as set forth in claim 1, further having a dental treatment explanatory data forming means for storing, in a storage means, subdivided moving image data which is formed as moving images which have been prepared in advance and subdivide dental treatment and selecting and linking and connecting said subdivided moving image data from said storage means so as to form data for explaining dental treatment and display it by said display means.

7. The intraoral video camera and display system as set forth in claim 1, further having a handheld type camera means which captures an image of said oral cavity and a sighting means which is provided at said camera means and emits a sighting beam which indicates an image capture portion.

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Fig.1A

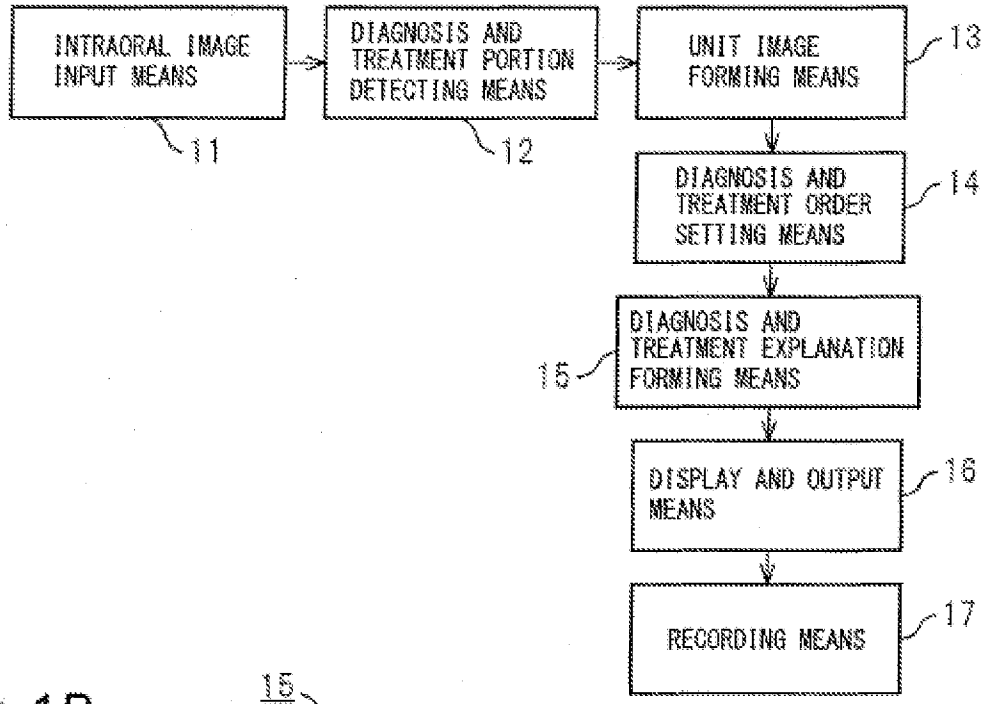


Fig.1B

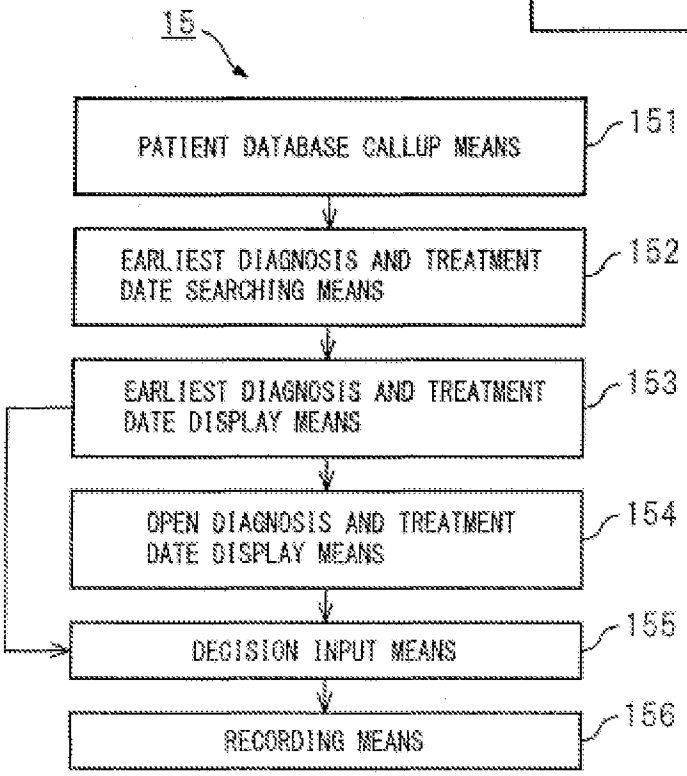


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Fig.2A

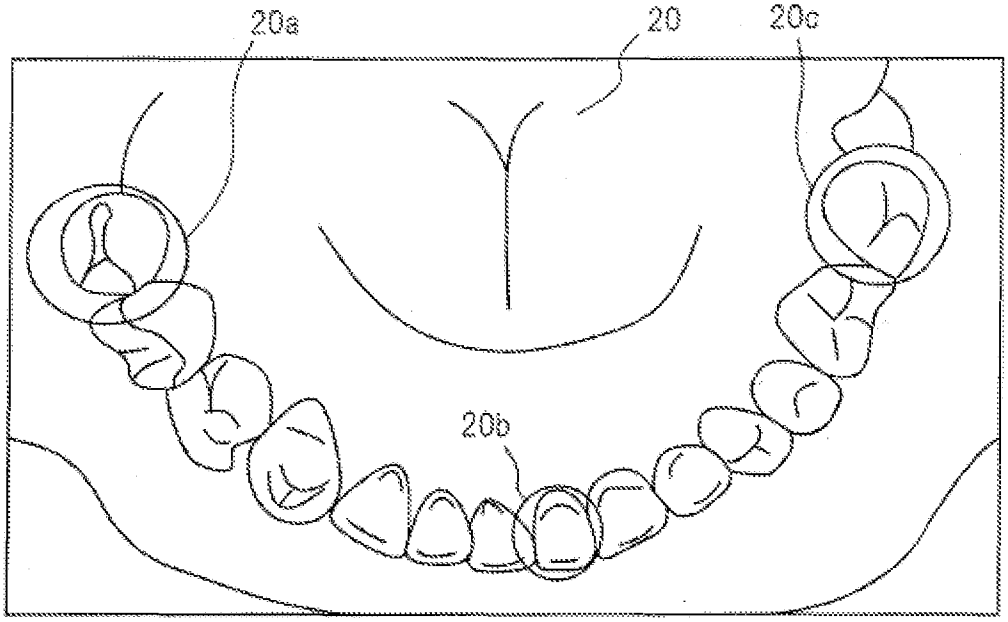


Fig.2B

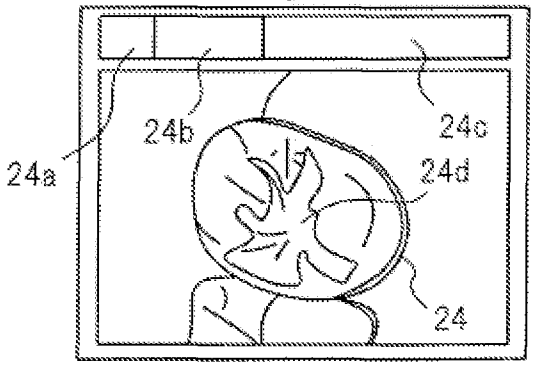
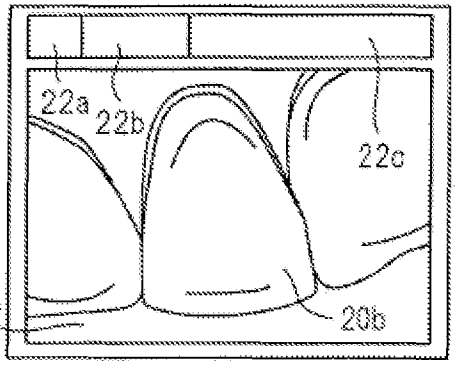


Fig.2D



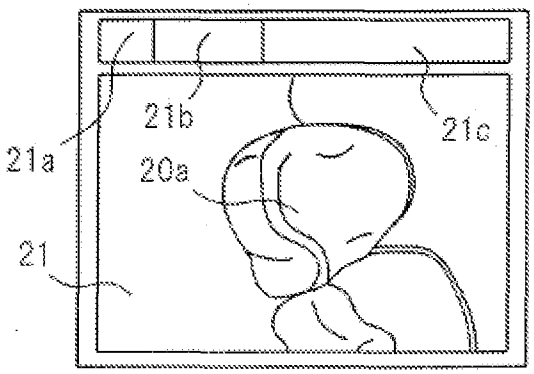


Fig.2C

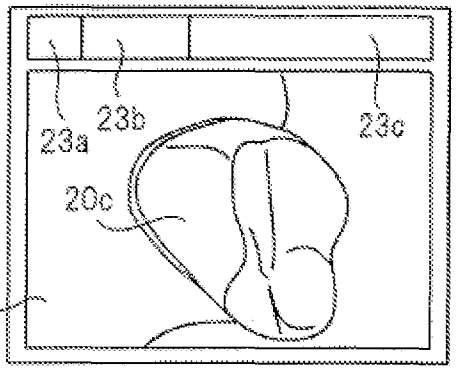


Fig.2E

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Fig.3A

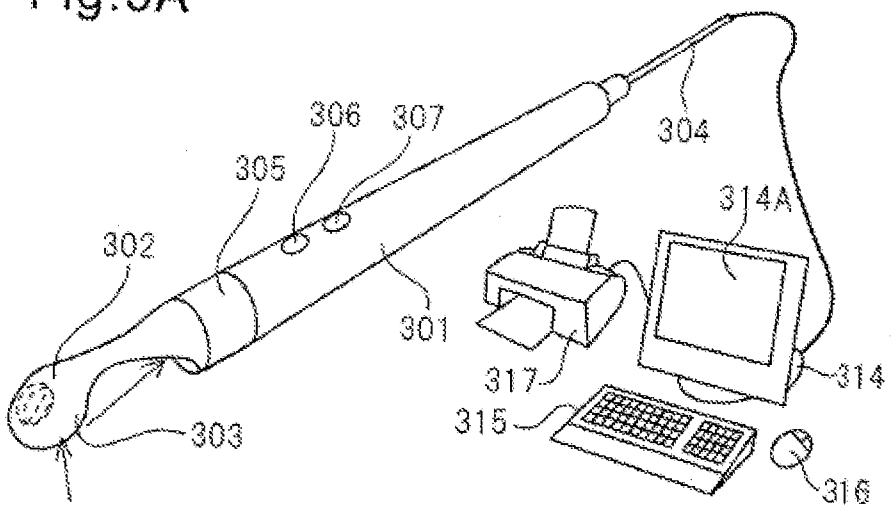


Fig.3B

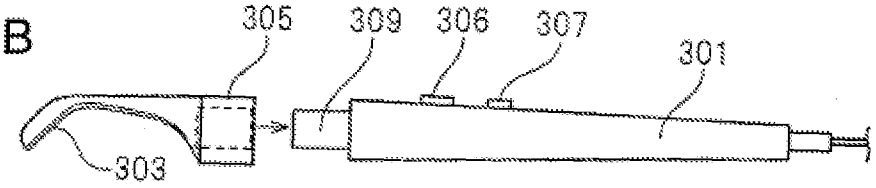


Fig.3C

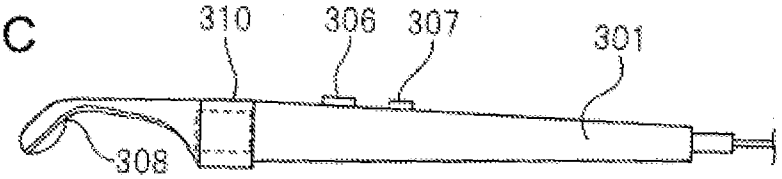


Fig.3D

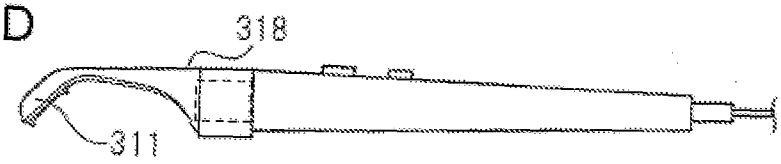


Fig.3E

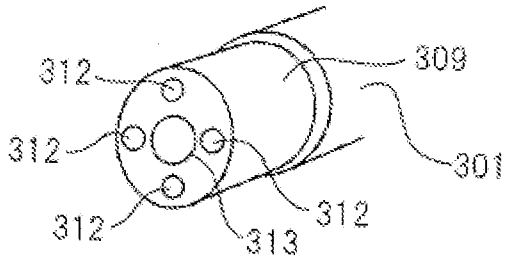


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Fig.4

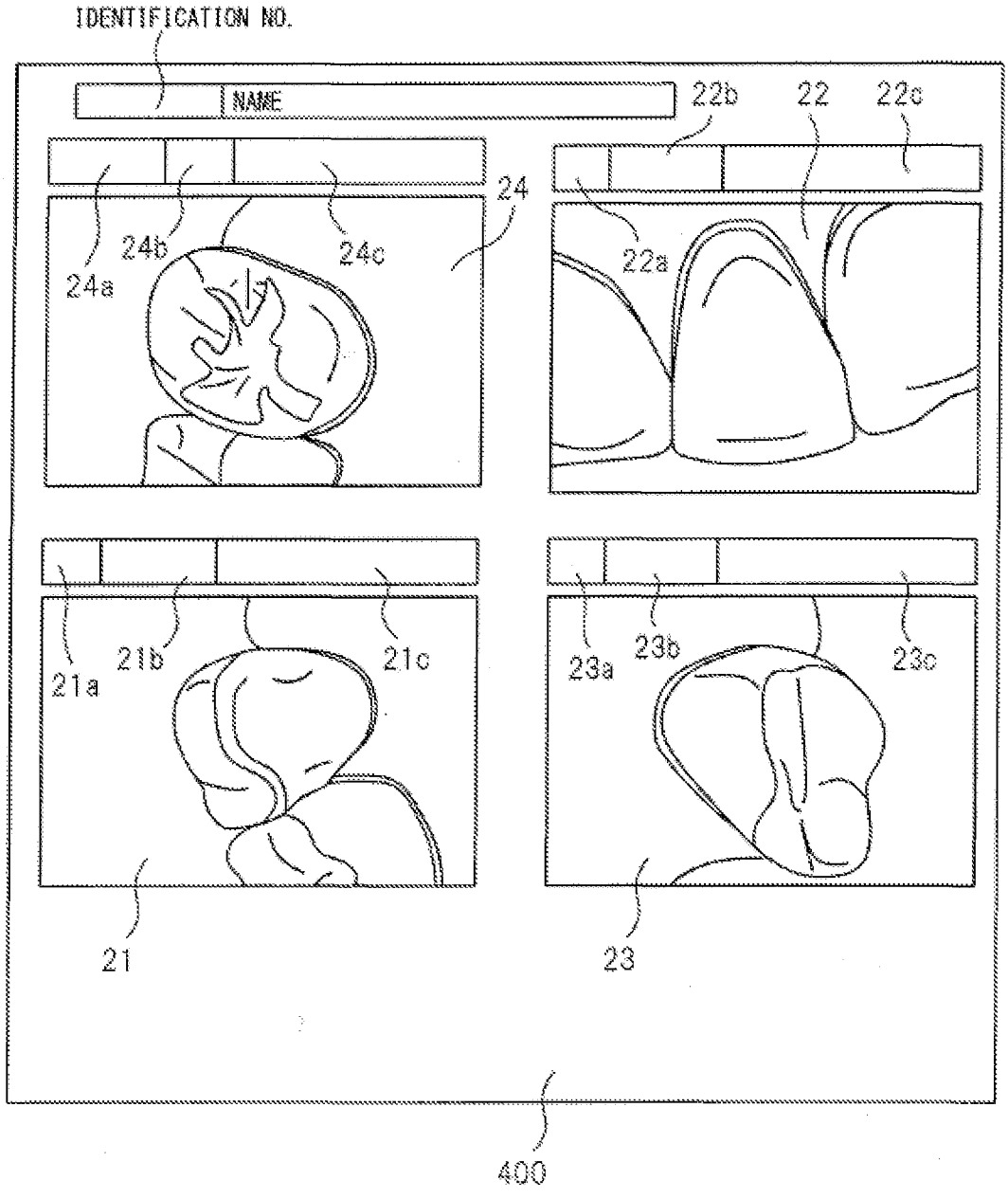


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Fig.5

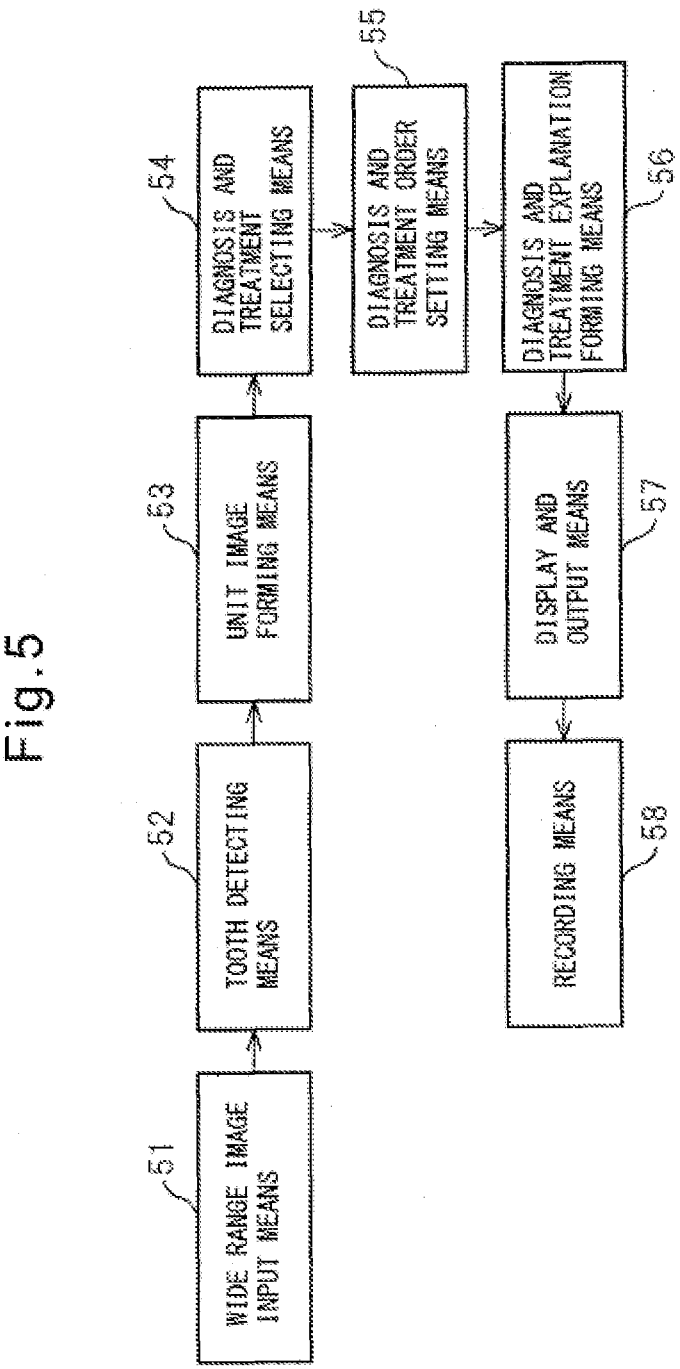


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Fig.6A

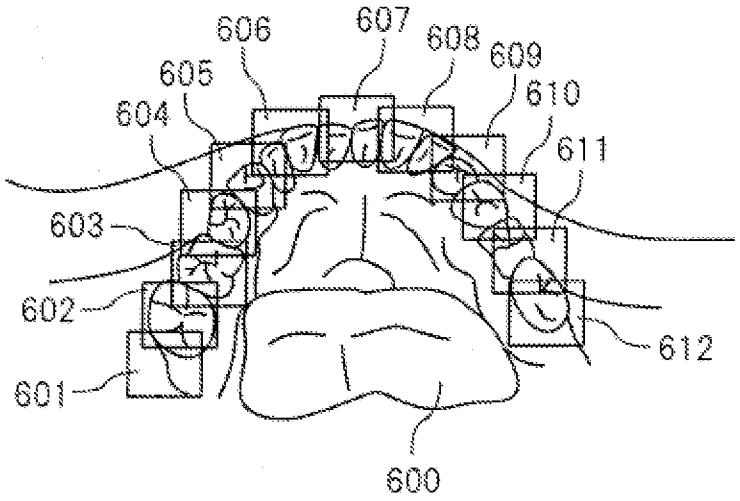


Fig.6B

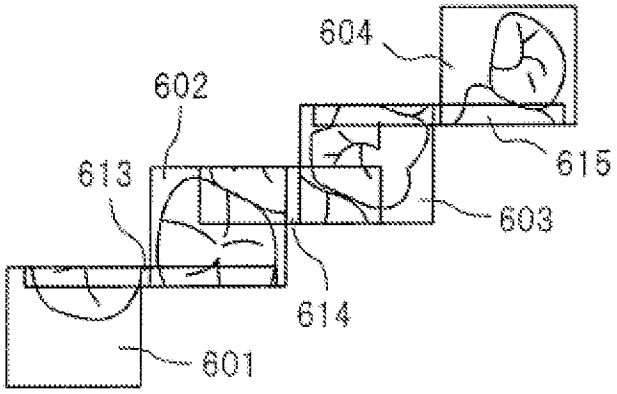


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Fig.7A

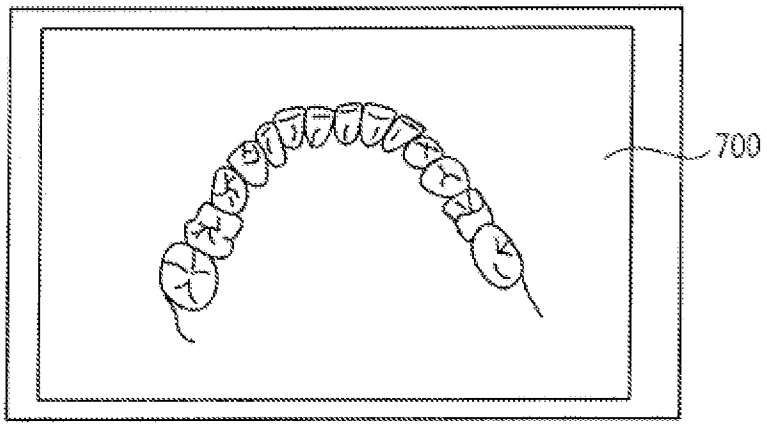


Fig.7B

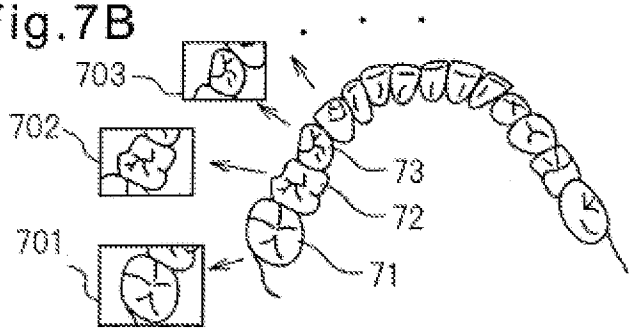


Fig.7D

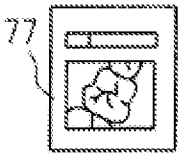


Fig.7C

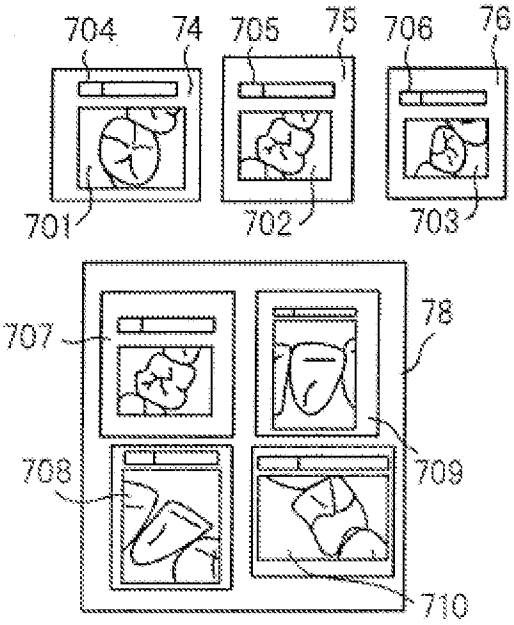


Fig.7E

Fig.7F

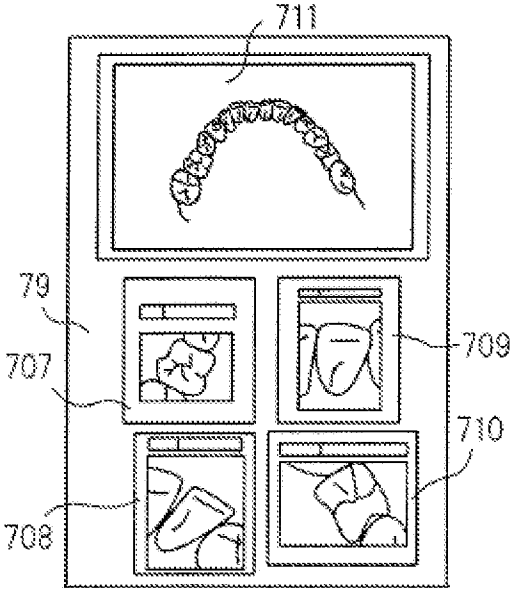


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Fig.8A

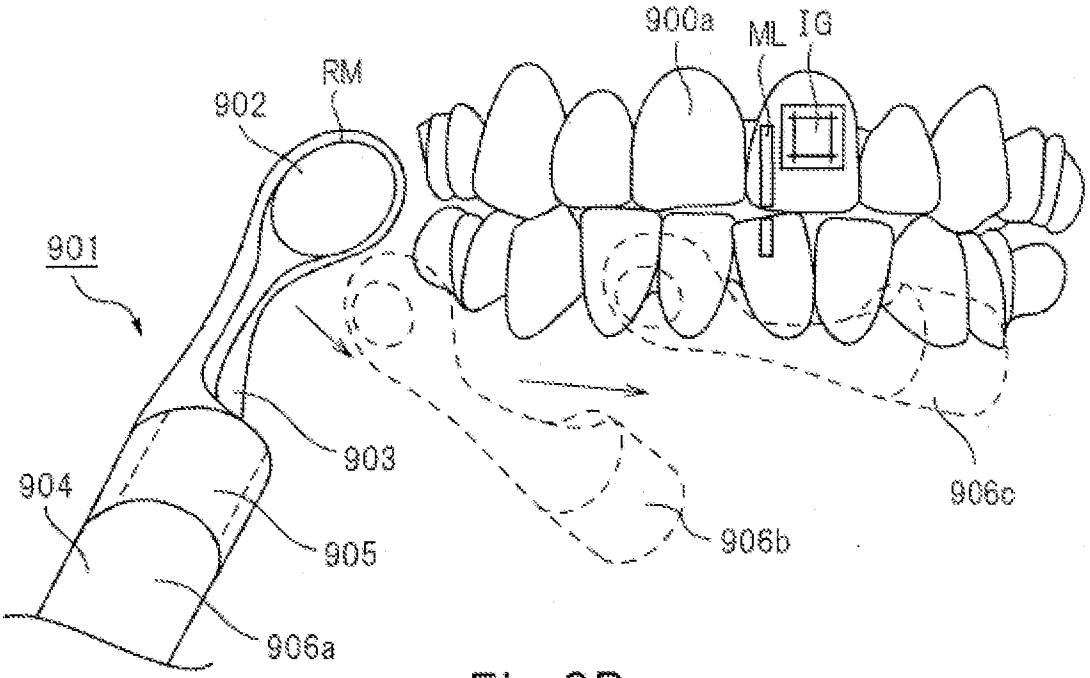


Fig.8B

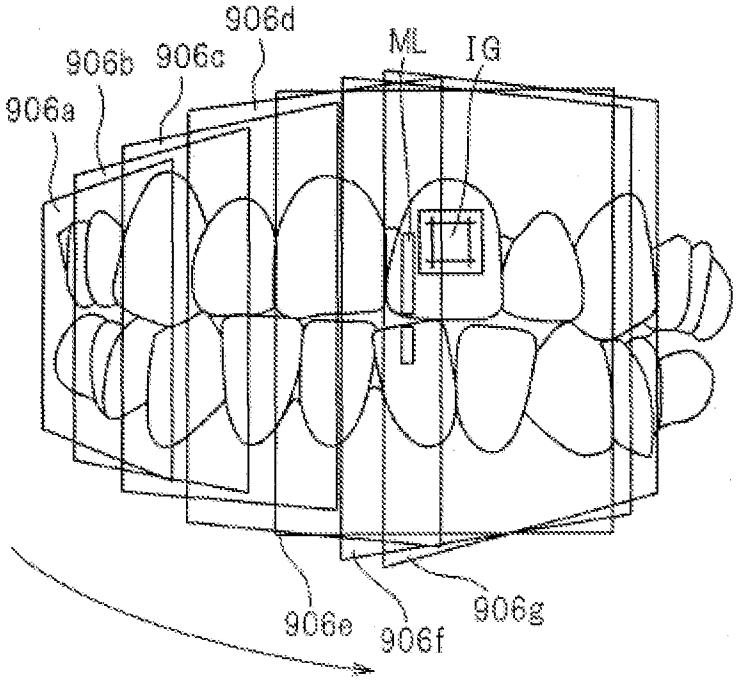


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Fig.9A

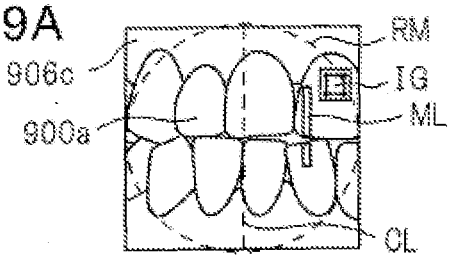


Fig.9B

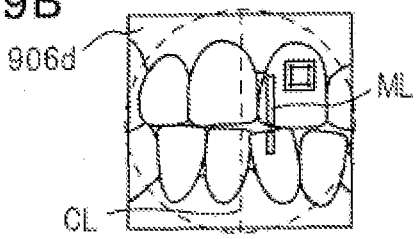


Fig.9C

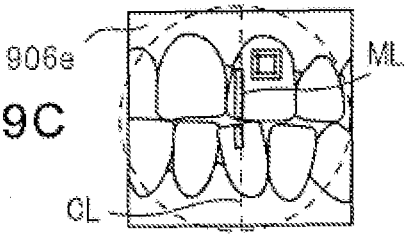


Fig.9D

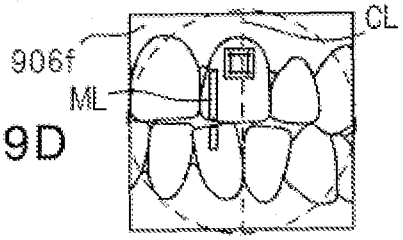


Fig.9E

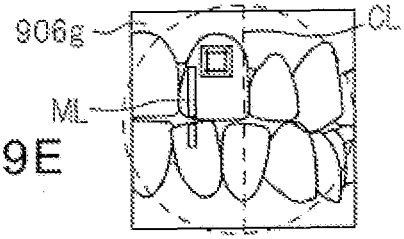


Fig.9F

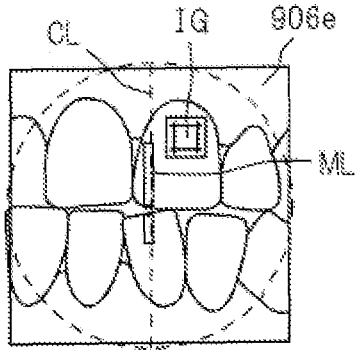


Fig.9G

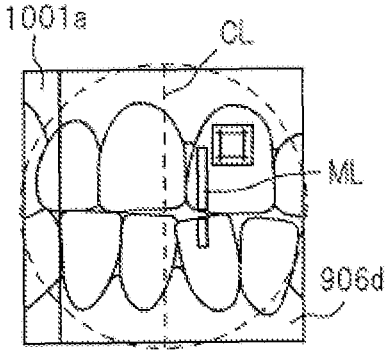


Fig.9H

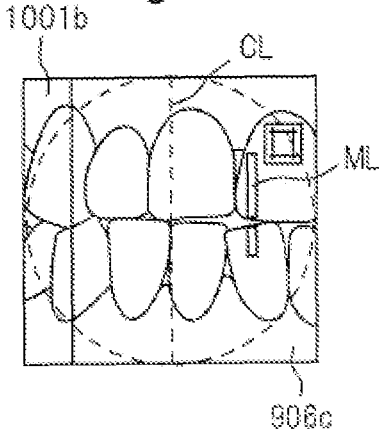


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Fig.10A

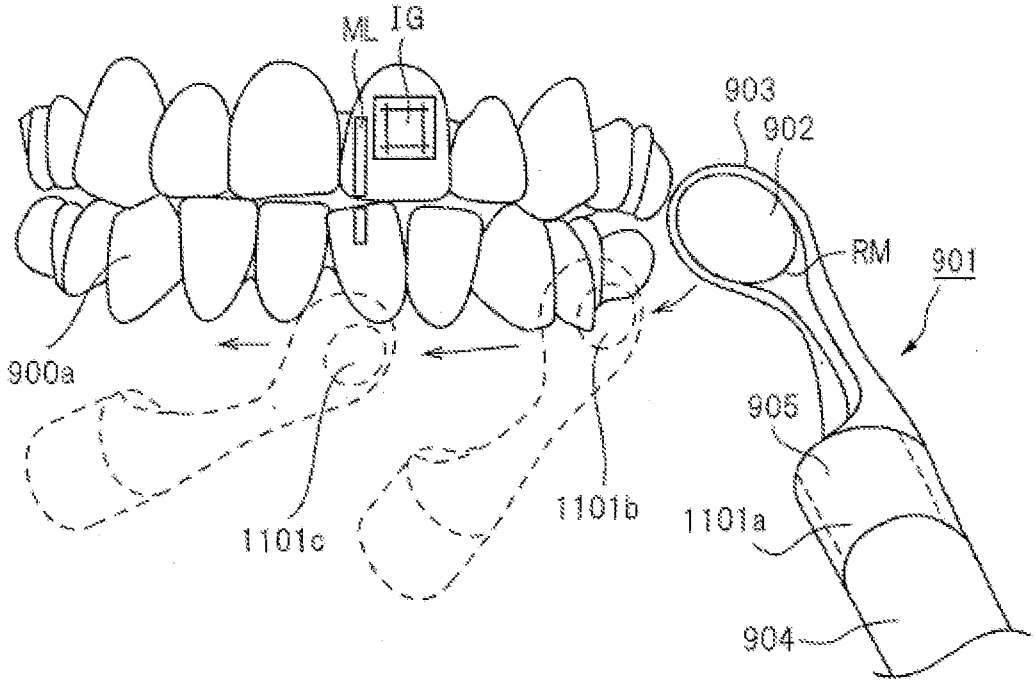


Fig.10B

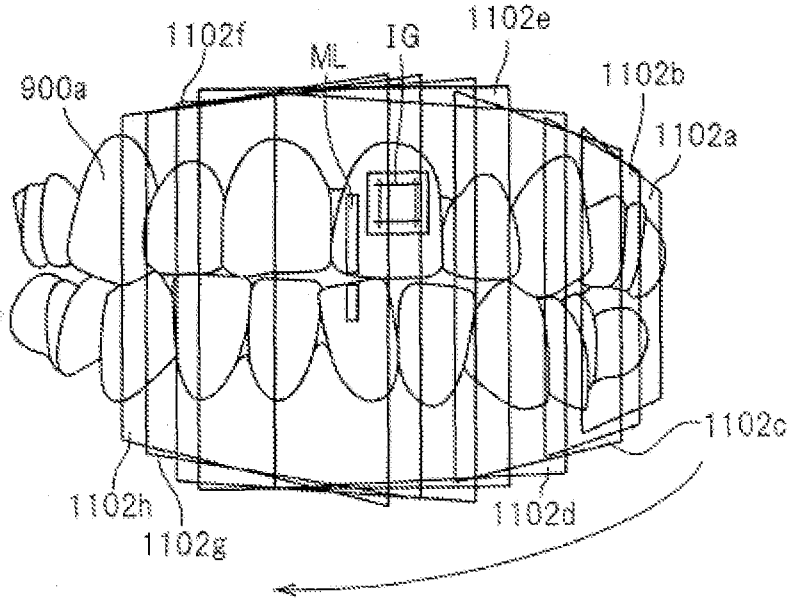


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Fig.11A

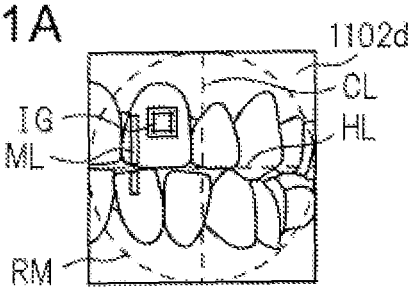


Fig.11B

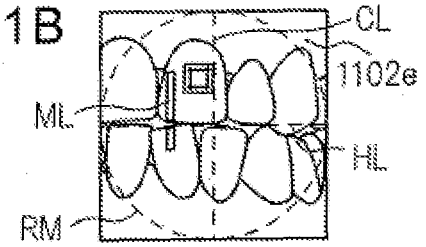


Fig.11C

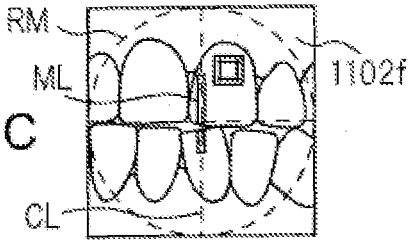


Fig.11D

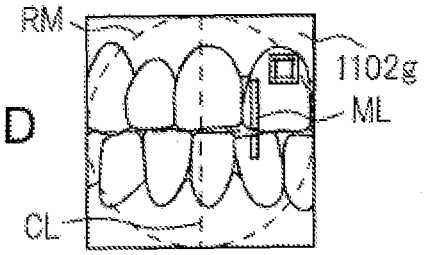


Fig.11E

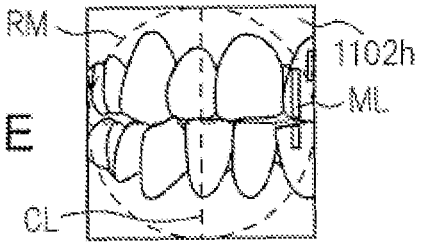


Fig.11F

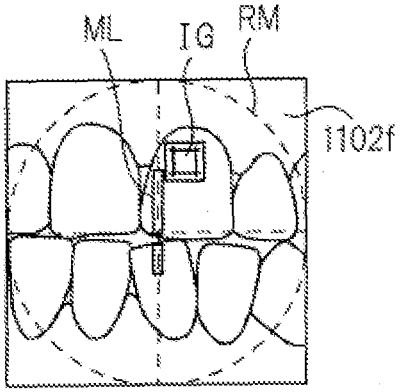


Fig.11G

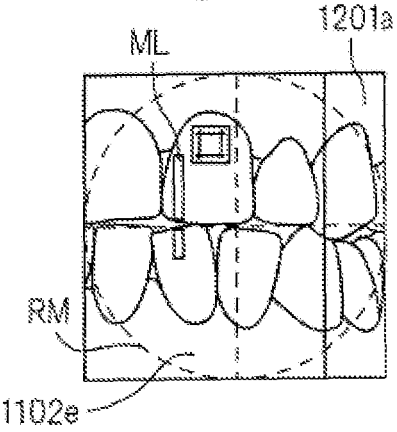


Fig.11H

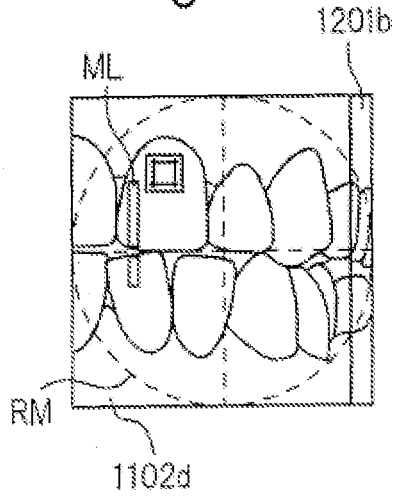


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Fig.12A

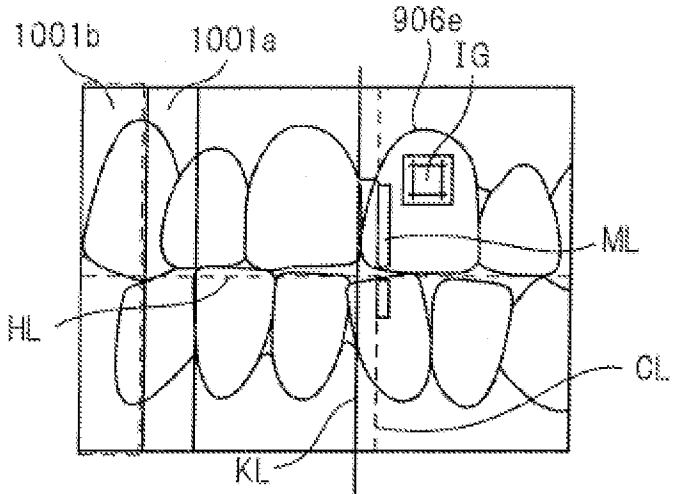


Fig.12B

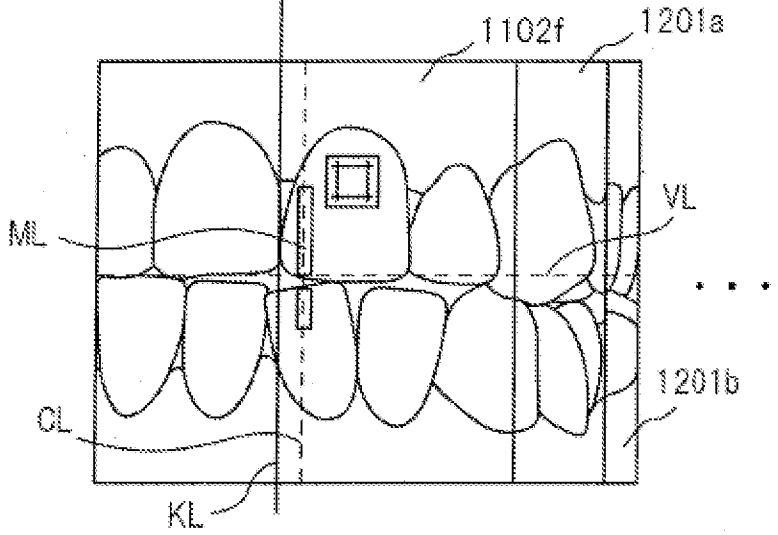


Fig.12C

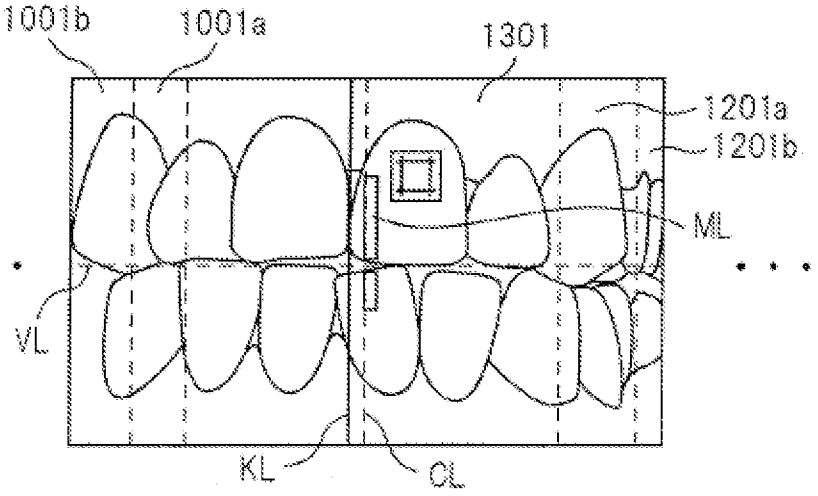


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Fig.13

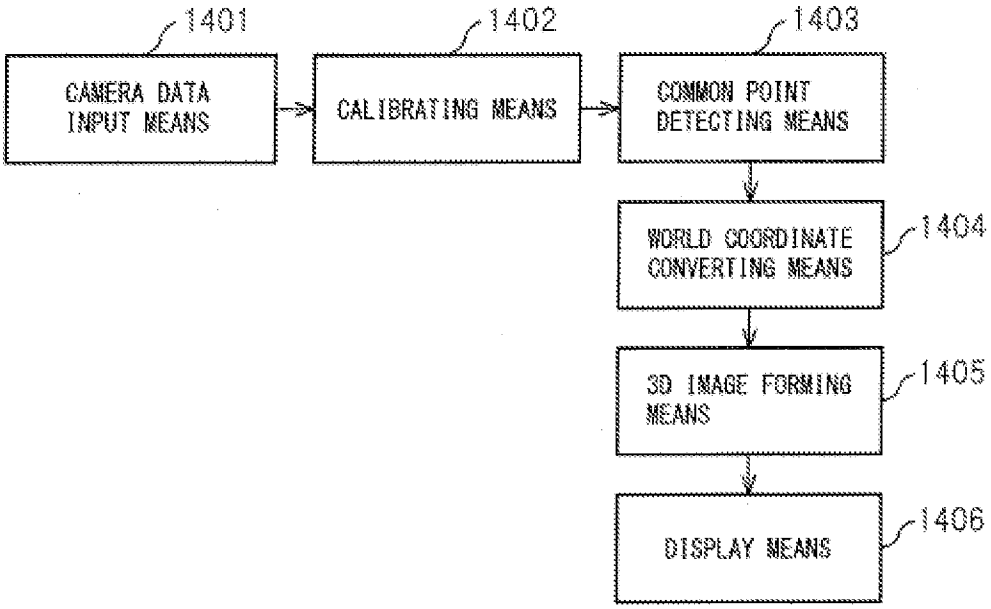


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Fig.14

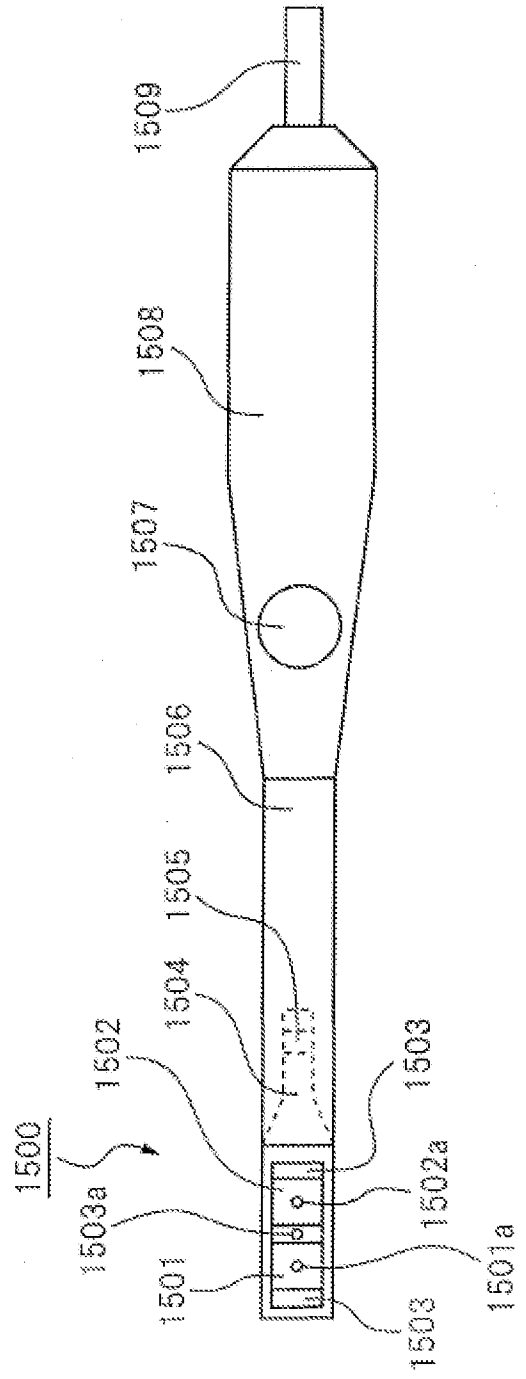


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Fig.15A

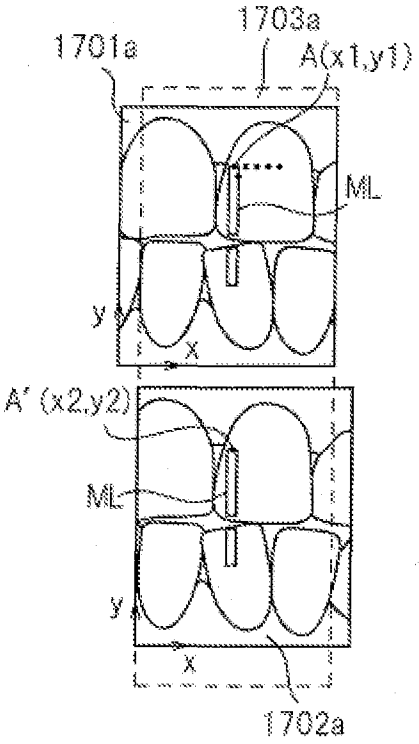


Fig.15B

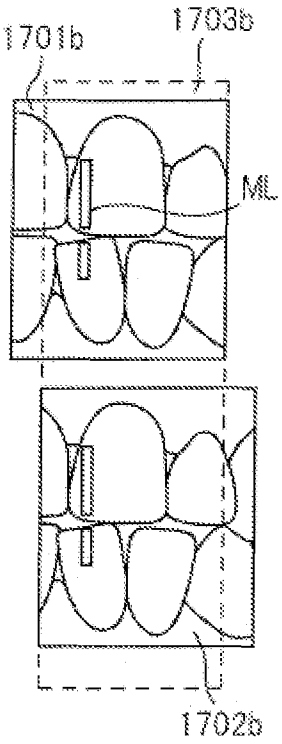


Fig.15C

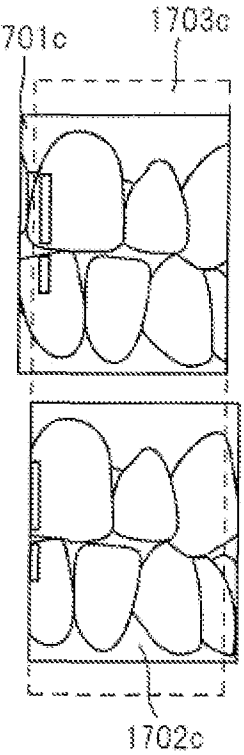


Fig.15D

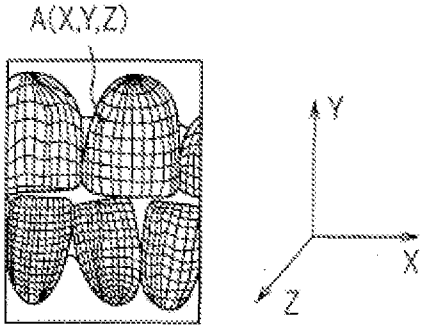


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Fig.16A

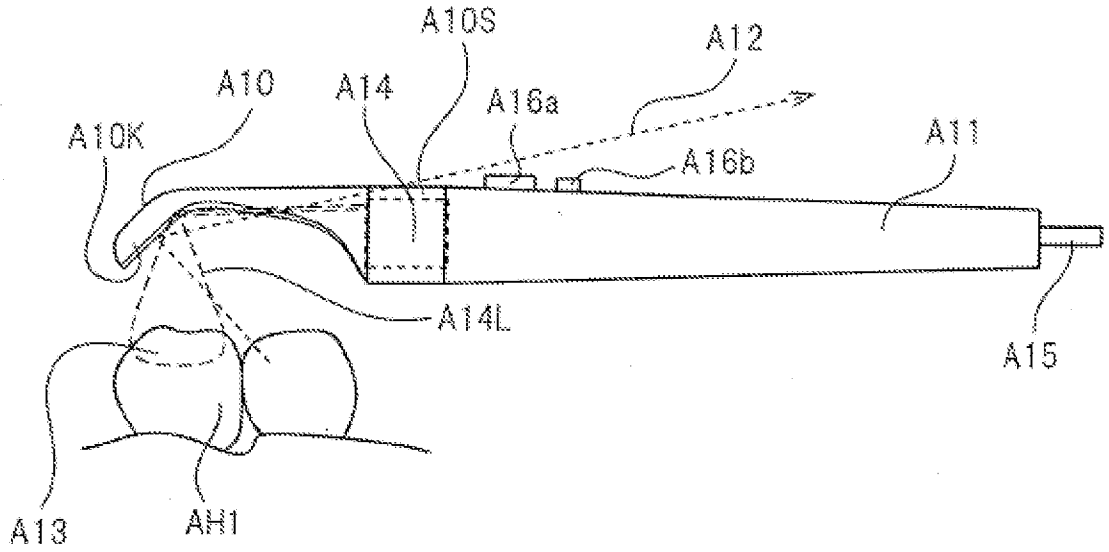


Fig.16B

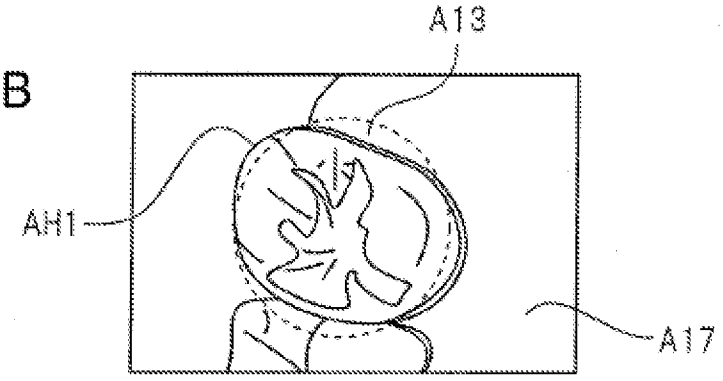


Fig.16C

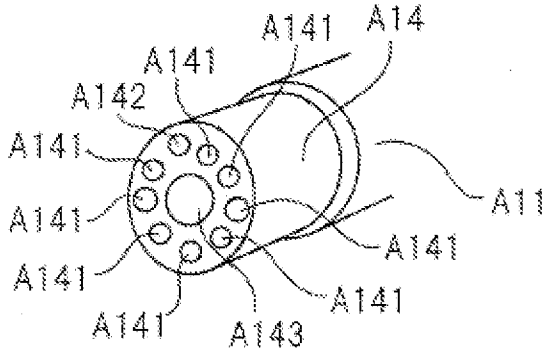


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Fig.17

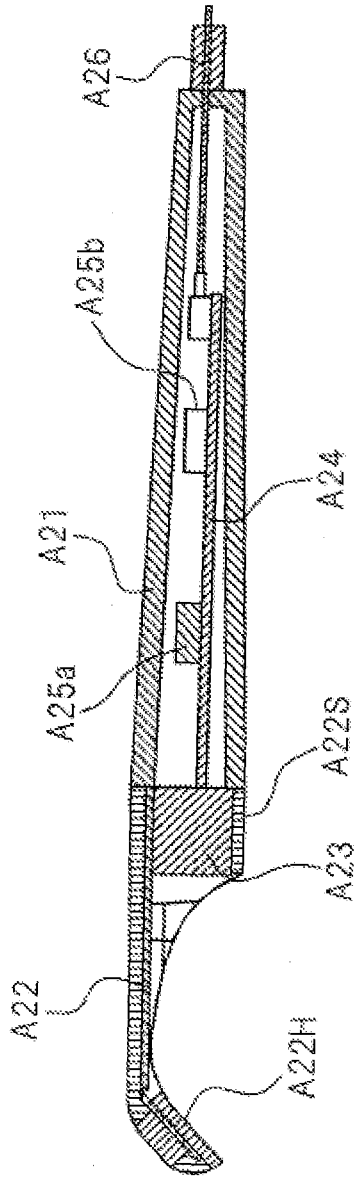


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Fig.18

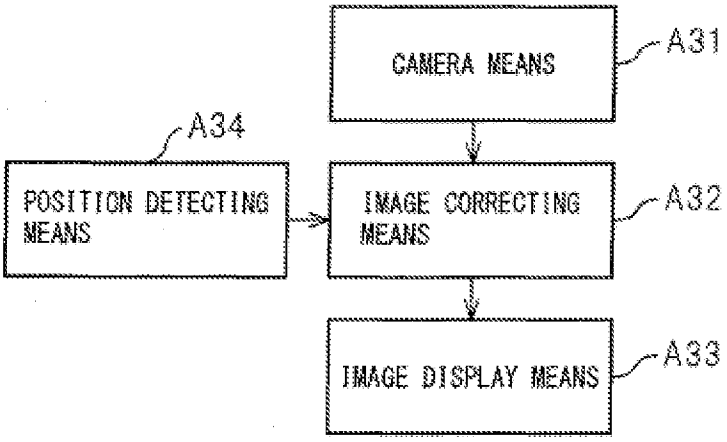


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Fig.19

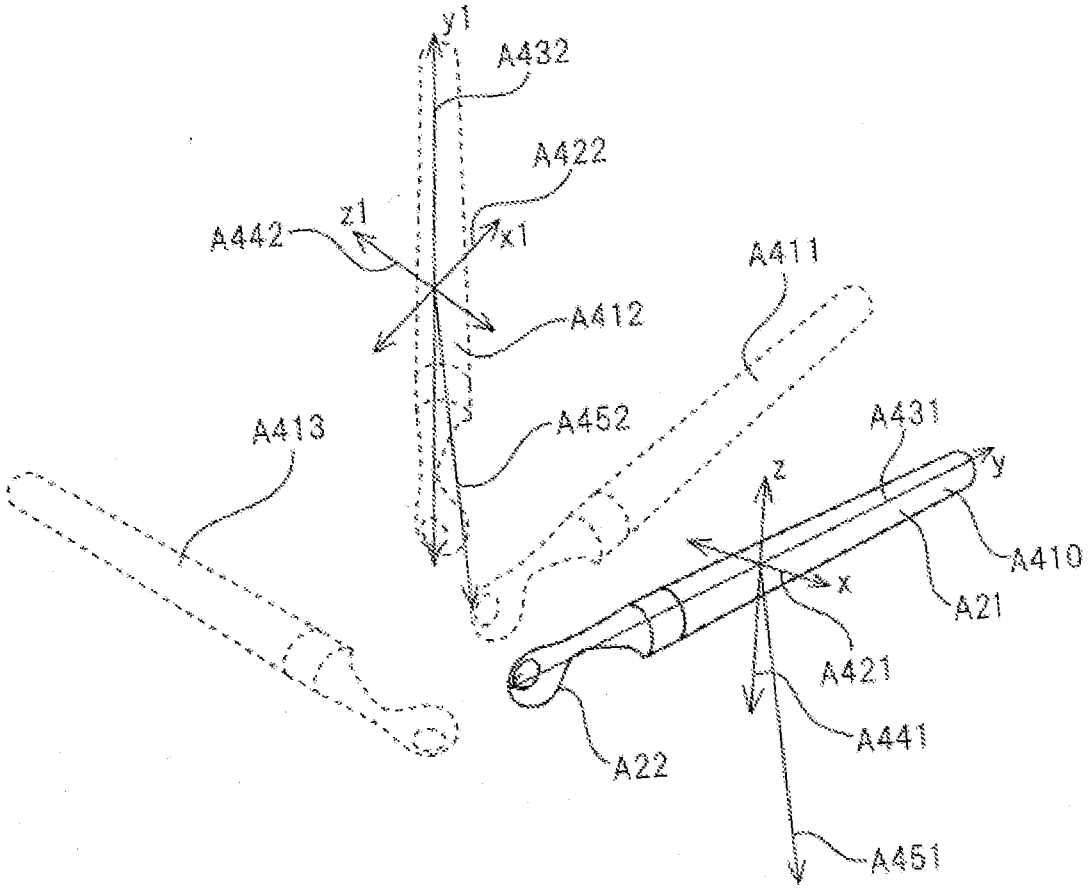


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Fig.20

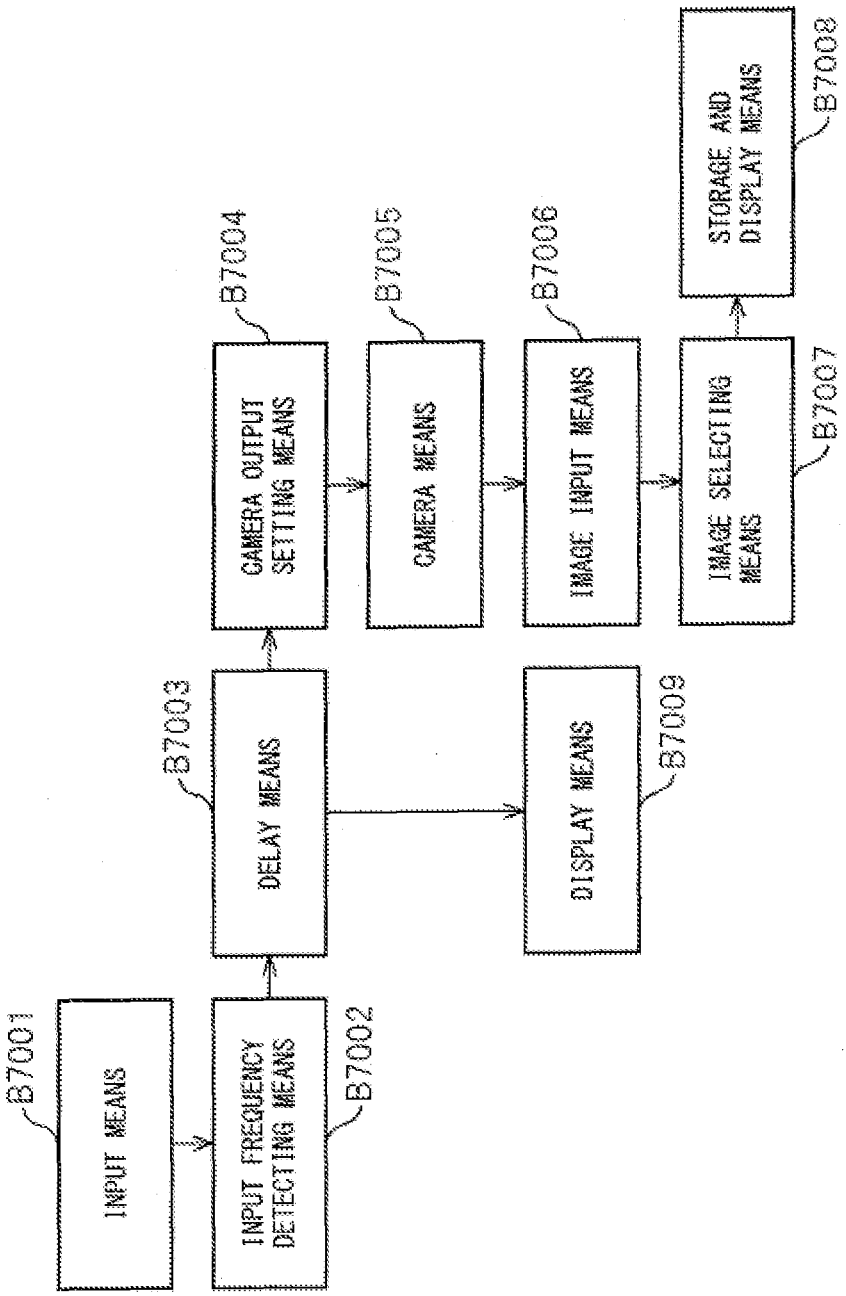


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DENTAL IMAGING

Fig.21A

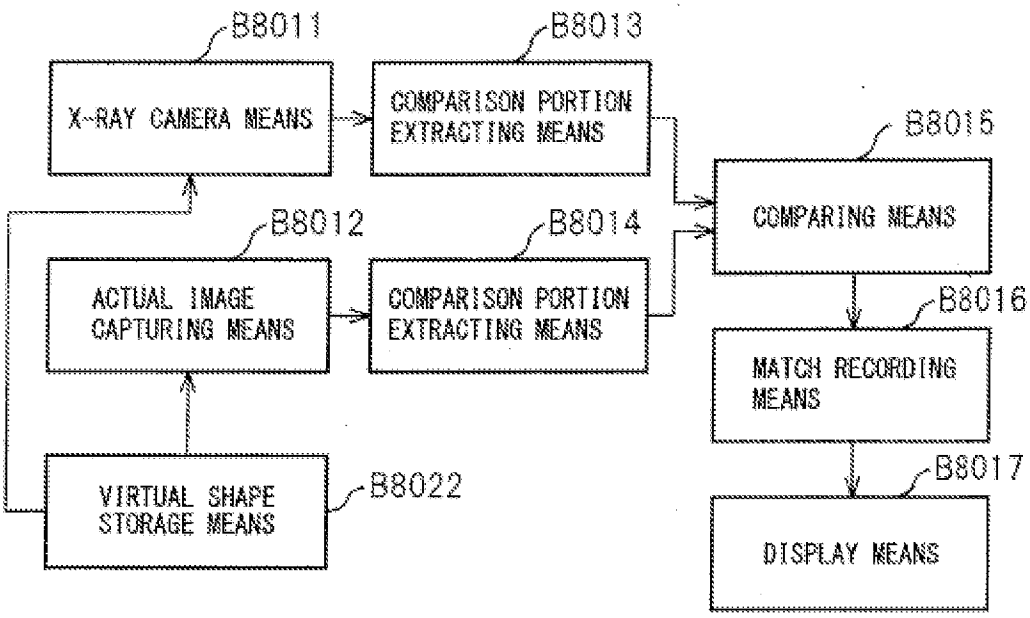


Fig.21B

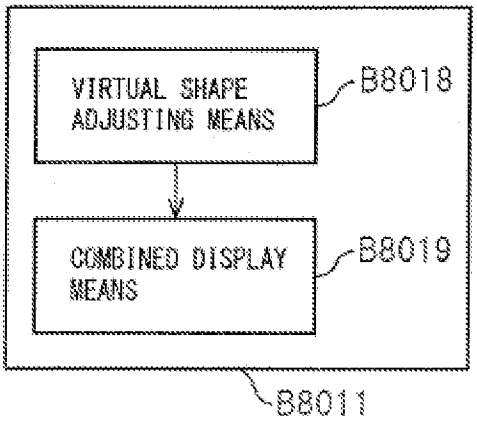


Fig.21C

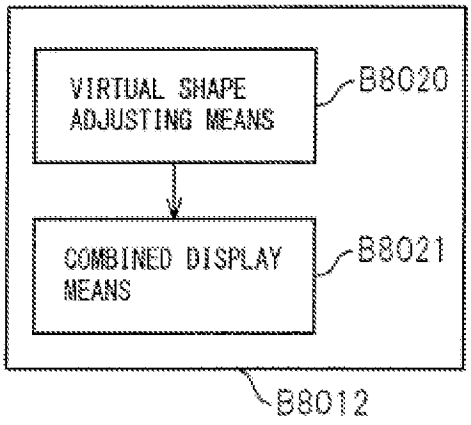


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Fig.22A

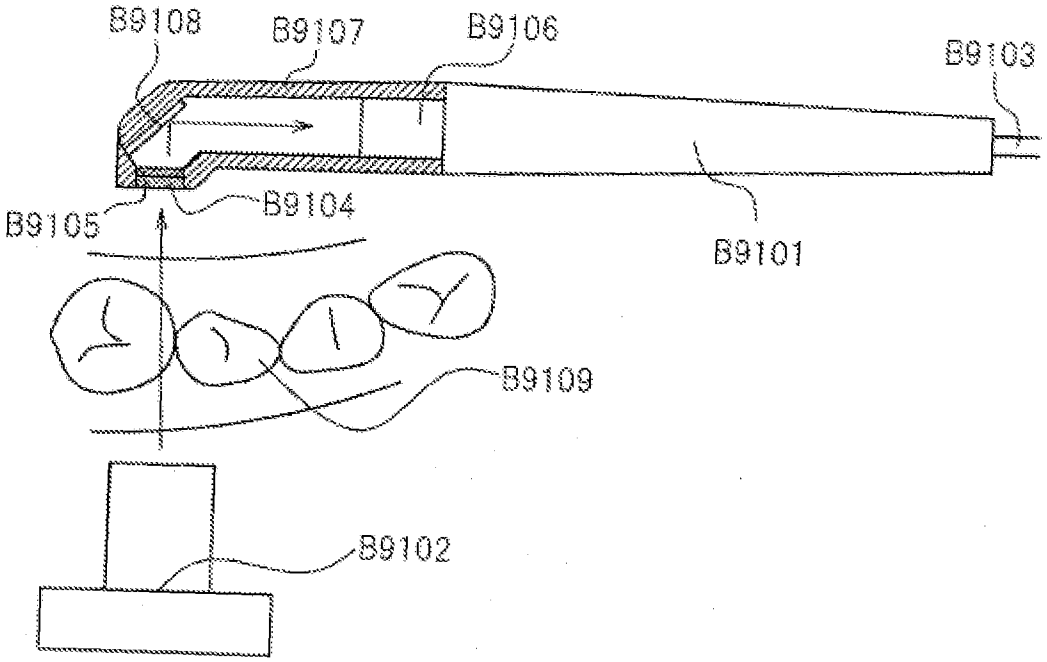


Fig.22B

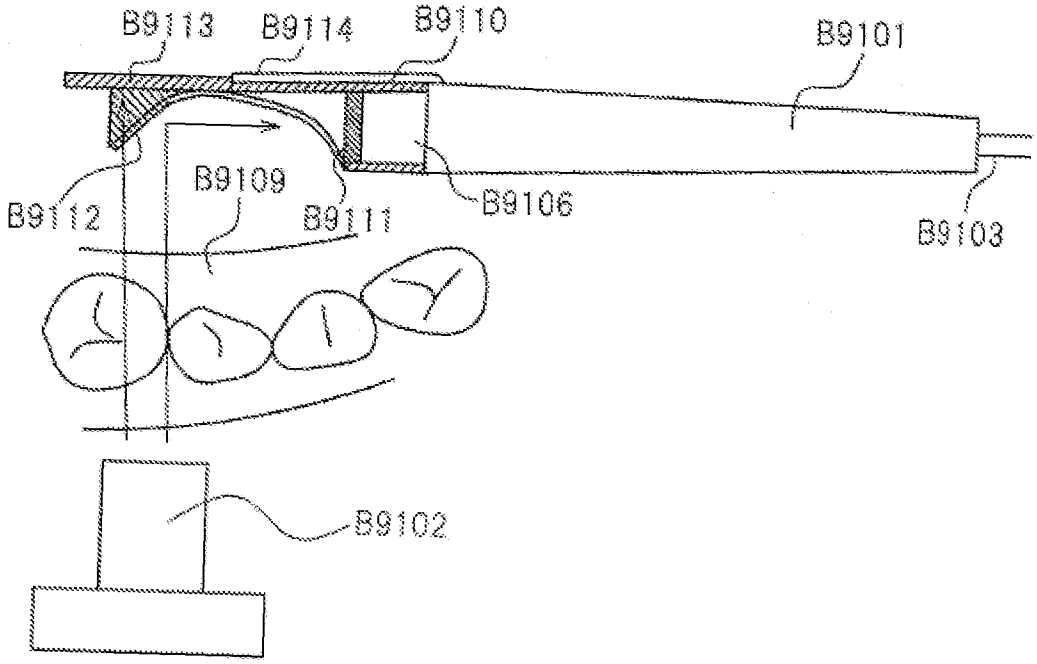


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Fig.23A

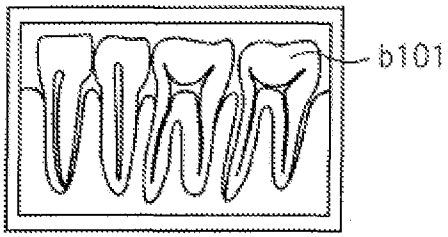


Fig.23C

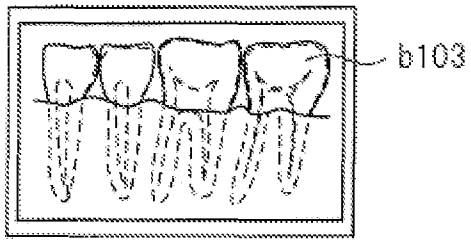


Fig.23B

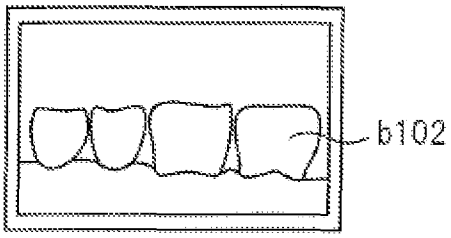


Fig.23D

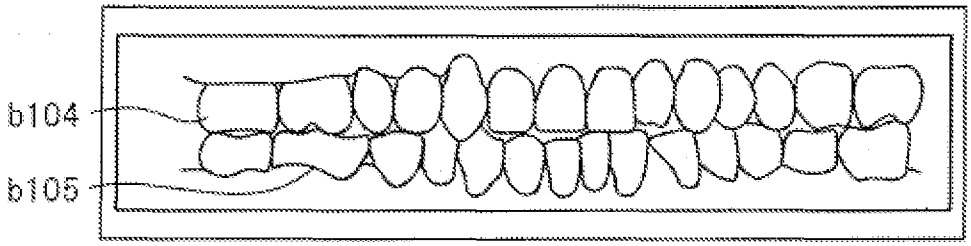


Fig.23E

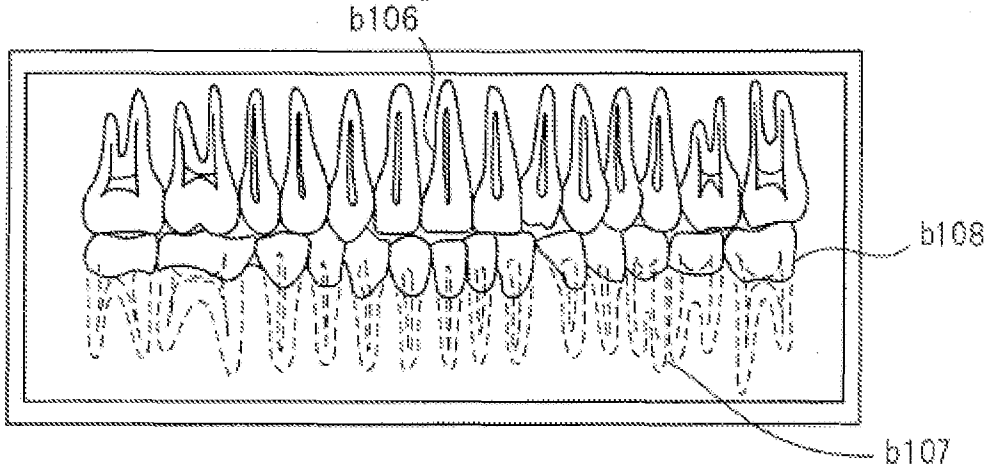


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Fig.24

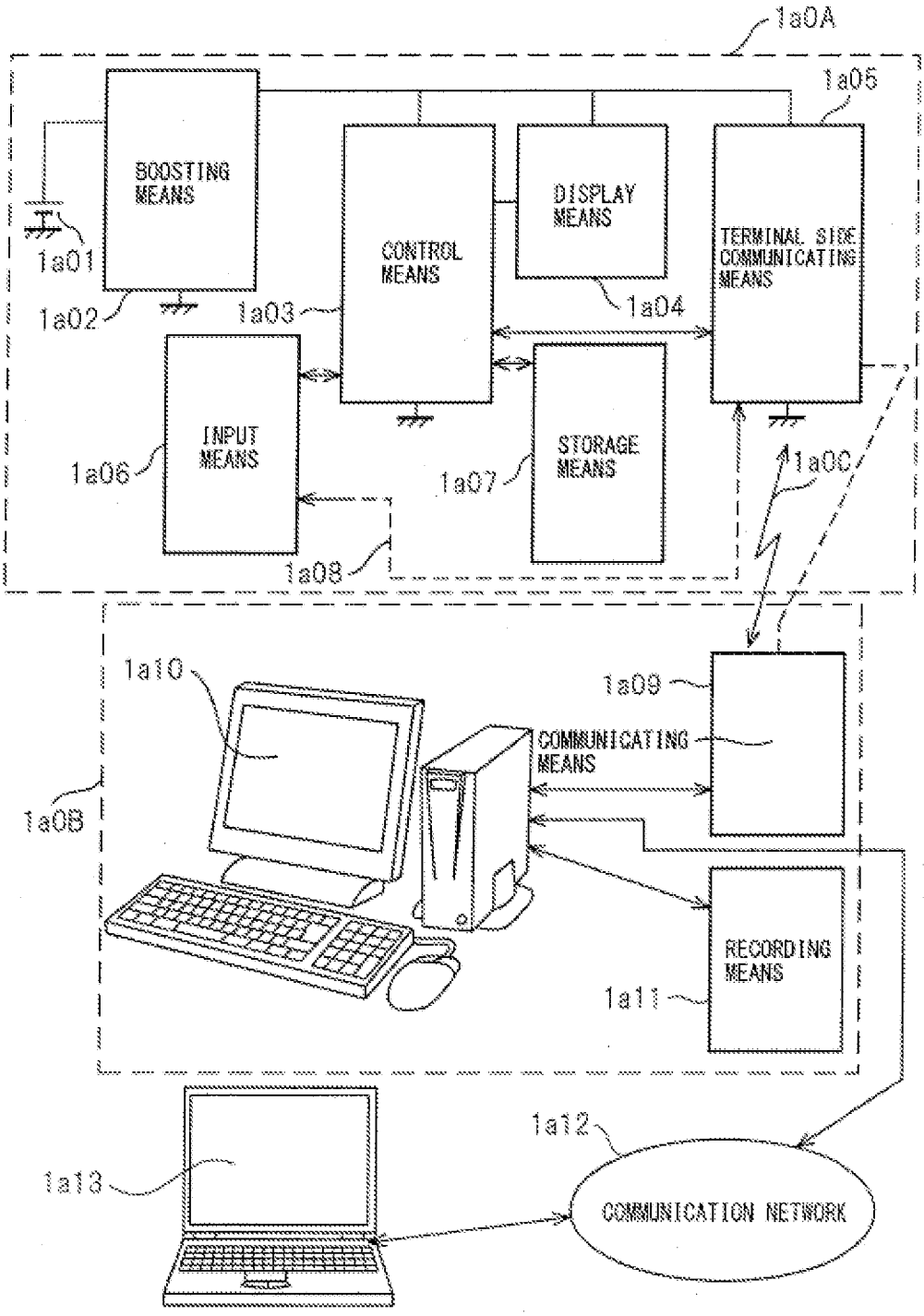


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Fig.25

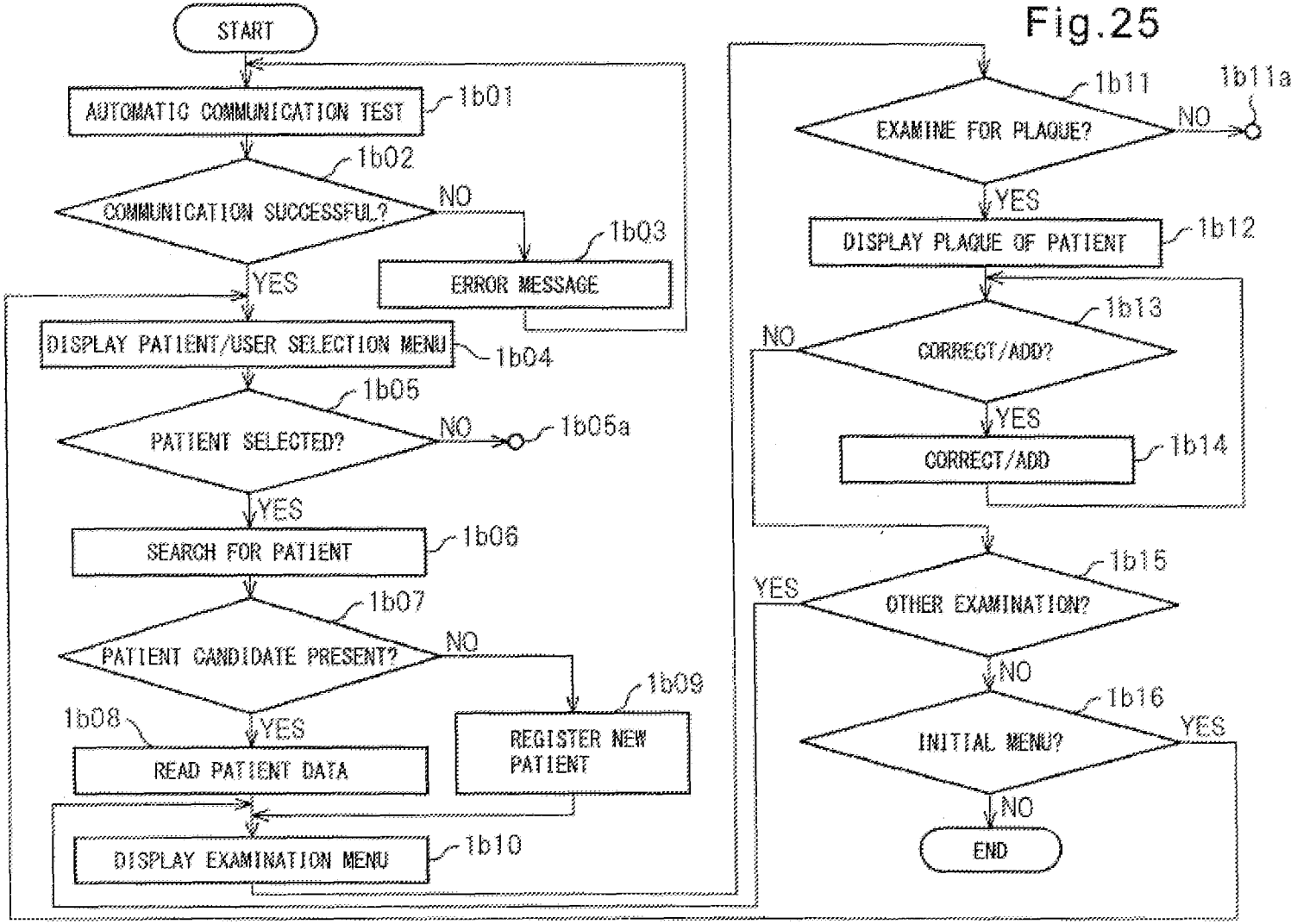

START
AUTOMATIC COMMUNICATION TEST
1b01
1b02
COMMUNICATION SUCCESSFUL?
NO
1b03
ERROR MESSAGE
YES
DISPLAY PATIENT/USER SELECTION MENU
1b04
1b05
PATIENT SELECTED?
NO
1b05a
YES
SEARCH FOR PATIENT
1b06
1b07
PATIENT CANDIDATE PRESENT?
NO
1b09
1b08
YES
READ PATIENT DATA
REGISTER NEW PATIENT
DISPLAY EXAMINATION MENU
1b10
1b11
1b11a
EXAMINE FOR PLAQUE?
NO
YES
DISPLAY PLAQUE OF PATIENT
1b12
1b13
NO
CORRECT/ADD?
YES
CORRECT/ADD
1b14
1b15
YES
OTHER EXAMINATION?
NO
1b16
INITIAL MENU?
YES
NO
END

Fig.26

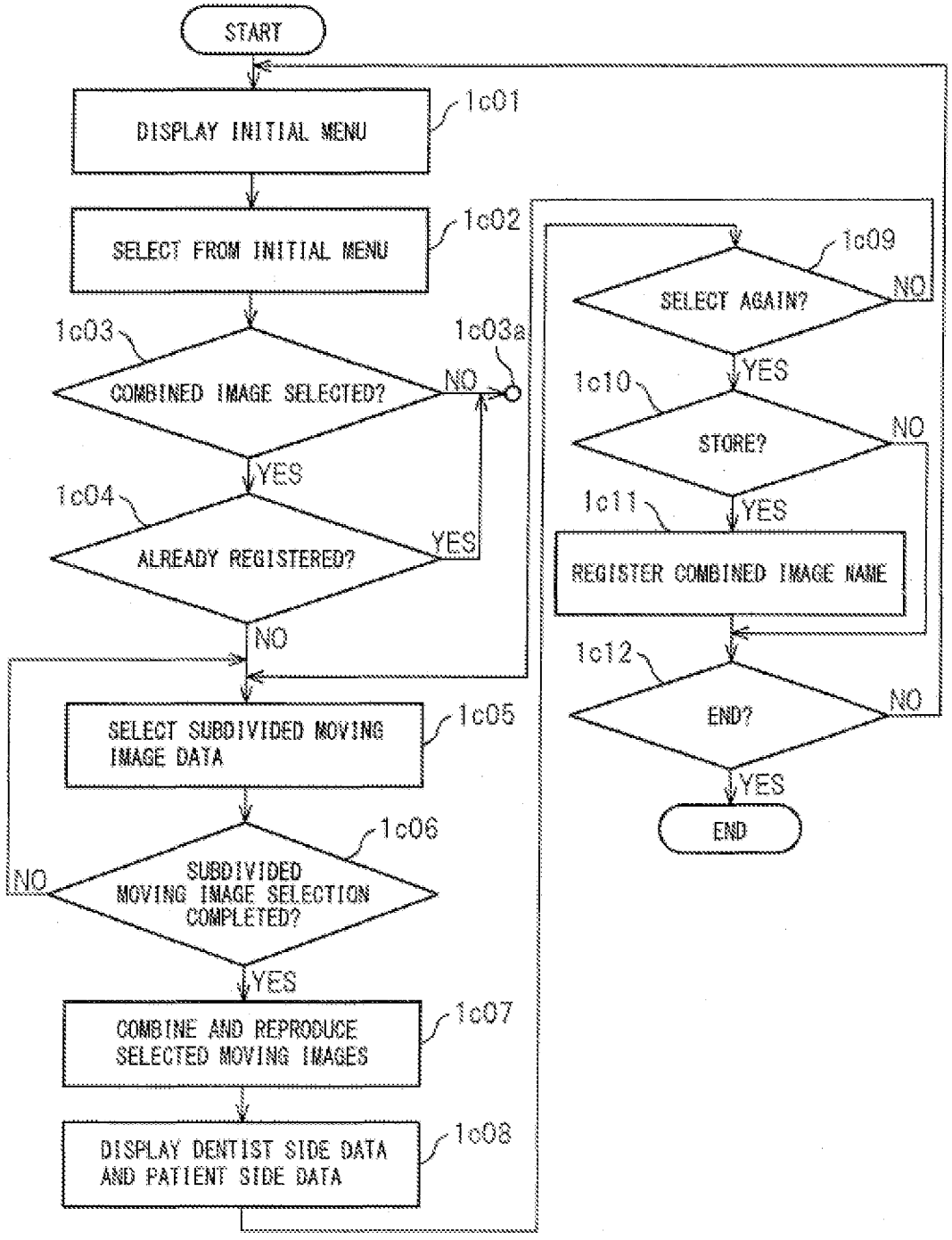


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Fig.27

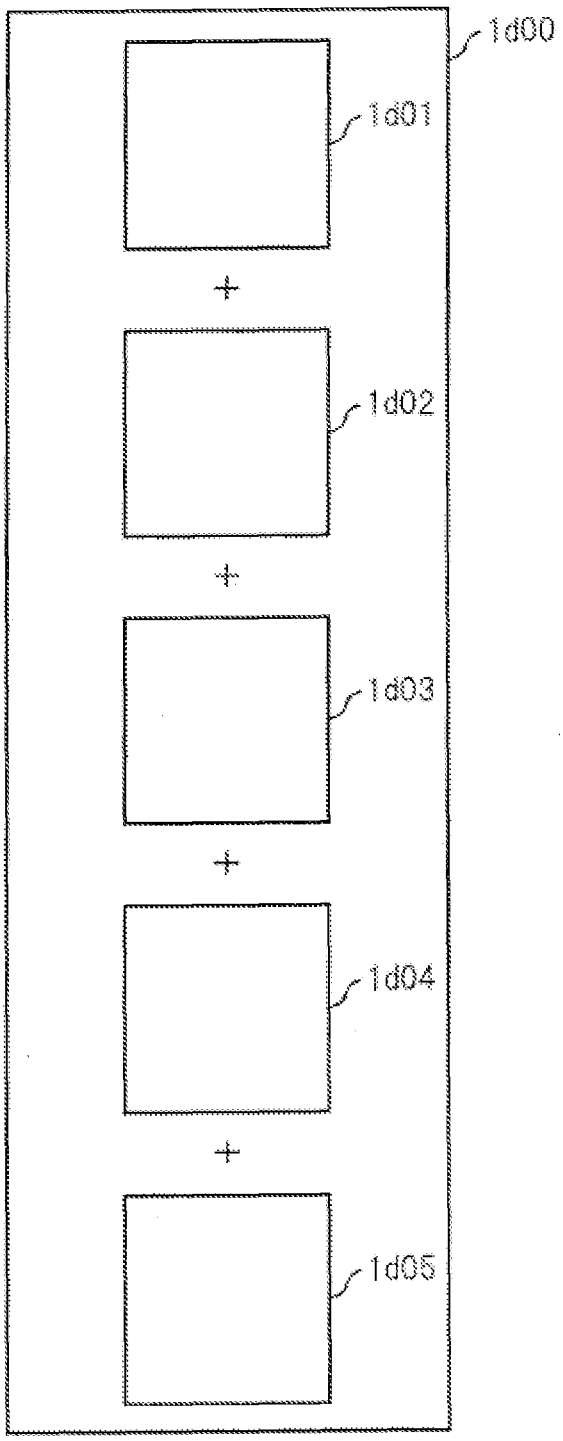


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Fig.28A

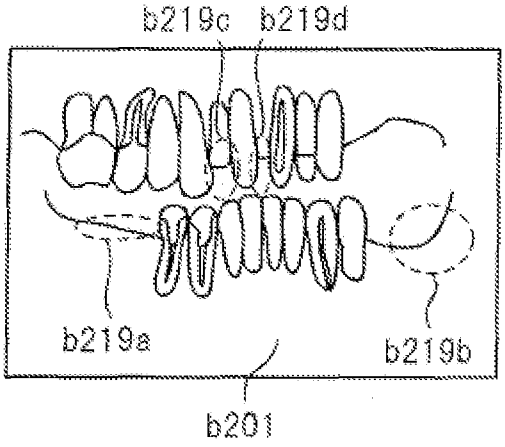


Fig.28B

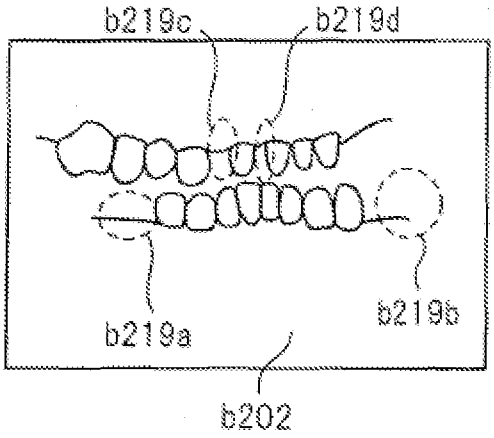


Fig.28C

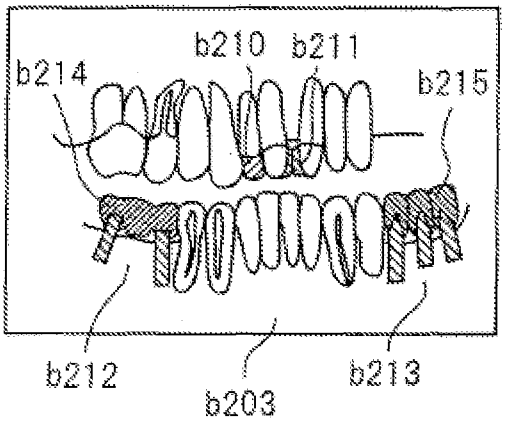


Fig.28D

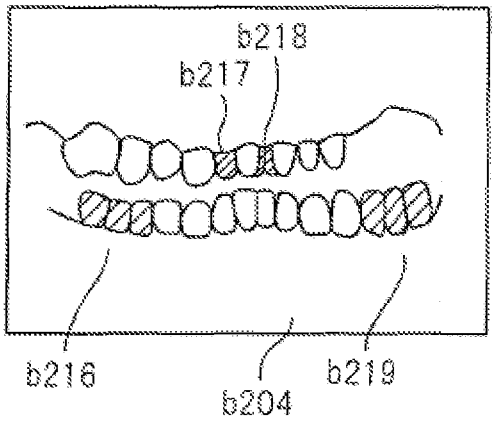


Fig.28E

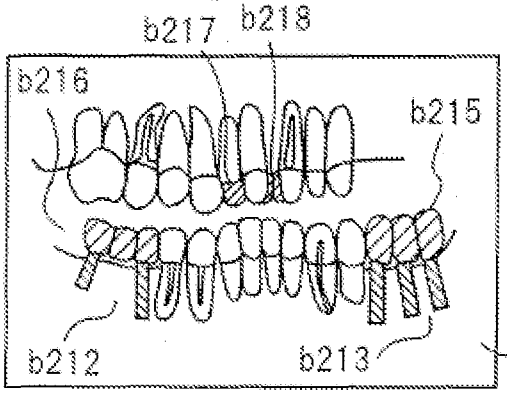


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Fig.29

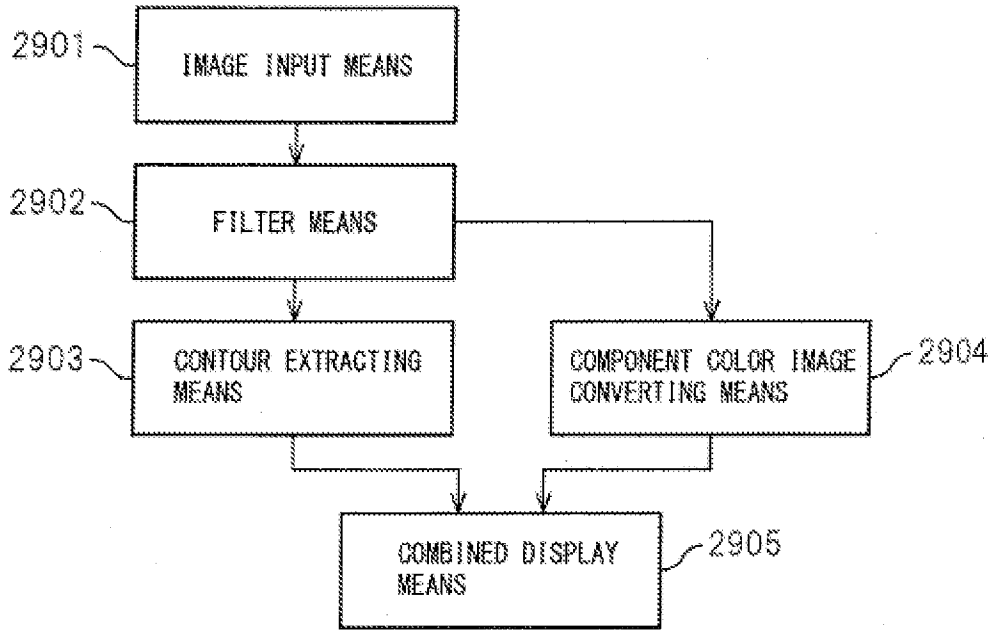


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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050384

A. CLASSIFICATION OF SUBJECT MATTER
A61B1/24(2006.01)i, G02B23/24(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B1/24, G02B23/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2004-202069 A (Mitsutoyo Corp.), 22 July 2004 (22.07.2004), paragraph [0027]; fig. 6 & US 2004/0136580 A1 & EP 1434028 A1	1,7 2,3,5,6 4
Y	JP 2008-125718 A (Shimadzu Corp.), 05 June 2008 (05.06.2008), paragraph [0008]; fig. 1, 2 (Family: none)	2
Y	JP 2001-333898 A (J. Morita Manufacturing Corp.), 04 December 2001 (04.12.2001), paragraphs [0043] to [0049]; fig. 3 (Family: none)	3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April, 2012 (10.04.12)	24 April, 2012 (24.04.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/050394

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2010-214055 A (South Coast Dental Kabushiki Kaisha), 30 September 2010 (30.09.2010), paragraphs [0042] to [0045]; fig. 11 (Family: none)	3
Y	Rikiya KIKUMOTO, "The mobile type teleradiology system contributes to a medical scene", Gekkan Shin Iryo, The August issue, 23 July 2010 (23.07.2010), (received date), pages 58 to 61	5
Y	JP 2003-299677 A (Shoichi TAKAMINE), 21 October 2003 (21.10.2003), paragraphs [0032] to [0033], [0038] (Family: none)	6
A	JP 2008-132336 A (Degudent GmbH), 12 June 2008 (12.06.2008), paragraph [0023]; fig. 3 to 4 & US 2008/0124677 A1 & EP 1927326 A1 & DE 502006005266 D & AT 446723 T	1

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2005334426 A **[0006]**
- JP 10097405 A **[0006]**
- JP 10201757 A **[0006]**
- JP 2001212161 A **[0006]**
- JP 2005144171 A **[0006]**
- JP 62246347 A **[0006]**
- JP 2001029315 A **[0006]**
- JP 2002355262 A **[0006]**
- JP 2005304600 A **[0006]**
- JP 5030402 U **[0006]**
- JP 3131408 U **[0006] [0010]**
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- **ZHANG.** *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2000, vol. 22 (11), 1330-1334 **[0148]**
- **MOTOKI ARAI et al.** Optimization of Correlation Functions and Subpixel Designation Formula in Block Matching of Images. *Research Reports of Information Processing Society of Japan*, 2004, 33-40 **[0198]**
- *Journal of the IEICE*, 2008, vol. 92 (6), 463-468 **[0203]**
- *Dental Materials and Equipment*, 2000, vol. 19 (3), 333-338 **[0204]**
- *Design Wave Magazine*, December 2008, 113-115 **[0285]**

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Espacenet

Bibliographic data: JP2008194108 (A) — 2008-08-28

THREE-DIMENSIONAL CHARACTERISTIC MEASURING AND DISPLAYING APPARATUS WITH POSITIONAL DIRECTION DETECTING FUNCTION

Inventor(s): TAMURA MASAMI ± (TAMURA MASAMI)

Applicant(s): SHOFU KK ± (SHIYOUFUU:KK)

Classification: - **international:** *A61B1/00; A61B1/24; A61B10/00; G01N21/17; A61B8/12*

- **cooperative:**

Application number: JP20070029914 20070209 Global Dossier

Priority number(s): JP20070029914 20070209

Abstract of JP2008194108 (A)

PROBLEM TO BE SOLVED: To enable the application of a probe even within a smaller area such as inside of an oral cavity while achieving the collective reviewing of measuring data over a wider range than that of a measuring area measurable by one operation by measuring and calculating the relationship of the relative positional direction between the probe and an object to be measured. ;SOLUTION: The apparatus has the probe or a positional direction measuring means for measuring the position and/or direction of the specified part arrayed in the object to be measured and carries out a measurement while making the positional direction of the probe move on a fixed track with respect to the object to be measured. Moreover, the moving track data generated in the relative one- to three-dimensional positional directions of the subject to be measured and the probe are arrayed in hourly and spatial synchronization with the one- to three-dimensional reflection characteristic data of the surface and the inside of the object to be measured to acquire the information on the two- to three-dimensional structure, on the composition or on changes in material of the object to be measured or the information on the motions involved. Thus, an optical coherent tomographic apparatus displays tomographic images of mainly the sectional surfaces involved. ;COPYRIGHT: (C)2008,JPO&INPIT

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2008-194108
(P2008-194108A)
(43)公開日　平成20年8月28日(2008.8.28)

(51)Int.Cl.		F I			テーマコード（参考）
A61B 1/24	(2006.01)	A61B	1/24		2G059
A61B 10/00	(2006.01)	A61B	10/00	E	4C061
G01N 21/17	(2006.01)	G01N	21/17	625	4C601
A61B 1/00	(2006.01)	A61B	1/00	300D	
A61B 8/12	(2006.01)	A61B	8/12		

審査請求 未請求　請求項の数 9　OL　（全 11 頁）

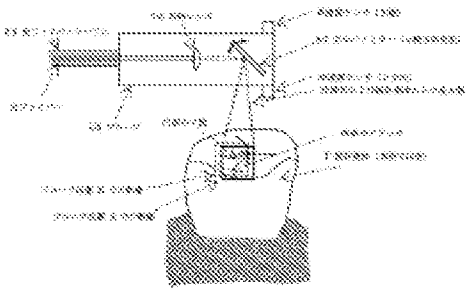
(21)出願番号　特願2007-29914(P2007-29914)
(22)出願日　平成19年2月9日(2007.2.9)

(71)出願人　390011343
株式会社松風
京都府京都市東山区福稲上高松町１１番地
(72)発明者　田村　雅巳
京都府京都市東山区福稲上高松町１１番地
株式会社松風内

Ｆターム(参考)　2C059 AA06 BB12 EE09 EE12 FF02
JJ05 JJ11 JJ15 JJ17 JJ22
KK04 MM01 MM03
4C061 AA03 BB08 HH52
4C601 BB03 BB09 EE05 GA19 GA21
JB48 JB51 JC02 JC04 JC20
KK12

(54)【発明の名称】位置方向検出機能付き３次元上特性測定・表示装置

(57)【要約】　（修正有）
【課題】プローブと被計測体の相対的位置方向関係を計測・算出し、１回で計測可能な計測領域より広い範囲の計測データを一括して見ると共に、口腔内等の小さな領域内にもプローブを適用できる様にする。
【解決手段】プローブまたは被計測体に配した特定部位の位置および／または方向を計測する位置方向計測手段を有するか、被計測体に対して前記プローブの位置方向が一定の軌跡で動きながら計測を行ない、さらに、生成した被計測体と前記プローブの相対的１～３次元位置方向運動軌跡データと被計測体表面および内部の１～３次元反射特性データを時空間的に同期重畳させることにより、被計測体の２～３次元的な構造情報または組成情報または材質変化情報またはこれらの運動情報を得て、これらの断面を主とした断層像を表示する光コヒーレンストモグラフィー装置を提供する。
【選択図】図４



【特許請求の範囲】
【請求項１】
被計測体の少なくとも１次元以上の空間上の特性を計測するために、３次元空間上で被計測体に対してその位置方向が相対的に移動可能な計測ヘッドであるプローブを持ち、さらに計測データを演算処理するデータ演算部を持つ３次元上特性測定・表示装置において、前記プローブまたは被計測体に配した特定部位の位置・方向のいずれかまたは双方を計測する位置方向計測手段を有するか、被計測体に対して前記プローブの相対的位置方向があらかじめ決まった軌跡で動きながら計測を行なうことを特徴とする３次元上特性測定・表示装置。
【請求項２】
前記位置方向計測手段が、単数または複数の角速度センサ・加速度センサのいずれかまたは双方であることを特徴とする請求項１記載の３次元上特性測定・表示装置。
【請求項３】
前記位置方向計測手段が。前記プローブと、被計測体に対して固定または静止している固定静止部との相対的な位置方向を計測するためのリニアゲージ、角度ゲージ、光学マーカーと位置検出器のセット、光学マーカーとイメージセンサのセット、または光学マーカーと３次元上特性測定・表示装置自身のセット、のいずれか少なくともひとつ以上であることを特徴とする請求項１記載の３次元上特性測定・表示装置。
【請求項４】
前記イメージセンサまたは３次元上特性測定・表示装置が検出した被計測体データの中から特定の光学マーカーまたは被計測体の特徴パターンの位置方向データを導出することを特徴とする請求項１または３記載の３次元上特性測定・表示装置。
【請求項５】
前記３次元上特性測定・表示装置による被計測体表面および内部の１～３次元上の特性データと前記位置方向計測手段による計測データとを時間的に同期させて計測し、前記位置方向計測手段による計測データに基づき生成した被計測体と前記プローブの相対的１～３次元位置方向運動軌跡データと被計測体表面および内部の１～３次元上の特性データを時空間的に同期配置させることにより、被計測体の２～３次元的な構造情報または組成情報または材質変化情報またはこれらの運動情報を得て、これらの断面を主とした断層像を表示または印刷する請求項１～４記載の３次元上特性測定・表示装置。
【請求項６】
被計測体の一部または全部、またはプローブのいずれか片方を静止して測定することを特徴とする請求項１～３または５記載の３次元上特性測定・表示装置。
【請求項７】
３次元上特性測定・表示装置のすべてのデータのうち、所望の分解能の範囲に複数の計測データが重複して存在した場合にこれらをひとつのデータで置き換えることを特徴とする請求項１～６記載の３次元上特性測定・表示装置。
【請求項８】
重複しているデータを、そのデータのうちのひとつのデータか、または前記所望の分解能の範囲またはその周囲の領域のデータの平均値または最小二乗法に基づく近似値で置き換えることを特徴とする請求項７記載の３次元上特性測定・表示装置。
【請求項９】
光源と、前記光源から出射した光源光を参照ミラーに照射する参照光と被計測体に照射する計測光とに分ける光分割部と、前記被計測体で反射した前記計測光と前記参照ミラーで反射した参照光とを干渉させて干渉光とする干渉部と、干渉光を計測する光検出部とを備え、計測した干渉光に基づいて被計測体の表面および内部の２～３次元的な光学的後方散乱特性データを得ることにより、被計測体の２～３次元的な構造情報または組成情報または材質変化情報を得て、これらの断面を主とした断層像を表示または印刷する光コヒーレンストモグラフィー装置であって、
前記光源が一定の波長帯域の点光束または線光束または面光束を同時に発生させる方式に

おいては干渉光と光検出部の間に干渉光を波長に応じて分光する回折格子と１次元または２次元の撮像装置による光検出部を成し、または前記光源が一定の波長帯域の点光束または線光束を時間的に走査する方式においては１個または複数個の光検出素子または少なくとも１次元のリニア光検出素子または２次元の撮像素子による光検出部を成し、前記光検出部が計測した分光または走査された干渉光の波長の各段階における強度をフーリエ変換またはフーリエ逆変換することにより、前記被計測体で前記計測光が反射した各深さ位置に対応した反射強度を表す深さ対反射特性データを生成し、被計測体各部における前記深さ対反射特性データにもとづき前記被計測体の２～３次元反射特性データを得るという所謂フーリエドメイン方式に基づく方式と、

前記光源が一定の波長帯域の点光束または線光束または面光束を同時に発生させる方式で光検出部は１個または複数個の光検出素子または少なくとも１次元のリニア光検出素子または２次元の撮像素子による光検出部を成し、前記光検出部が計測した干渉光に基づいて前記光検出部が計測した干渉光により前記被計測体で前記計測光が反射した各深さ位置に対応した反射強度を表す深さ対反射特性データを生成し、被計測体各部における前記深さ対反射特性データにもとづき前記被計測体の１～３次元反射特性データを得るという所謂タイムドメイン方式に基づく方式と、

いずれかの方式における光コヒーレンストモグラフィー装置である請求項１～８記載の３次元上特性測定・表示装置。

【発明の詳細な説明】

【技術分野】

【０００１】

本発明は。生物体の表面および内部の特性を３次元空間上の特性値として測定し。測定データを演算部において演算処理し、２次元または３次元の画面または印刷物に表示する３次元上特性測定・表示装置に関する。３次元上特性測定・表示装置に具体的な例としては、Ｘ線ＣＴ装置・ＭＲＩ装置・２～３次元超音波画像診断装置・ＰＥＴ装置・ＳＰＥＣＴ装置・光ＣＴ装置および光コヒーレンストモグラフィー装置が含まれるが。特に１回あたりの計測範囲の小さい光コヒーレンストモグラフィー装置や近接磁場を用いたMRI装置・３次元超音波診断装置には特に有用である。また３次元空間上の２次元表面の可視光学的撮像装置であるビデオカメラも近接した場合には撮像範囲が狭いので有用となる。これらの中で。被写体を固定し３次元空間上で自由に位置方向付け可能なプローブを使用する様な医療機器、特に歯科領域である口腔内の軟硬組織の２～３次元上の特性をプローブを口腔内に挿入して測定する様な用途に好適である。また。超音波画像診断装置は通常２次元の断面を計測するものであるが、これを断面に垂直な方向に動かす場合等には特に有用である。また、光コヒーレンストモグラフィー装置は計測範囲が数ｍｍ～十数ｍｍ範囲と狭く、これを歯科に適用する様な用途にも特に有用である。

【背景技術】

【０００２】

従来、歯科の診断において、顎口腔領域を撮影するために、Ｘ線撮影装置、口腔内カメラ、歯科用カメラ、Ｘ線ＣＴ、ＭＲＩ等が使用されてきた。また、最近光コヒーレンストモグラフィーを歯科に適用する発明考案等もなされてきている。

Ｘ線撮影装置で得られる像は、あくまで透過像であり、被計測体のＸ線進行方向の情報は重ねあわされて検出される。そのため、被計測体の内部構造を３次元的に知ることができない。また、Ｘ線は人体に有害であるため、年間被爆線量が決められており、資格を持った術者しか装置を扱えない上に、鉛・鉛ガラスなどの遮蔽部材に囲まれた部屋でしか使用できない。

【０００３】

口腔内カメラは、口腔内組織の表面のみを撮像するので。歯等の内部情報が得られない。Ｘ線ＣＴは、Ｘ線撮影装置と同様人体に有害である上に、分解能が悪く、装置も大型かつ高価である。通常使用されているＭＲＩ装置は、分解能が悪く。装置が大型かつ高価である上に、水分のない歯の内部構造は撮影できない。

ところで、光コヒーレンストモグラフィー装置（以下、ＯＣＴ装置と称する）は、人体に無害で、被計測体の３次元情報が高分解能で得られるため、角膜や網膜の断層計測等の眼科の分野で応用されている。なお、ＯＣＴは、Ｏｐｔｉｃａｌ　Ｃｏｈｅｒｅｎｃｅ　Ｔｏｍｏｇｒａｐｈｙの略である。また、光コヒーレンストモグラフィー装置は、光学干渉断層撮影装置と呼ばれることもある。また、歯科分野においても光コヒーレンストモグラフィー装置を応用した発明考案がなされている。（特許文献１～４、実用新案文献１～４、非特許文献１～１０参照）

【０００４】

ここで、ＯＣＴ装置の計測範囲がどの様に構成されるかを示すために、その基本構成について説明する。

（ＯＣＴ装置の基本構成・基本用語の説明および動作原理）

本発明にかかる歯科用光コヒーレンストモグラフィー装置の形態を図１を持って説明する。図１において、時間的に低コヒーレントまたはコヒーレントな光源１と、ファイバーカップラー２ａ（光分割部・干渉部）と、参照ミラー３と、光検出器４（光検出部）と、コンピュータ５（演算部）をＯＣＴの基本構成として示している。

この基本構成において、光源よりファイバーカップラーへ至る光を光源光、ファイバーカップラーより参照ミラーへ至り参照ミラーから反射して再びファイバーカップラーへ戻る光を参照光、ファイバーカップラーより被計測体Ｔへ至る光を計測光、被計測体Ｔ各部より反射して再びファイバーカップラーへ戻る光をｚ方向物体反射光、ファイバーカップラーより光検出器４および光源１へ至る光を干渉光という。

【０００５】

この基本構成において、光源より出射した光源光はファイバーカップラーに至って参照光と計測光の２系統に分岐し、参照光は参照ミラー３によって鏡面反射して再びファイバーカップラーに戻り、計測光は被計測体各部より反射・散乱・透過作用を受けその一部である後方散乱光がｚ方向物体反射光として被計測体Ｔ各部（基本構成においては時間軸上に変換されたｚ方向の被計測体各部）の後方散乱係数情報を担いつつ再びファイバーカップラーへ戻る。ファイバーカップラーへ戻った参照光とｚ方向物体反射光はファイバーカップラーにより干渉し、干渉光となって光源１と光検出器４の方へ分岐出射する。この干渉光の強度を光検出器４で検出し、その干渉光強度をコンピュータ５に入力して時間軸上で計測解析し、物体各部の後方散乱係数情報すなわち物体各部の情報を表示するものである。ｚ方向物体反射光はその電磁波としての波形上に物体情報を担っているが、光波形はあまりにも現象が速すぎて時間軸上で直接計測できる光検出器は存在しないが、参照光と干渉させることによって被計測体各部の後方散乱特性情報が光の強度の変化に変換されるので光検出器で時間軸上での検出が可能となる。

【０００６】

説明の都合上、計測光の進行方向をｚ方向とし、計測光と参照光の光路差がゼロとなる干渉の中央地点のデータを得る動作をＰモード、ｚ方向の線状データを得る動作をＡモード、ｚ方向とそれに垂直なｘ方向による２次元断面の断層データを得る動作をＢモード、さらにＢモードの各断層の位置をずらしてｚ方向とｘ方向とｙ方向の３次元データを得る動作をＣモードとし、これらの被計測体における座標系を図１に記載のごとく定義する。これらｚ・ｘ・ｙの各方向の情報を得るために、図１の従来例ではｘ方向およびｙ方向に計測光束を走査するためのガルバノミラー８－１～２を用いる。ｚ軸方向の情報を得るための手段は、参照ミラー３を光軸方向に駆動する参照ミラー駆動法（所謂タイムドメイン方式）と、レンズ７－６の出力側に回折格子を置いてｚ軸方向の時間軸情報を回折格子の回折方向の空間軸情報に変換し、光検出器４としてＣＣＤ等の１～２次元の撮像素子を用い、コンピュータ５上で時間軸情報すなわちｚ軸方向情報を再構成するスペクトルドメイン方式（フーリエドメイン方式のひとつ）、光源１として可変波長光源を用いて回折格子を用いないスウェプトソース法（フーリエドメイン法のひとつ）がある。

【０００７】

ファイバーカップラー２ａを使ったＯＣＴの基本構成としてはこの他に、ファイバーカ

ッブラーへの光の入出力に用いられる光ファイバー６－１～４、光源光・参照光・干渉光をコリメートまたは集光するためのレンズ７－１～５、７－７、および計測光を集光しｚ方向物体反射光をコリメートするための対物レンズ７－６が必要である。なお、ファイバーカップラーの代わりにビームスプリッター２ｂ（図示無し）を使った構成も考えられる。この場合、光ファイバー６－１～４は必ずしも必要なくなるが、光源１・ビームスプリッター２ｂ・参照ミラー３・対物レンズ７－６・光検出器５を光学的に適切に配置する必要があり、コンパクトな配置等のために各所にミラーを用いたり場合によっては部分的に光ファイバーを用いたりするが、基本構成としては干渉を行う部材としてファイバーカップラー２ａを用いるかビームスプリッター２ｂを用いるかの違いだけであり原理的構成は同一である。

【０００８】

なお、少なくとも計測光およびｚ方向物体反射光の導光部および対物レンズ７－６を含むユニットをプローブユニット（Ｐｒｏｂｅ　Ｕｎｉｔ）Ｕ２、少なくとも光源のコントロール出力・光検出器４からの入力およびコンピュータ５を含むユニットをＰＣユニット（ＰＣ　Ｕｎｉｔ）Ｕ３、少なくとも光源１・ファイバーカップラー２ａ・参照ミラー３・光検出器４を含むユニットをＯＣＴユニット（ＯＣＴ　Ｕｎｉｔ）Ｕ１とする。

【０００９】

図１に基づく前述の従来例では、ｚ方向のAモードを得るためにタイムドメイン法では参照ミラーの光束方向への走査・フーリエドメイン法では光源の波長毎のデータの逆フーリエ変換を利用し、ｘ方向とｙ方向のBモードとCモードに関してはガルバノミラーによる走査を紹介したが、これら各モードを実現する方法については様々な方式が提案されている。たとえば参照ミラー走査によるｚ方向Aモードに加えて、点光源からの点光束をシリンドリカルレンズにより線光束としてｘ方向Bモード画像を得て（シリンドリカルレンズ方式）、さらにガルバノミラーによるｙ方向走査と組み合わせてCモードを得ることもその方法のひとつである。この方法においてAモードの実現に参照ミラーを固定したフーリエドメイン法を組み合わせても良い。また、シリンドリカルレンズを用いる特殊な方法として、深さ方向走査もフーリエドメイン法も用いずにｘ方向やｙ方向のガルバノミラー走査だけを行なってｘ方向線上データやｘｙ方向の面上データを得る特殊なモードも可能である。さらに光源からの光をレンズを使って２次元面状に広げ、空中光学系を使って被写体に面計測光束を照射し、参照ミラーと同一光路長となる深さの被計測体内部のｘｙ面（厳密にはｘｙ面に近い球面となるが）上データを得るフルフィールド方式を用いた特殊なモードや、これに参照ミラーのAモード走査を組み合わせる特殊なCモード動作も可能である。

【００１０】

この様なＯＣＴ装置によって、非破壊、非接触で被計測体内部の高分解能な画像を得ることができる。用途としては一般の物体から、生体、人体、医用、眼科・皮膚科・内視鏡分野・歯科分野への適用有用性が発表されている。ＯＣＴ装置の歯科の分野への適用については、ＯＣＴ装置を用いて、歯の断層を撮影した例が開示されている（例えば、特許文献１～４、実用新案文献１～４、非特許文献１～１０参照）。

【００１１】

特許文献１～３は、光コヒーレンストモグラフィーを歯科に適用する場合に従来の歯科用の設備にいかに組み込むかというものであり、また光ファイバーケーブルあるいは電力・信号線をつかって計測用のプローブの把持位置および方向を自由にし、特に深さ方向の走査をプローブ内でいかに行なうか、プローブから計測光をいかに射出するかについて言及している。また、特許文献４は、光源の波長を走査するフーリエドメイン光コヒーレンストモグラフィーを開示し、その波長域やプローブの構成等について言及している。さらに実用新案文献１～４については歯科用のハンドピースにプローブを組み込む提案がなされている。また、非特許文献１～１０に光コヒーレンストモグラフィーを歯科に適用した場合の撮像性能についての報告が成されている。

これら歯科用途に用いられる光コヒーレンストモグラフィー装置は、全て眼科をはじめと

する歯科以外において実用または研究開発発表されている光コヒーレンストモグラフィー装置を歯科に適用したもので、上記に述べた基本構成は同一である。
以上、光コヒーレンストモグラフィー装置について従来技術を述べてきたが、２次元超音波画像診断装置についてもこれを２次元の撮像断面に対して垂直な方向に連なる断面を撮像する場合にはプローブをその方向に動かすのが常である。また、口腔内にプローブを挿入して口腔内の軟硬組織の断層像を観察する様な用途においても、その撮像範囲は限られるであろう。また、近接磁場を使う内視鏡型のMRI装置についても内視鏡として使用する場合・口腔内に使用する場合いずれにおいてもその計測範囲は限られている。
【００１２】
【特許文献１】特開２００４－３４４２６０A号
【特許文献２】特開２００４－３４４２６２A号
【特許文献３】特開２００４－３４７３８０A号
【特許文献４】特開２００６－１９１９３７
【特許文献５】実用新案登録第３１１８７１８号
【特許文献６】実用新案登録第３１１８８２３号
【特許文献７】実用新案登録第３１１８８２４号
【特許文献８】実用新案登録第３１１８８３９号
【特許文献９】レーザー研究　２００３年１０月号：医療を中心とする光コヒーレンストモグラフィーの技術展開
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【非特許文献６】２００４年度日本光学会年次学術講演会予稿集、５ａＦ６、フーリエドメイン光コヒーレンストモグラフィーによる歯科試料計測
【非特許文献７】２００５年度日本光学会年次学術講演会予稿集、２４ｐＥ５、３次元歯科計測へのスペクトル干渉断層法の応用
【非特許文献８】Photonics West2006, 6079-66, In-Vivo three dimensional Fourier-Domain Optical CoherenceTomography for soft and hard oral tissue measurements
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【非特許文献１０】Journal ofDental Research 85(9)2006,Remineralization of Enamel Caries Can DecreaseOptical Reflectivity
【発明の開示】
【発明が解決しようとする課題】
【００１３】
これらの従来の３次元上特性測定・表示装置の典型的な構成である光コヒーレンストモグラフィー装置においては、前述の様にｘ・ｙ・ｚの各方向の情報を得るために、ｘ方向およびｙ方向に計測光束を走査するためのガルバノミラー８－１～２を用いている。また、単にｙ・ｚの各方向の情報を得るためだけにおいても、ｙ方向に計測光束を走査する必要がある。シリンドリカルレンズを用いた方法についても、Ｃモード画像を得るには１次元のガルバノミラー走査が必要となる。このため、歯科の特に口腔奥部にプローブを挿入する必要のある臼歯部や歯の舌側面からの計測においては、非常に小型のプローブが要求される。
【００１４】
一方でガルバノミラーはその駆動用のモーターがセットになっており、口腔内に挿入する

にはかなりの大きさを有しているのが現状であり、歯科の様な分野において光コヒーレンストモグラフィーを用いることの大きな障害となる。また、大きさだけでなくガルバノミラーの重量も操作者にとっては大きな負担となる。このため、プローブを口腔内に持ち込むことが出来ないので例えば臼歯部の舌側面等を測定する場合にガルバノミラーから被写体までの距離が非常に長くなり、設計も困難をきたすし仮に設計できたとしても分解能や測定深度、アーティファクト等の性能劣化の要因となる。また、重いプローブであれば、測定時に被計測体に何らかの方法で固定する必要があるが、固定方法としては手持ちで被計測体に対して一定の位置方向を維持することは非常に困難である。

【００１５】

現状のＯＣＴ（一般的な光コヒーレンストモグラフィー）の性能ではＢモードでは毎秒３０コマの計測スピードが実現しているがＣモードでは数秒～数十秒かかるので、この間大きくて重いプローブを一定の位置方向に維持することは不可能に近い。この対策として例えば歯科の場合マウスピースを患者が噛むかまたはシーネを歯牙に固定し、これらマウスピースまたはシーネをプローブに固定する方法がある（特願２００５－３３７３７２）が、手持ちタイプの大きく重いプローブでは操作者の腕への負担が重くなるか患者の顎または歯列への負担が重くなり、測定に支障をきたす。特許文献１～３にプローブ部分を口内法Ｘ線装置の様に多関節アームで支持するタイプのものが開示されているが、この開示の中にはプローブを被写体に固定する方法については示されておらず、固定が無い状態では、被写体への精密な位置付けが困難なだけでなく、数十秒かかるＣモードの撮影の場合に多関節アームで固定されたプローブが振動したり、患者が動いたりして外乱やアーティファクトを生じる要因ともなる。そこで本発明では、患者が治療椅子から移動することなく、プローブを操作者や患者への負担なく、被写体にしっかりと固定する方法を提供することを解決すべき課題とするものである。そこで、プローブを小型・軽量化して扱い易くするとともに、必要に応じプローブを口腔内に持ち込み可能として性能劣化をきたさない歯科用コヒーレンストモグラフィー装置を提供することを解決すべき課題とするものである。

【００１６】

また、ｘ方向およびｙ方向に計測光束を走査するためにガルバノミラー８－１～２を用いた場合においてもその走査系計測範囲は非常に限られており、数ｍｍから十数ｍｍの範囲が限界となっている。このため、歯科における全歯列を一括して計測する様な広い範囲の計測用途において、走査系計測範囲を超える領域は空間的に互いに関連付けの無い複数の計測データとなってしまう問題がある。フルフィールド方式においてはガルバノミラーが不必要となるが、この方式においても計測範囲はレンズで計測光を照射可能な範囲に限られている。プローブを移動して計測位置を変更した場合、移動後の計測データと移動前の計測データの３次元的な位置を共通に把握する手段は講じられていない。そのために１０数ミリ×１０数ミリ×深さ数ミリという現状の計測範囲性能では歯牙・歯周全体を計測表示したり、上顎・下顎全体の歯列を表示したりすることが出来ない。そこで歯牙・歯周全体を同一位置方向の基準で計測表示したり、上顎・下顎全体の歯列を表示したりすることを解決すべき課題とするものである。以上、３次元上特性測定・表示装置の一種である光コヒーレンストモグラフィー装置についてその課題を述べたが、これは計測範囲の狭い３次元上特性測定・表示装置の全般、特に２次元の超音波画像診断装置や内視鏡型のMRI装置についても同様である。

【課題を解決するための手段】

【００１７】

本発明を決するための基本的な手段は、プローブまたは被計測体に配した特定部位の位置・方向のいずれかまたは双方を計測する位置方向計測手段を備えるか、または被計測体に対して前記プローブの位置方向が一定の軌跡で動きながら計測を行ない、３次元上特性測定・表示装置、特に光コヒーレンストモグラフィー装置による被計測体表面および内部の１～３次元反射特性データと前記位置方向計測手段計測データとを時間的に同期させて計測するかまたはプローブを一定の軌跡で動かして計測することにより、被計測体と前記プ

ローブの相対的１～３次元位置方向データを生成し、被計測体表面および内部の１～３次元反射特性データを時空間的に同期配置させることにより、被計測体の２～３次元的な構造情報または組成情報または材質変化情報またはこれらの運動情報を得て、これらの断面を主とした断層像を表示または印刷することである。

さらに、前記位置方向計測手段として、単数または複数の角速度センサまたは加速度センサを構成し用いることである。

さらに、前記位置方向計測手段が、前記プローブと、被計測体に対して固定または静止している固定静止部との相対的な位置方向を計測するためのリニアゲージまたは角度ゲージ、または光学マーカーおよび位置検出器のセット、光学マーカーまたはイメージセンサ、または光学マーカーまた光コヒーレンストモグラフィー装置自身を構成し用いることである。

さらに、前記イメージセンサまたは光コヒーレンストモグラフィー装置が、自身で検出した被計測体データの中から特定の光学マーカーまたは被計測体の特徴パターンの位置方向データを導出することである。

さらに、被計測体の一部または全部、またはプローブのいずれかを静止させることである。被計測体の一部または全部、またはプローブのいずれかを静止させることである。同期させて計測し、時空間的に同期配置させた３次元上特性測定・表示装置・特に光コヒーレンストモグラフィー装置のすべてのデータのうち、所望の分解能の範囲に複数の計測データが重複して存在した場合にこれらを適切なひとつのデータで置き換えることである。重複しているデータを前記所望の分解能の範囲またはその周囲の領域のデータの平均値または最小二乗法に基づく近似値で置き換えることである。

【発明の効果】

【００１８】

本発明による位置方向検出方法は、いずれもガルバノミラーよりもかなり小型軽量の部品を使用して実現可能であり、光コヒーレンストモグラフィーにおいてガルバノミラーを不要とするかまたは減らすことにより、プローブを超小型にして歯科の様な非常に狭い空間での操作性の良い計測を可能にするものである。また、ガルバノミラーによる走査の有無に関わらず、歯周組織を含む歯列全体の様な被計測体の表面・内部の広範囲の２～３次元的な構造情報または組成情報または材質変化情報または運動情報を得て、これらの断面を主とした断層像を表示または印刷する光コヒーレンストモグラフィー装置を実現するものである。これらは光コヒーレンストモグラフィー装置に限らず、計測範囲の狭い３次元上特性測定・表示装置の全般、特に２次元の超音波画像診断装置や内視鏡型のMRI装置についても同様である。

【発明を実施するための最良の形態】

【００１９】

本発明を実施するための最良の形態として、光コヒーレンストモグラフィーを例にして述べる。被計測体全体を静止固定し、位置方向計測手段として光コヒーレンストモグラフィー自身が計測した特定部位のデータを基に、プローブと被計測体の特定部位の相対的な位置方向を計測し、生成した被計測体とプローブの相対的１～３次元位置方向運動軌跡データと被計測体表面および内部の１～３次元反射特性データを時空間的に同期配置させることにより被計測体の２～３次元的な構造情報または組成情報または材質変化情報またはこれらの運動情報を得て、さらに所望の分解能の範囲に重複して存在する複数の計測データを平均値や最小二乗法に基づく近似値で置き換え、これらの断面を主とした断層像を表示または印刷する光コヒーレンストモグラフィー装置について、図２～３を用いて説明する。

【００２０】

図２は本実施形態全体を説明するための概念図であり、光ファイバーケーブル６－３により導かれた計測光が対物レンズ・ｙ軸方向駆動のガルバノミラーを通して被計測体に照射され、後方散乱反射光が再びガルバノミラー・対物レンズを通して光ファイバーに入射し、光ファイバーケーブル６－３を通してＯＣＴユニット１１へ導かれることを示す。この

例においてｘ軸方向走査のガルバノミラーは本発明の効果により不要となっている。図２中には被計測体の例として歯を、さらにその断面の例として内部の構造・病変である表面の断面線・ウ蝕の断面およびクラックの断面を示している。この実施形態において、プローブは移動させることによりその計測部位が移動することを前提としており、歯の部分にプローブ位置Ａおよびプローブ位置Ｂにおける計測断面領域を示している。

【００２１】

図３はこのプローブ位置Ａおよびプローブ位置Ｂにおける計測断面領域の計測結果の断層画像をそれぞれ四角い枠で示している。実際は２つの画像の位置方向は角度を含む６次元的に移行するが、図ではｙ方向ｚ方向の２次元的な移行を例示している。光コヒーレンストモグラフィーの生データの状態ではこれら２つの画像データは空間的な位置方向関係が存在しない互いに独立したデータとなっておるが、図では本発明の実施の結果として２つの画像にまたがる被計測体の連続した領域を重ね合わせて表示している。本実施の形態においては連続した領域を重ね合わせているためのひとつの例として次の様な方法をとっている。

１．２つの計測領域のデータからそれぞれ図に示す様な形状の特徴面（例：強度の程度によって連続した領域として抽出される面、特徴線によって囲まれる面）・特徴線（例：特徴面の境界、強度が急変する点を急変する方向に垂直な方向に連ねた線、特徴点によって結ばれる線）・特徴点（例：強度が急変する点、特徴線の方向が急変する点）を抽出する。

２．２つの計測領域の相対的位置方向を６次元的に移動回転させ、２つの領域の特徴点・特徴線・特徴面が一致する様な移動量と回転量を見出す。プローブの移動方向や１つの断層データ取得に要する時間との関係によっては２つの計測領域は平行移動したものとみなし、これを２次元的な移動で処理してもよい。

３．２つの計測領域に対応する計測体の連続した領域のデータが重ね合わさる様に、見出した移動量および回転量によって２つの計測データを３次元空間上の６次元位置・方向に配置する。全ての計測領域について１～３の処理を行う。

４．時空間的に配置させた２つの計測データのセットのうち、所望の分解能の範囲に複数の計測データが重複して存在しているデータを平均値に置き換え、さらに空間的に近傍にある計測領域の複数のセットの平均値から最小二乗法に基づく近似値を算出して平均値をこれに置き換える。

本実施の形態においては、位置方向検出手段として光コヒーレンストモグラフィー自身のデータを使った例を示したが、プローブに固定した異なる角度からの複数のイメージセンサの同時画像から共通の特徴点・特徴線・特徴面を抽出し、レンジファインダーの原理に基づいて被計測体とプローブの相対的位置方向関係を見出す方法もある。さらにプローブと被計測体の双方に固定されていない複数のイメージセンサの被計測体とプローブを含む画像から被計測体とプローブの位置方向関係を見出す方法もある。

（２番目の実施の形態）

位置方向計測手段が、３個の加速度センサと３個の角速度センサである例を図４に示す。図４は図２の構成に対して３方向の加速度センサと３方向の角速度センサがプローブに固定され、さらに被計測体は地球に対して静止または等速度運動している（地球の自転等の天体運動は無視可能である）ことが前提である。この様な構成においてプローブを動かしながら角速度センサと加速度センサの出力と光コヒーレンストモグラフィーの出力データを同期取得する。適当な初期値を定めておき、加速度センサの出力を時間的に２回積分し角速度センサの出力を時間的に１回積分することでプローブと被計測体の相対的位置方向を算出することで、時間的に同期して取得した光コヒーレンストモグラフィーの各データを被計測体の座標系上に配置するものである。

リニアゲージあるいは角度ゲージについては、被計測体に固定した装着部とプローブの間にリニアゲージと角度ゲージを装着するものであり、これらの出力からプローブと被計測体の相対的位置方向を算出する。

さらにプローブの機械的走査については、静止した被計測体に対してプローブの初期位

置を定めて、一定の軌跡でプローブを動かし、これに同期して光コヒーレンストモグラフィーのデータを取得するものであり、プローブと被計測体の相対的位置方向はあらかじめ決まっている。

いずれの方法にしても、プローブと被計測体の相対的位置方向を知ることで、光コヒーレンストモグラフィーのデータを被計測体の座標系上に再配置することが可能である。

【産業上の利用可能性】

【００２２】

本発明は光コヒーレンストモグラフィーの適用分野のうち、広い範囲の断像画像を必要とする分野に利用可能である。特に医療の分野においては有用である。さらに歯科の分野においては、従来の光コヒーレンストモグラフィーの計測領域は歯１本よりも小さいのに対して、本発明は歯全体あるいは臨在歯や歯列全体を同一の患者座標系上で計測し、画像として再配置して表示・印刷することが可能である。

本発明は、光コヒーレンストモグラフィー装置に限らず、生物体の表面および内部の特性を３次元空間上の特性値として測定し、測定データを演算部において演算処理し、２次元または３次元の画面または印刷物に表示する３次元上特性測定・表示装置全般について適用可能である。３次元上特性測定・表示装置に具体的な例としては、Ｘ線ＣＴ装置・ＭＲＩ装置・２～３次元超音波画像診断装置・ＰＥＴ装置・ＳＰＥＣＴ装置・光ＣＴ装置および光コヒーレンストモグラフィー装置が含まれるが、特に１回あたりの計測範囲の小さい光コヒーレンストモグラフィー装置や近接磁場を用いたMRI装置・３次元超音波診断装置には特に有用である。また３次元空間上の２次元表面の可視光学的撮像装置であるビデオカメラも近接した場合には撮像範囲が狭いので有用となる。これらの中で、被写体を固定し３次元空間上で自由に位置方向付け可能なプローブを使用する様な医療機器、特に歯科領域である口腔内の軟・硬組織の２～３次元上の特性をプローブを口腔内に挿入して測定する様な用途に好適である。また、超音波画像診断装置は通常２次元の断面を計測するものであるが、これを断面に垂直な方向に動かす場合等には特に有用である。また、光コヒーレンストモグラフィー装置は計測範囲が数ｍｍ～十数ｍｍ範囲と狭く、これを歯科に適用する様な用途にも特に有用である。

【図面の簡単な説明】

【００２３】

【図１】ＯＣＴの基本構成の一例を示す図

【図２】実施形態全体を説明するための概念図

【図３】計測断面領域の計測結果の断層画像

【図４】位置方向計測手段が、３個の加速度センサと３個の角速度センサである例

【符号の説明】

【００２４】

１　光源

２ａ　ファイバーカップラー（光分割部・干渉部）

３　参照ミラー

４　光検出器（光検出部）

５　コンピューター（演算部）

６－１～４　光ファイバー

７－１～５、７－７　レンズ

７－６　（対物）レンズ

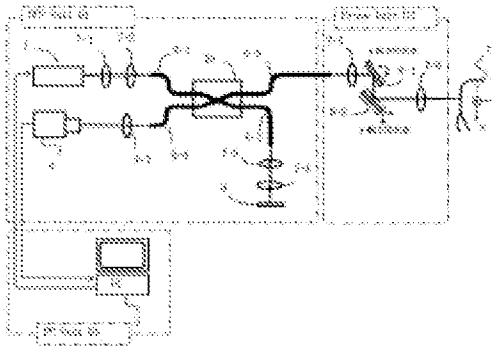
８－１～２　ガルバノミラー

Ｕ２　プローブユニット

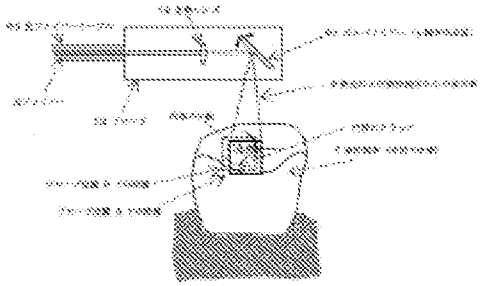
Ｕ３　ＰＣユニット（PC Unit）

Ｕ１　ＯＣＴユニット

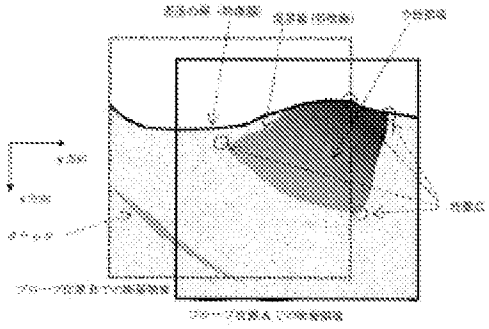
【図１】



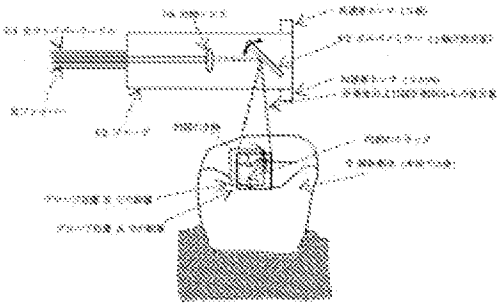
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【図３】



【図４】



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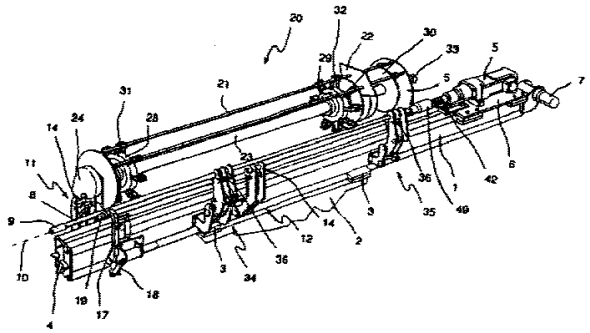
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(54) Title: ARRANGEMENT FOR FIXING ROCK BOLTS DURING ROCK REINFORCEMENT



(57) Abstract: The invention concerns an arrangement for fixing rock bolts during rock reinforcement that includes: a drilling machine (5) that is forwards and backwards displaceable along an axis of rotation (10); an adapter (42) attached to the chuck of the drilling machine, the free end of which is designed for the removable fixation and rotatable driving of one end of a drilling rod (8) with a drilling cutter (9) that is appropriate for rock drilling, or of one end of a rock bolt (21) for introduction into a drilled hole; holder devices (20; 34, 35) for removable retention of the drilling rod or rock bolt in a storage position; and devices (20; 34, 35) for transfer of the drilling rod or rock bolt from the storage position to a position for connection to the adapter that is coaxial with the axis of rotation of the drilling machine; together with devices (20; 34, 35) for removal of the drilling rod from the said connection position to the storage position. In order to make possible the use of only one machine for both drilling and insertion of bolts, the drilling machine (5) is reversible and the free end of the adapter (42) and the end of the drilling rod (8) for attachment to the adapter include sections that are designed to enter into and be removed from rotational engagement with each other by mutual rotation whereby the grip devices (36) are arranged to be brought into and out of engagement with the drilling rod, that the free end of the adapter (42) and the end of the rock bolt (21) for connection to the adapter include sections (46; 21') that can be axially connected to each other whereby one of the sections is rotationally incorporated into the other.

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Arrangement for fixing rock bolts during rock reinforcement

The present invention concerns an arrangement for fixing rock bolts during rock reinforcement according to the preamble to claim 1.

The invention particularly concerns an arrangement for fixing roof-anchoring bolts or what are known as "rock bolts" in tunnels and other underground constructions in mine locations.

Specially developed devices known as "rigs" are used during rock reinforcement by the fixing of rock bolts. The rigs are equipped with equipment for drilling holes in the rock, injecting cartridges that contain a hardenable resin into the drilled hole and finally fixing a rock bolt into the hole. The rock bolt is set into the hole by the execution of a slow rotary motion and it is provided at its front end with a drilling tip, the purpose of which is to perforate the cartridges so that the hardenable resin is brought into contact with the atmosphere and hardens. The rock bolt that is anchored in the hole is pressed against the rock surface by the tightening of a nut, with its associated plate, arranged on a threaded part of the free end of the rock bolt.

The use of a special adapter for transfer of the rotary motion of the drilling machine and blows to the drilling rod and its associated drilling cutter is known. The known adapter is designed for the connection of a drilling rod and displays at its free end a centrally placed bottom hole for connection to the end of the drilling rod and a radial hole that communicates with the axial bottom hole. The opening of the radial hole is surrounded by a water box by means of which fluid can be led to flow *via* the said opening into the radial hole and further through the axial hole before being finally led through the drilling rod and out through the drilling cutter in order to rinse away debris and dust that has been produced during the drilling operation.

Once the hole has been drilled and the cartridge containing resin has been injected into the drilled hole, the drilling machine is taken away and replaced by a machine for fixing the rock bolts in the drilled hole that is placed in line with the drilled hole. Thus it should be realised that the operation requires two sets of machines, a drilling machine with its associated drilling rod for drilling the hole and a drilling machine for fixing the rock bolt itself.

One disadvantage of known arrangements for this purpose is thus that they require two separate machines. Furthermore, arrangements for swapping between the said machines are required.

The intention of the present invention is to achieve an arrangement of the type

described above that makes it possible to use only one machine for both drilling and for fixing the bolt.

The intention is achieved by the arrangement according to the present invention demonstrating the characteristics that are specified in the claims.

The invention will be described in more detail in the following with reference to the attached drawings, of which **fig. 1** shows a view in perspective of the arrangement for fixing rock bolts according to the invention, **fig. 2** shows the parts that are included in the arrangement according to the invention in an exploded view, **fig. 3** shows a side view, in partial longitudinal section, of a drilling machine that is part of the arrangement when in the drilling position, **fig. 4** shows a side view, in partial cross section, of the drilling machine seen in fig. 2 when in the position for fixing a rock bolt into a drilled hole, **fig. 5** and **fig. 6** show a schematic cross-section through a part of a provision that is included in the arrangement for removal of a drilling rod from the drilling machine, **fig. 7** and **fig. 8** show a schematic cross-section through part of a magazine for rock bolts that is included in the arrangement together with a provision for transfer of rock bolts from the magazine to the position for fixing into a drilled hole, **fig. 9** and **fig. 10** show a schematic cross-section through a part of a support for the drilling rod that is included in the arrangement in an inactive position and in an active position, and **fig. 11** and **fig. 12** show a schematic cross-section through a part of a provision that is included in the arrangement for injecting plastic cartridges that contain resin into a drilled hole.

The arrangement shown in fig. 1 includes a feed beam 1 that is supported on a feed beam holder 2. The feed beam holder 2 is supported in a known manner on a bar that in turn is supported by a carrier, not shown in the figure. The feed beam holder 2 is arranged to pivot around the said bar *via* a joint, not shown in the figure. The feed beam 1 is displaceably guided in the longitudinal direction by means of the guides 3, and can be adjusted relative to the feed beam holder 2 by the influence of suitably arranged piston- and cylinder devices. The feed beam 1 is equipped at its front end with a tip 4 for pressing against a rock surface.

A reversible drilling machine 5 is carried by a sledge 6 which can be guided as it slides along the feed beam 1. A driving mechanism for the sledge 6 is arranged in the form of a chain transmission, taken up into the feed beam, that is driven by a driving device 7, with the aid of which the drilling machine 5 can perform forward and backward, working and return motions along the feed beam 1. During the said motions, a drilling rod 8 that is fixed into the drilling machine 5 moves, together with its associated drilling cutter 9, along an axis

10 that is coaxial with the axis of rotation of the drilling machine and that lies parallel to the principal axis of the feed beam 1. The drive device 7 is designed in a known manner in such a way that the sledge 6 can be driven with a variable speed of feeding, and is equipped with pulse sensors or other known technology that makes it possible to determine the position of the sledge 6, and thus also the position of the drilling machine 5, on the feed beam 1 at any instant. Signals from the said sensor are fed to a control unit, and it is appropriate that the control unit includes a computer.

The arrangement is equipped with supports for the drilling rod 8, of which a first, forward, drill support 11 is arranged at the front end of the feed beam 1 and a second, rear, drill support 12 is arranged in the region of the approximate centre of the length of the feed beam 1. The drill supports 11, 12 are positioned on opposite sides of the feed beam 1 and each includes, as is shown in figs. 7-10, an arm 13 that is jointed to pivot with the feed beam 1 and arranged to pivot into and out from the feed beam 1 by means of a piston- and cylinder device, not shown in the figure, that operates between the feed beam and the arm 13. The arm 13 is equipped at its free end with a claw-like control 14 for the drilling rod 8. As is most clearly seen in figs. 7-10, the claw-like control 14 includes a holder defined by two halves of circles that can be moved relative to each other, one half 15 being stationary while the other half 16 is designed as a link that is jointed to pivot with the arm 13 and arranged to pivot between an open and a closed position with the aid of a piston- and cylinder device 16′. When the control 14 is in the closed position, it follows that a ring-shaped holder for the drilling rod 8 is formed, while the drilling supports 11, 12 are allowed to pivot out from the drilling rod when the control is in its open position.

As is most clearly shown in figs. 11 and 12, one end of an arm 17 is pivotally fixed at the front end of the feed beam 1, opposite to the front drill support 11, and arranged to pivot into and out from the feed beam 1 by means of a piston- and cylinder device 18 that is active between the feed beam and the arm. At its free end, the arm 17 supports a mouthpiece 19 that forms part of a device for the injection of plastic cartridges containing resin into a drilled hole. When the arm is pivoted in against the feed beam 1, the mouthpiece 19 can be brought into a position in which it coincides with the central axis 10 of the drill.

As is shown in fig. 1, a holder in the form of a drum-like magazine for rock bolts, generally denoted by the figure 20, is attached to the feed beam. The rock bolts 21 are of the type that is provided at one end with plates 22 for pressing against the rock surface. The magazine for rock bolts 21 is constructed around a shaft 23 that is supported in rotating bearings by a first arm 24 and a second arm 25, each of which is jointed to pivot with the

feed beam 1 and arranged for simultaneous pivoting into and out from the feed beam 1 by means of a piston- and cylinder device 26, 27. The shaft 23 is provided at each end with a set of flange-like parts 28, 29, 30 that protrude radially from the shaft, around the perimeter of which the rock bolts are equally distributed. The functions of the said flange-like parts are to hold the rock bolts separate at a distance from each other both in the radial and in the axial direction, and to allow a detachable mounting of the rock bolts, which in the embodiment that is described here is achieved by means of sprung finger-like grip devices 31, 32 produced from wire-like material and arranged at mutually equal distances around the circumference of two of the said flange-like parts 28, 29.

The shaft 23 provides rotational driving of the magazine 20, by means of a transmission that is connected in a manner that transfers power from a drive unit in the form of a motor 33. The said drive unit is designed in such a way that the magazine 20 can be positioned into specified angular positions. Transfer of rock bolts 21 from the magazine 20 to a position that is coaxial with a previously drilled hole occurs by the magazine 20 being turned or indexed forward to a specified angular position, after which the magazine is pivoted in towards the feed beam 1 such that the rock bolt 21 that is to be fixed into the hole is positioned coaxial with the axis of rotation 10 of the drilling machine 5.

A first holder 34 and a second holder 35 for the drilling rod are arranged on the side of the feed beam that is situated opposite to the magazine 20, each of which includes grip devices 36 that can be engaged with and disengaged from a drilling rod 8 that is fixed into the drilling machine 5, and that can also remove the gripped drilling rod from its working position in the drilling machine. As is most clearly seen in figs. 5 and 6, each of the said holders contains an arm 37 that is jointed to pivot with the feed beam 1 and arranged to pivot into and out from the feed beam 1 by means of a piston- and cylinder device 38. The grip device 36 is arranged at the free end of the arm 37 and contains a stationary part 39 in the form of an opening in the form of a semicircle positioned at one end of the arm, together with a mobile part 40 in the form of an opening similarly shaped in the form of a semicircle attached by a pivot to the arm which, by means of a piston- and cylinder device 41, is arranged to pivot between an open position and a closed position in collaboration with the stationary part 39. In order to ensure that the drilling rod is securely fixed in the grip devices it is appropriate that at least one of the grip devices 36 is provided with internal teeth that act against the circumference of the gripped drilling rods.

An adapter 42 that is part of the present invention is shown in fig. 2. The adapter demonstrates a first end 43 that is designed for attachment to the chuck of the drilling

machine 5 and a second free end to which it is intended that one end of the drilling rod 8 or one end of the rock bolt 21 is to be removably attached, for rotating driving. The free end 43 of the adapter is provided with an external thread that is designed to collaborate with an equivalent internal thread 45 arranged at the end of the drilling rod 8. An axial recess, generally denoted by 46, is arranged at the centre of the free end of the adapter, and demonstrates a non-circular section 47 at its outer part and a circular section 48 at its inner part, and in which sections it is intended that one end, denoted by 21', of the rock bolt 21 is to be screwed in.

Since the free end of the adapter 42 and the end of the drilling rod 8 that is intended for connection to it both normally demonstrate external threads, an intermediate piece 49 has been arranged for the connection between the free end of the adapter 42 and the drilling rod 8, which intermediate piece is arranged with internal threads in the bottom hole. The holes in the intermediate piece 49 are connected with each other *via* a channel 50 such that rinse water can be led through the intermediate piece 49 and onwards through the drilling rod 8.

It is appropriate if the free end of the adapter 42 and the end of the intermediate piece 49 for attachment to the same are provided with pipe threads of type R55, and that the connection to the drilling rod is provided with pipe threads of type R32.

The non-circular recess 46 in the centre of the operative end of the adapter 42 demonstrates a shape that is hexagonal when seen in cross-section and, in other words, has a shape that is equivalent to the shape of nut 51 that is arranged at the end of the rock bolt 21. The axial circular bore 48 that is positioned further into the depression 46 has a diameter that is selected such that the threaded axial section of the rock bolt 21 can be inserted into the same. Somewhat further into the recess 46, the axial bore 48 becomes a bore with a reduced diameter that communicates with a channel that runs radially and that opens out into the perimeter of the adapter (not shown in the figure). The opening can, by means of a water box that surrounds the adapter 42, or similar, be connected in a known manner with a source that supplies rinse water which, *via* the said opening and radial holes, is led onwards through the axial hole in the adapter 42 *via* the hole 50 in the separate intermediate piece 49 before being finally led through the drilling rod 8 and further out through the drilling cutter in order to rinse away debris and dust that is produced during the drilling operation.

As is shown in figs. 3 and 4, the sledge is equipped with a device 52 the function of which is to lock the nut 51 of the rock bolt 21 in place when it is located in the recess 46 of the adapter 42. The locking device in principle includes a fork 53 that can be moved *via* a manoeuvring link 54 and a piston- and cylinder device 55 between a first, non-operational

position in which the fork 53 is positioned at a distance such that the end of the drilling rod 8 can be connected to the free end of the adapter 42, as is shown in fig. 3, and a second, operational position in which the nut 51 of the rock bolt 21 is fixed to the adapter 42, as is shown in fig. 4.

The function and method of operation of the arrangement described above are most clearly explained by figs. 5-12. When the sledge 6, and thus also the drilling machine 5, is located at the rear end position along the feed beam 1, the first holder 34 and the second holder 35 of the drilling rod 8 are pivoted inwards, as is shown by the arrow 44 in fig. 5, such that the drilling rod that is positioned in the grip devices 36 of the holders is positioned with an orientation that is coaxial with the axis of rotation 10 of the drill, and is thus positioned for connection to the free end of the adapter 42 of the drilling machine 5. The sledge 6 is fed forwards during slow anti-clockwise rotation of the adapter 42 positioned in the chuck of the drilling machine 5, until the drilling rod 8 has been screwed fast onto the end of the adapter. The rear support 12 for the drilling rod is pivoted inwards from its outward rest position and the claw-like control 14 is closed around the drilling rod 8 in order to control the same. The grip devices 36 of the first holder 34 and the second holder 35 for the drilling rod 8 are opened and the said holders return to their rest positions, as is shown in fig. 6.

The drilling machine 5 is rotated and fed forwards along the feed beam 1 by means of the sledge 6 with parameters with respect to rate of revolution and speed of feed that are determined for the drilling operation. When the drilling cutter 9 has passed the forward drilling support 11, which in this case is positioned in an outward rest position, this support is also pivoted in and the drilling rod 8 is enclosed by the claw-like control 14 of the same. During the forward motion of the sledge 6 along the feed beam 1 the supports 11 and 12 are pivoted outwards at appropriate times in order to prevent collision with the drilling machine 5. When the sledge 6, and thus also the drilling machine 5, has reached its end position on the feed beam 1, a hammer arrangement that is part of the drilling machine is activated in order to free initially the drilling rod 8 from the adapter 42. The sledge 6 is fed backwards along the feed beam 1 towards the rear initial position, whereby the drill supports 11, 12 are pivoted inwards during the motion of the sledge as the drilling machine passes the said drill support. When the sledge 6 is located in the rear initial position, the first holder 34 and the second holder 35 for the drilling rod are pivoted in and their respective grip devices 36 are activated in order to grip the drilling rod 8, whereby the drilling machine is slowly rotated clockwise until the drilling rod 8 has been unscrewed from the adapter 42.

In association with the exchange of tools in the drilling machine described above, the arm 17 is pivoted in, as is shown in figs. 11-12, such that the mouthpiece 19 that is part of the injection device is positioned coaxial with the drilled hole. By means of the injection device, which is connected by the tube 56 to a source of pressure medium for injection of cartridges containing resin, the said cartridges are fed into the hole, after which the arm 17 that carries the mouthpiece 19 is pivoted outwards to its resting position.

The bolt magazine 20 is indexed as is shown in figs. 7 and 8 such that a rock bolt 21 is presented in a position for delivery, after which the magazine is pivoted in such that the said rock bolt is placed coaxial with the drilled hole and thus is also positioned in line with the axis of rotation 10 of the drilling machine, and hence for connection to the free end of the adapter 42 of the drilling machine 5. The sledge 6 is fed forwards during slow anti-clockwise rotation of the adapter 42 that is fixed into the chuck of the drilling machine 5, until the nut of the rock bolt has been inserted into the recess of the adapter, after which the locking device 52 for the nut 51 is placed into its operational position such that the nut is securely located in the adapter. The forward support 11 and the rear support 12 are pivoted in from their outward rest positions and the claw-like control 14 is caused to enclose the rock bolt 21 for control of the same, after which the rock bolt magazine 20 is pivoted out to its rest position. The drilling machine 5 is rotated anticlockwise and fed forwards along the feed beam by means of the sledge 6 towards the rock surface for fixing of the rock bolt 21 into the drilled hole. During the forward motion of the sledge 6 along the feed beam 1, the supports 11, 12 are pivoted outwards at appropriate times in order to prevent collision with the drilling machine 5. The locking device 52 for the nut is positioned into its inactive position just before the rock bolt 21 reaches its end position. When the rock bolt 21 reaches its end position, the drilling machine 5 stops until the resin has hardened in the hole, after which the drilling machine is reactivated and rotated clockwise for placement of the nut 51 and plate 22 against the rock surface. The sledge 6 is once again fed backwards along the feed beam 1 towards its initial position, and a new work-cycle can begin.

The present invention is not limited to that which is described above and shown in the drawings, but can be changed and modified in a number of different ways within the framework of the innovative concept specified in the following claims.

CLAIMS

1. Arrangement for fixing rock bolts during rock reinforcement that includes a drilling machine (5) that is forwards and backwards displaceable along an axis of rotation (10), an adapter (42) attached to the chuck of the drilling machine, the free end of which is designed for the removable fixation and rotatable driving of one end of a drilling rod (8) with a drilling cutter (9) that is appropriate for rock drilling, or of one end of a rock bolt (21) for introduction into a drilled hole whereby the rock bolt is of the type that for pressing against the rock surface demonstrates at one end a body (51) that can be axially positioned on a thread with a non-circular outer cross-section designed for influence by turning, holder devices (20; 34, 35) for removable retention of the drilling rod or rock bolt in a storage position and devices (20; 34, 35) for transfer of the drilling rod or rock bolt from the storage position to a position for connection to the adapter that is coaxial with the axis of rotation of the drilling machine, together with devices (20; 34, 35) for removal of the drilling rod from the said connection position to the storage position, **c h a r a c t e r i s e d in that** the drilling machine (5) is reversible and that the free end of the adapter (42) and the end of the drilling rod (8) for attachment to the adapter include sections that are designed to enter into and be removed from rotational engagement with each other by mutual rotation whereby grip devices (36) are arranged to be brought into and out of engagement with the drilling rod, that the free end of the adapter (42) and the end of the rock bolt (21) for connection to the adapter include sections (46; 21′) that can be axially connected to each other whereby one of the sections is rotationally incorporated into the other.

2. Arrangement according to claim 1, wherein the free end of the adapter (42) includes an external thread (44) designed to collaborate with an equivalent internal thread (45) arranged at the end of the drilling rod (8) and in that an axially running recess (46) is arranged at the centre of the free end of the adapter into which it is intended that the adjustable body (51) of the rock bolt is to be rotationally inserted.

3. Arrangement according to claim 1 or 2, wherein the grip devices (36) form part of the holder devices (34, 35) for the drilling rod (8).

4. Arrangement according to any of claims 1-3, wherein the holder devices (34, 35; 20) for the drilling rod (8) and the rock bolt (21) are located on opposite sides of the axis of rotation (10) of the drilling machine (5).

5. Arrangement according to any of claims 1-4, wherein it includes controls (14) for the drilling rod (8) that is attached to the drilling machine, which controls can be opened and moved between a closed position in which they form a holder that surrounds the drilling rod,

and an open position in which the control can be removed from the said drilling rod.

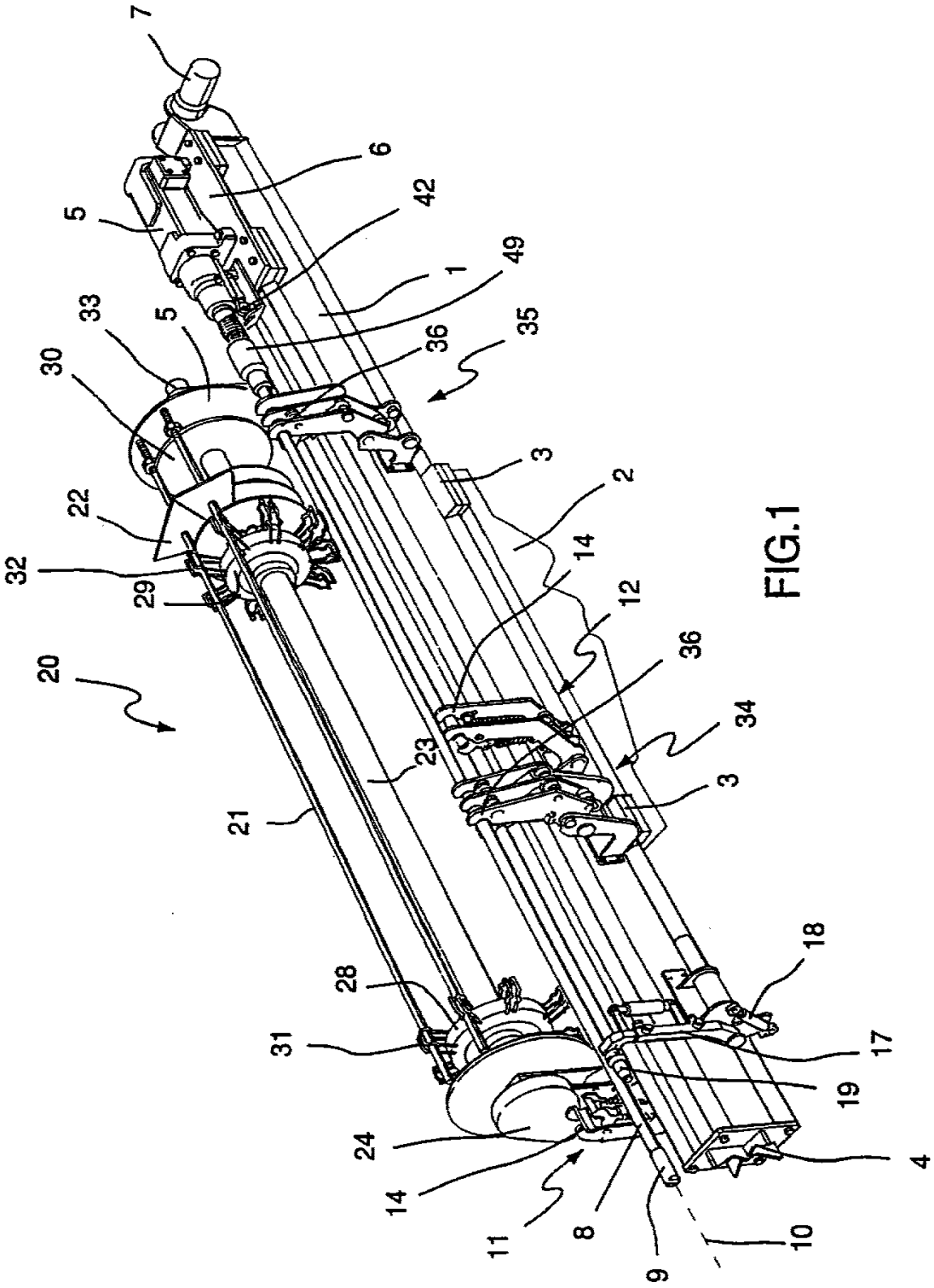

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FIG.1

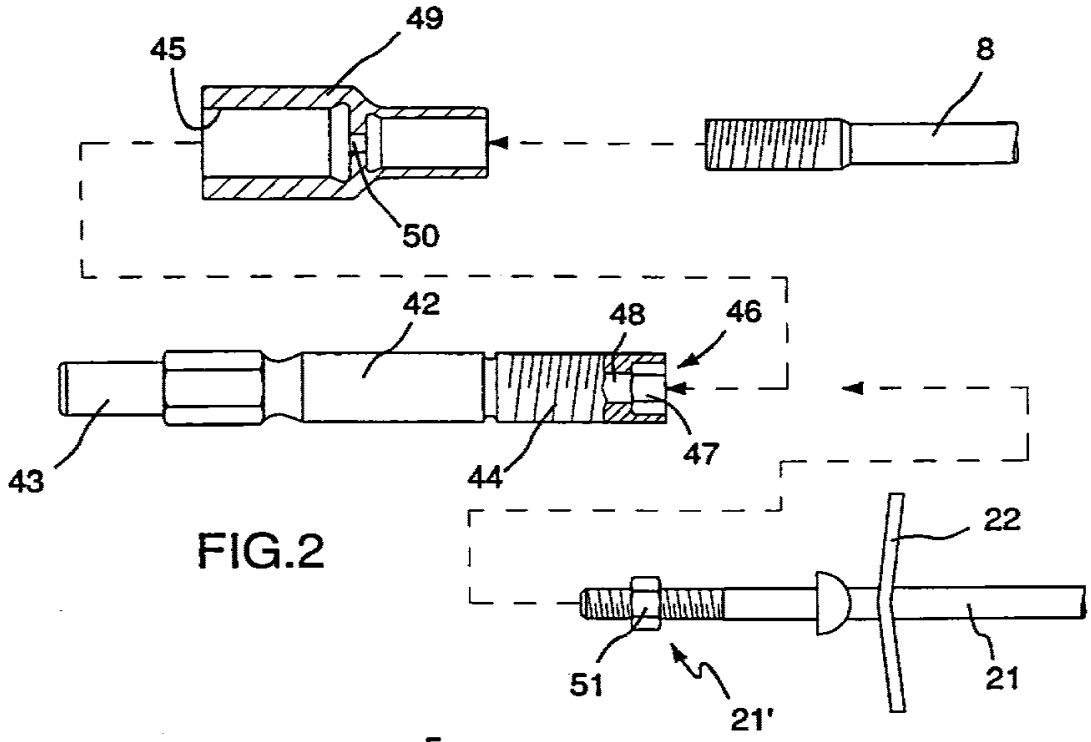


FIG.2

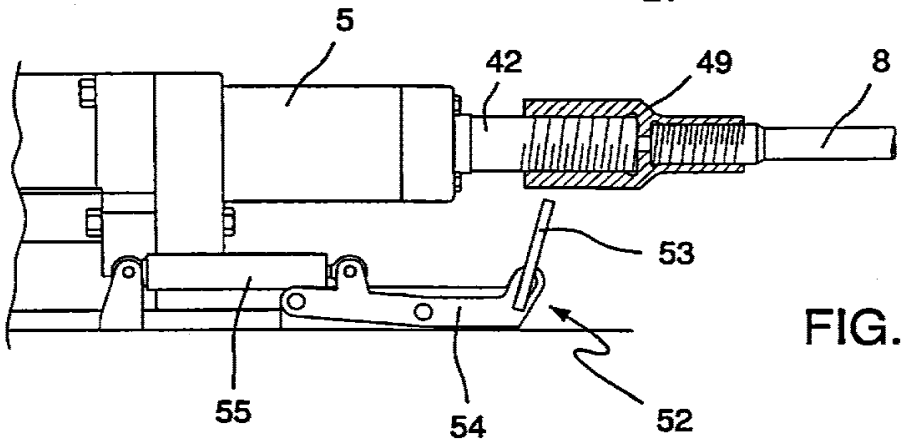


FIG.3

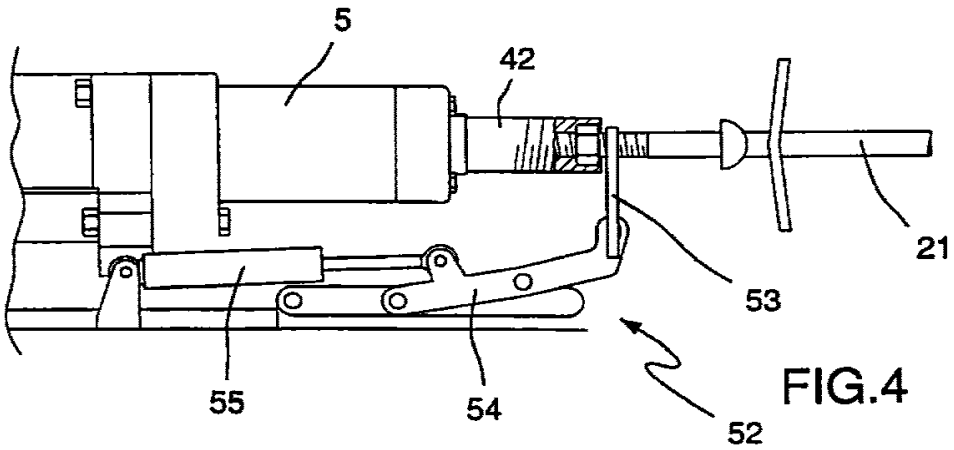


FIG.4

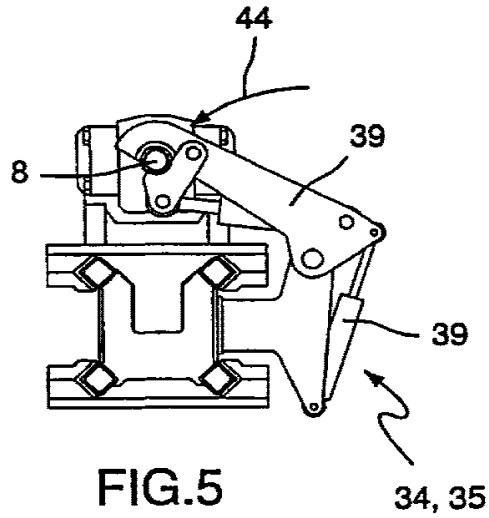


FIG.5

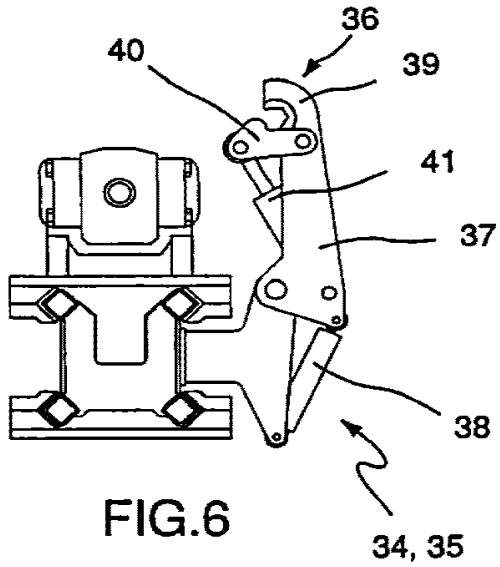


FIG.6

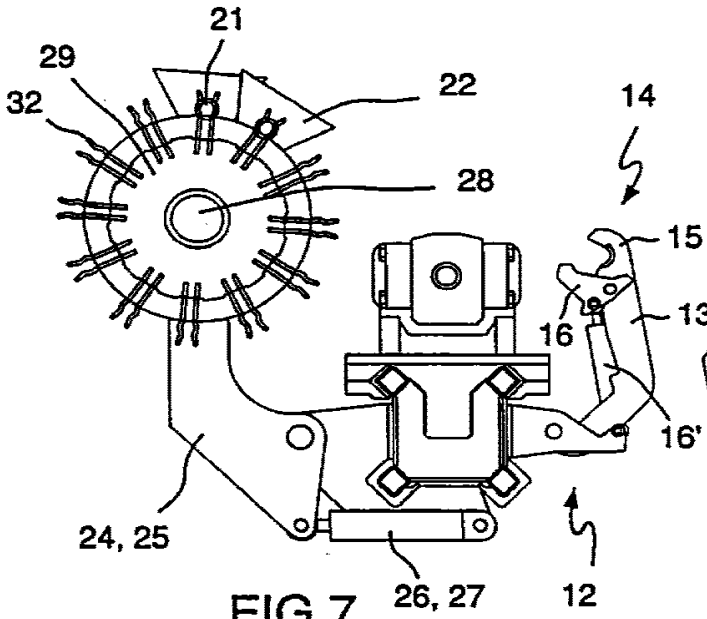


FIG.7

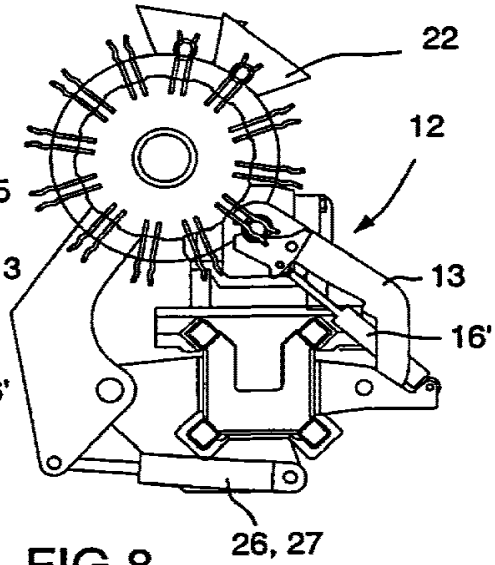


FIG.8

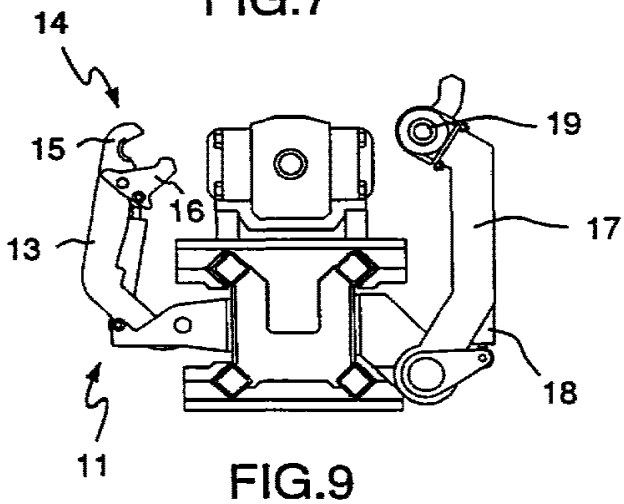


FIG.9

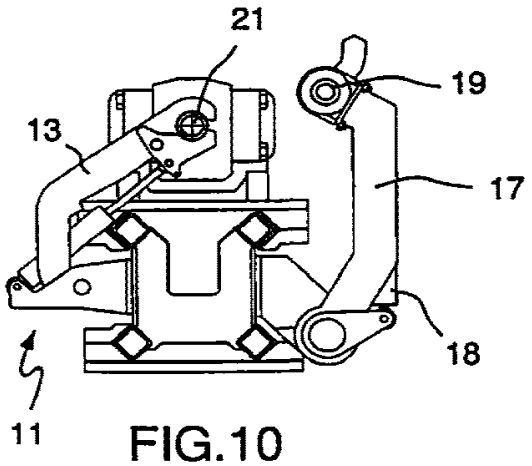


FIG.10

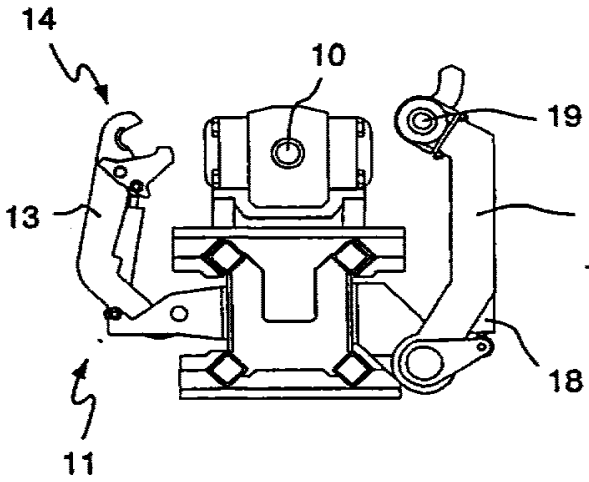


FIG.11

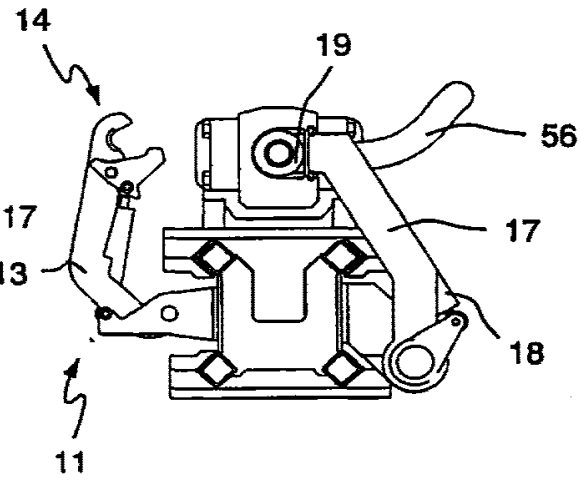


FIG.12

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

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B. FIELDS SEARCHED

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2196884 A (SIG SCHWEIZERISCHE INDUSTRIE-GESELLSCHAFT), 11 May 1988 (11.05.88), the whole document ---	1-5
A	EP 0130969 A2 (VEREINIGTE EDELSTAHLWERKE AKTIENGESELLSCHAFT (VEW)), 9 January 1985 (09.01.85), the whole document --- --------	1-5

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 November 2000	09 -11- 2000
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Exhibit 1004 page 181 of 1621
DENTAL IMAGING

GB	2196884	A	11/05/88	AU	580225	B	05/01/89
				AU	8048187	A	26/05/88
				CH	673873	A	12/04/90
				DE	3735388	A	11/05/88
				GB	8725231	D	00/00/00
				US	4832536	A	23/05/89
EP	0130969	A2	09/01/85	SE	0130969	T3	
				AT	240583	A	15/06/87
				AT	384860	B	25/01/88
				AU	569091	B	21/01/88
				AU	2972484	A	17/01/85
				CS	273315	B	12/03/91
				CS	8405054	A	14/08/90
				DE	3481856	D	00/00/00
				FI	80948	B,C	30/04/90
				FI	842438	A	31/12/84
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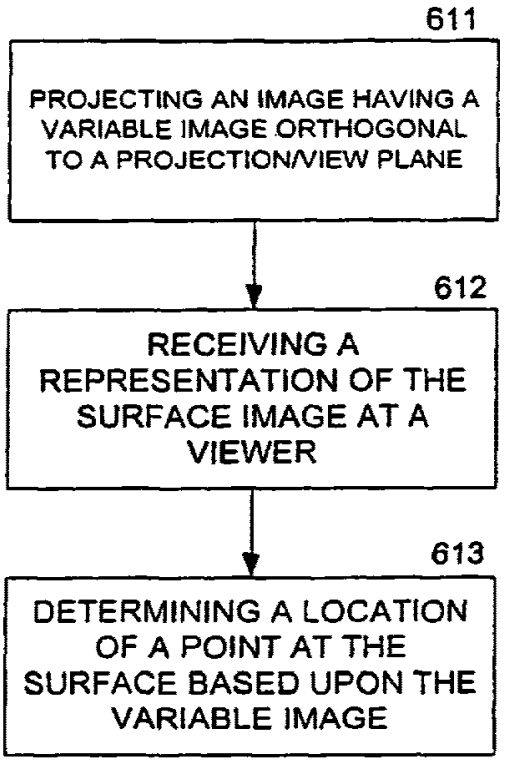
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[Continued on next page]

(54) Title: METHOD AND SYSTEM FOR SCANNING A SURFACE AND GENERATING A THREE-DIMENSIONAL OBJECT



(57) Abstract: An image is projected upon a surface of a three dimensional object (611), the image can include a pattern having plurality of individual shapes used to measure and map the surface. The image further comprises a feature containing an encoding information for identifying the plurality of shapes individually. The feature containing encoding information is oriented such that encoding information is retrieved along a line perpendicular to aplane formed by the projection axis and the point along the view axis (613). The use of the feature is used to perform multiframe independant scanning (612).

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METHOD AND SYSTEM FOR SCANNING A SURFACE AND GENERATING A THREE-DIMENSIONAL OBJECT

RELATED APPLICATIONS

This application claims priority to U.S. Application No. 09/560,131 filed on April 28, 2000; U.S. Application No. 09/560,132 filed on April 28, 2000; U.S. Application No. 09/560,583 filed on April 28, 2000; U.S. Application No. 09/616,093 filed on July 13, 2000; U.S. Application No. 09/560,645 filed on April 28, 2000; U.S. Application No. 09/560,644 filed on April 28, 2000; U.S. Application No. 09/560,584 filed on April 28, 2000; and U.S. Application No. 09/560,133 filed on April 28, 2000, the entire teachings of which are incorporated herein by reference.

Field of the Invention

The present invention relates generally to the mapping of objects, and more specifically to creating three-dimensional models of objects, to registering object portions to generate a model of the object, to registering scanned portions of the object to provide a three-dimensional object, to scanning anatomical structures to treat and diagnose, as well as develop and manufacture medical and dental devices and appliances and to providing specific images to aid the mapping of objects.

Background of the Invention

The ability to generate anatomical devices such as prosthetics, orthotics, and appliances such as orthodontics is well known. Current methods of generating anatomical devices is subjective, whereby a practitioner specifies, or designs, the anatomical device based upon subjective criteria such as the practitioner's view of the anatomical structure, the location where a device is to be used, and the practitioner's experience and recall of similar situations. Such subjective criteria results in the development of an anatomical device that can vary significantly from practitioner to practitioner, and prevents the acquisition of a knowledge database that can be used by others.

One attempt to make the development of an anatomical devices less subjective includes taking an impression of the anatomical structure. From the impression, which is a negative representation of the anatomical structure, a positive model of the anatomical structure can be made. However, impressions, and models made from impressions, are subject to distortion, wear, damage, have a limited shelf life, are imprecise, require additional cost to generate multiply copies, and have an accuracy that is not readily verifiable. Therefore, whether an impression or a model of a structure is a true representation of the anatomical structure is not readily verifiable. Furthermore, impression processes are generally uncomfortable and inconvenient for patients, require a visit to a practitioner's office, and are time consuming. Furthermore, where multiple models are needed, either multiple impressions must be made, or multiple molds must be made from a single impression. In either case, no

reliable standard reference is available to guarantee the similarity of each of the models. Furthermore, the mold still must be visually interpreted by the solo practitioner, resulting in a subjective process.

Another attempt to make development less subjective includes using two-dimensional images. However, the use of 2-dimensional images as known can not provide precise structure information, and still must be objectively interpreted by the practitioner. Furthermore, the manufacturing of the device is still based upon an objective interpretation.

When an impression is shipped from the practitioner to a manufacturing facility, communication between the practitioner and the technicians about issues pertaining to the model or device being manufactured is impeded, since the three-dimensional model which is being used to design a prosthetic device is available only to the manufacturing facility. Even if multiple molds exist, they can't be viewed simultaneously from the same perspective, as they are physically separate objects, nor is there an interactive way of referencing the multiple models to one another.

Other types of records, in addition to molds and impressions, that maintained by practitioners, such as dentists and orthodontists are subject to being lost or damaged, and are costly to duplicate. Therefore, a method or system that overcomes these disadvantages would be useful.

The use of scanning techniques to map surfaces of objects is well known. Prior art Figure 1 illustrates an object 100 having visible surfaces 101-

104. Generally, the visible surfaces 101-103 form a rectangular shape residing on top of a generally planer surface 104.

Projected onto the object 100 is an image, which includes the line 110. In operation, the image of line 110 is received by a viewing device, such as a camera, (not shown) and processed in order to determine the shape of that portion of object 100 where the line 110 resides. By moving the line 110 across the object 100, it is possible to map the entire object 100. Limitations associated with using an image comprising a single line 110 is that a significant amount of time is needed to scan the object 100 to provide an accurate map, and a fixed reference point is needed at either the scanner or the object.

Figure 2 illustrates a prior art solution to reduce the amount of time taken to scan an object. Specifically, Figure 2 illustrates an image including lines 121 through 125. By providing multiple lines, it is possible to scan a greater surface area at once, thus allowing for more efficient processing of data associated with the object 100. Limitations of using patterns such as are illustrated in Figure 2 include the need for a fixed reference point, and that the surface resolution capable of being mapped can be reduced because of the potential for improper processing of data due to overlapping of the discrete portions of the image.

In order to better understand the concept of overlapping, it is helpful to understand the scanning process. Prior art Figure 3 illustrates the shapes of Figures 1 and 2 from a side view such that only surface 102 is visible. For discussion purposes, the projection device (not illustrated) projects a pattern in a

direction perpendicular to the surface 101 which forms the top edge of surface 102 in Figure 3. The point from the center of the projection lens to the surface is referred to as the projection axis, the rotational axis of the projection lens, or the centerline of the projection lens. Likewise, an imaginary line from a center point of the viewing device (not shown) is referred to as the view axis, the rotational axis of the view device, or the centerline of the view device, extends in the direction which the viewing device is oriented.

The physical relationship of the projection axis and the view axis with respect to each other is generally known. In the specific illustration of Figure 3, the projection axis and the view axis reside in a common plane. The relationship between the projection system and the view system is physically calibrated, such that the relationship between the projector, and the view device is known. Note the term "point of reference" is to describe the reference from which a third person, such as the reader, is viewing an image. For example, for Figure 2, the point of reference is above and to the side of the point that is formed by surfaces 101, 102, and 103.

Figure 4 illustrates the object 100 with the image of Figure 2 projected upon it where the point of reference is equal to the projection angle. When the point of reference is equal to the projection angle, no discontinuities appear in the projected image. In other words, the lines 121-125 appear to be straight lines upon the object 100. However, where the point of reference is equal to the projection axis, no useful data for mapping objects is obtained, because the lines appear to be undistorted.

Figure 5 illustrates the object 100 from a point of reference equal to the view angle fleet of Figure 2. In Figure 5, the surfaces 104, 103 and 101 are visible because the view axis is substantially perpendicular to the line formed by surfaces 101 and 103, and is to the right of the plane formed by surface 102, see Figure 2, which is therefore not illustrated in Figure 5. Because of the angle at which the image is being viewed, or received by the viewing device, the lines 121 and 122 appear to be a single continuous straight line. Likewise, line pairs 122 and 123, and 123 and 124, coincide to give the impression that they are single continuous lines. Because line 125 is projected upon a single level surface elevation, surface 104, line 125 is a continuous single line.

When the pattern of Figure 5 is received by a processing device to perform a mapping function, the line pairs 121 and 122, 122 and 123, and 123 and 124, will be improperly interpreted as single lines. As a result, the two-tiered object illustrated in Figure 2 may actually be mapped as a single level surface, or otherwise inaccurately displayed because the processing steps can not distinguish between the line pairs.

Figure 6 illustrates a prior art solution for overcoming the problem described in Figure 5. Specifically, Figure 6 illustrates the shape 100 having an image projected upon it whereby a plurality of lines having different line widths, or thickness, are used. Figure 7 illustrates the pattern of Figure 6 from the same point of reference as that of Figure 5.

As illustrated in Figure 7, it is now possible for a processing element analyzing the received data to distinguish between the previously

indistinguishable line pairs. Referring to Figure 7, line 421 is still lined up with line 422 to form what appears to be a continuous line. However, because line 421 and line 425 have different thickness, it is now possible for an analysis of the image to determine the correct identity of the specific line segments. In other words, the analysis of the received image can now determine that line 422 projected on surface 104, and line 422 projected on surface 101 are actually a common line. Utilizing this information, the analysis of the received image can determine that a step type feature occurs on the object being scanned, resulting in the incongruity between the two segments of line 422.

While the use of varying line thickness, as illustrated in Figure 7, assists identifying line segments, objects that have varying features of the type illustrated can still result in errors during the analysis of the received image.

Figure 8 illustrates from a side point of reference a structure having a surface 710 with sharply varying features. The surface 710 is illustrated to be substantially perpendicular to the point of reference of Figure 8. In addition, the object 700 has side surfaces 713 and 715, and top surfaces 711 and 712. From the point of reference of Figure 8, the actual surfaces 711, 712, 713 and 715 are not viewed, only their edges are represented. The surface 711 is a relatively steep sloped surface, while the surface 712 is a relatively gentle sloped surface.

Further illustrated in Figure 8 are three projected lines 721 through 723 having various widths. A first line 721 has a width of four. A second projected line 722 has a width of one. A third projected line 723 has a width of eight.

The line 721, having a width of four, is projected onto a relatively flat surface 714. Because of the angle between the projection axis and the view axis, the actual line 721 width viewed at the flat surface 714 is approximately two. If the lines 722 and 723 where also projected upon the relatively flat surface 714 their respected widths would vary by approximately the same proportion amount as that of 721, such that the thickness can be detected during the analysis steps of mapping the surface. However, because line 722 is projected onto the angled surface 711, the perspective from the viewing device along the viewing axis is such that the line 722 has a viewed width of two.

Line 722 appears to have a width of two because the steep angle of the surface 710 allows for a greater portion of the projected line 722 to be projected onto a greater area of the surface 711. It is this greater area of the surface 722 that is viewed to give the perception that the projected line 722 has a thickness of two.

In a manner opposite to how line 722 is affected by surface 711, line 723 is affected by surface 712 to give the perception that the projected line 723 having an actual width of eight, has a width of two. This occurs because the angle of the surface 712, relative to the viewing device allows the surface area with the projected line 723 to appear to have a width of two. The results of this phenomenon are further illustrated in Figure 9.

Figure 9 illustrates the shape 700 of Figure 8 from the point of reference of the view axis. From the point of reference of the view axis, the lines 721-723 are projected onto the surface 714 in such a manner that the difference between

the line thickness can be readily determined. Therefore, when an analysis of the surface area 714 occurs, the lines are readily discernable based upon the viewed image. However, when an analysis includes the surfaces 711 and 712, the line 722 can be erroneously identified as being line 721 because not only are the widths the same, but line 722 on surface 711 lines up with line 721 on surface 714. Likewise, the line 723, having a projected width of eight, has a viewed width of two. Therefore, during the analysis of the received images, it may not be possible to distinguish between lines 721, 722, and 723 on surfaces 711 and 712. The inability to distinguish between such lines can result in an erroneous analysis of the surfaces.

One proposed method of scanning, disclosed in foreign patent DE 198 21 611.4, used a pattern that had rows of black and white triangles and squares running parallel to a plane of triangulation. The rows used measuring features that include a digital encrypted pattern. However, when a surface being scanned causes shadowing and/or undercuts, a break in the sequence can result due to a portion of the pattern be hidden. Furthermore, the disclosed encrypted pattern is such that breaks in the sequence can result in the inability to decode the pattern, since it may not be possible to know which portion of the pattern is missing. A further limitation of the type of encoding described is that distortion can cause one encoding feature to look like another. For example, a triangle can be made to look like a square.

Therefore, a method and apparatus capable of overcoming the problems associated with the prior art mapping of objects would be advantageous.

Brief Description of the Drawings

Figure 1 illustrates an object being scanned by a single line in accordance with the prior art;

Figure 2 illustrates an object being scanned by a plurality of lines in accordance with the prior art;

Figure 3 illustrates a projection axis and a view axis associated with the lines of Figure 2 in accordance with the prior art;

Figure 4 illustrates the object of Figure 1 from a point of reference equal to the projection axis of Figure 3;

Figure 5 illustrates the object of Figure 3 from the view axis of Figure 3;

Figure 6 illustrates an object having a plurality of lines of varying thickness projected upon it in accordance with the prior art;

Figure 7 illustrates the object of Figure 6 from a point of reference equal to the view axis as shown in Figure 3;

Figure 8 illustrates an object from a side view having varying projected line thickness in accordance with the prior art;

Figure 9 illustrates the object of Figure 8 from point of reference equal to the view axis of Figure 8;

Figure 10 illustrates a system in accordance with the present invention;

Figure 11 illustrates a portion of the system of Figure 10 in accordance with the present invention;

Figure 12 illustrates, in flow diagram form, a method in accordance with the present invention;

Figure 13 illustrates, the object of Figure 3 from a point of reference equal to the view axis of Figure 3 in accordance with the present invention;

Figure 14 illustrates, the object of Figure 3 from a point of reference equal to the view axis of Figure 3 in accordance with the present invention;

Figure 15 illustrates an object having a pattern projected upon it in accordance with the present invention;

Figure 16 illustrates a table identifying various types of pattern components in accordance with the present invention;

Figure 17 illustrates a set of unique identifiers in accordance with the present invention;

Figure 18 illustrates a set of repeating identifiers in accordance with the present invention;

Figures 19-22 illustrate, in flow diagram form, a method in accordance with the present invention;

Figure 23 illustrates a sequence of images to be projected upon an object in accordance with an embodiment of the present invention;

Figure 24 illustrates an image having varying features in accordance with an embodiment of the present invention;

Figure 25 illustrates a projected image feature being reflected off surfaces at different depths in accordance with a preferred embodiment of the present invention;

Figure 26 illustrates the projected image of Figure 25 as viewed at the different depths;

Figures 27-30 illustrate a dentition object from various perspectives in accordance with preferred embodiments of the present invention;

Figure 31 illustrates a method in accordance with a specific embodiment of the present invention;

Figures 32 and 33 illustrate a dentition object being scanned from various perspectives in accordance with preferred embodiments of the present invention;

Figure 34 illustrates primitive shapes for modeling a dentition object;

Figures 35 and 36 illustrate methods in accordance with a specific embodiment of the present invention;

Figure 37 illustrates a graphical representation of a method for selecting various entry points for registration in accordance with a preferred embodiment of the present invention;

Figures 38-43 illustrate methods in accordance with a specific embodiment of the present invention; and

Figures 44-52 illustrate specific flows in accordance with specific embodiments of the present invention.

Detailed Description of Preferred Embodiments

In accordance with a specific embodiment of the present invention, an image is projected upon a surface. The image can include a pattern having a plurality of individual shapes used to measure and map the surface. The plurality of individual shapes include features that are detectable in a direction parallel to the plane formed by a projection axis of the projected shapes and a point associated with a view axis. The image further comprises a feature containing encoding information for identifying the plurality of shapes individually. The encoding feature varies in a direction substantially orthogonal to a plane formed by the projection axis and a point of a view axis, and can be a separate feature from each of the plurality of individual shapes, can be a feature integral to the plurality of individual shapes, and/or be displayed at different time intervals from the plurality of individual shapes. The feature containing encoding information is oriented such that the encoding information is retrieved along a line substantially perpendicular to a plane formed by the projection axis and the point along the view axis. The use of the feature is used to perform multiframe reference independent scanning. In a specific embodiment, scanned frames are registered to one another.

Specific embodiments of the present invention are best understood with reference to the accompanying Figures 10-24. Figures 10 and 11 represent a system for implementing a specific embodiment of the present invention, Figures 12, and 19-22 illustrate specific methods in accordance with the present

invention, and Figures 13-18, 23, 24 illustrates specific implementations of the method in combination with the system.

Figures 44-52 illustrate a specific method and apparatus of another inventive embodiment that uses three-dimensional scan data of an anatomical structure, which may be obtained in the specific manner described herein. The three-dimensional scan data is transmitted to a remote facility for further use. For example, the three-dimensional scan data can represent the anatomy of an anatomical structure which is used to design an anatomical device, manufacture an anatomical device, monitor structural changes of the anatomy, archive data pertaining to the anatomical structure, perform a closed-loop iterative analysis of the anatomical structure, perform an interactive consultation of the structure, perform simulations based upon the structure, make a diagnosis related to the anatomical structure, or determine a treatment plan based on the anatomical structure.

Figure 10 illustrates a system controller 951 that provides control signals to the scanning device 980. The scanning device 980 projects an image bound by lines 962 and 963, and retrieves, or views, the images within the reflected lines 972 and 973.

In one operation, the system controller 951 provides specific information to the scanner 980 specifying a specific image to be projected upon the surface 991 of the object 990. The reflected image is captured by the scanning device 980, which in turn provides the captured information back to the system controller 951. The captured information can be provided back to

system controller 951 automatically, or can be stored within the scanning device 980 and retrieved by the system 951. The image data once received by the system controller 951 is analyzed in order to determine the shape of the surface 991. Note that the analysis of the received data can be performed either by the system controller 951, or by an external-processing device that is not shown.

Further illustrated in Figure 10 is the scanning device 980, which includes a projecting device (projector) 960 and a viewing device (viewer) 970. The projector 960 is oriented such that the image is projected on the object 990. The projector 960 has a projection axis 961. The projection axis 961 begins at the center of the lens projecting the image and is representative of the direction of projection. Likewise, the viewer 970 has a view axis 971 that extends from the center of the lens associated with the viewer 970 and represents the direction from which images are being received.

Once the scanning device is calibrated, analysis of the received signals can be performed to map the scanned surface. One skilled in the art will recognize that the angles represented in the Figures herein are represented as such for illustrative purposes only. The actual angles and distances may vary substantially from those illustrated.

Figure 11 illustrates in greater detail the system controller 951 of Figure 10. The system controller 951 further includes data processor 952, a projection image representation 953, the projector controller 954, and a viewer controller 955.

The viewer controller 955 provides the interface needed to receive data from the viewer 970 representing the reflected image data. The reflected image data is received from the viewer 970 at the viewer controller 955, and subsequently provided to the data processor 952. In a similar manner, the projector controller 954 provides the interface necessary to control the projector 960. The projector controller 954 provides the projector 960 with the image to be projected in a format supported by the projector. In response, the projector 960 projects the image onto the surface of the object. The projector controller 954 receives or accesses the projection image representation 953 in order to provide the projector with the image.

In the embodiment illustrated, the projection image representation 953 is an electronic representation of the image stored in a memory location. The stored image can represent a bit mapped image, or other standard or custom protocol used to define the image to be projected by the projector 960. Where the projection image is a digital image (electrically generated), the representation can be stored in memory by data processor 952, thereby allowing the data processor 952 to modify the projection image representation, it is possible to vary the image as necessary in accordance with the present invention.

In another embodiment, the projection image representation 953 need not be present. Instead, the projection controller 954 may select one or more transparencies (not illustrated) associated with the projector 960. Such

transparencies can include any combination of films, plates, or other types of retical devices that project images.

The data processor 952 controls the projection and reception of data through the controller 954 and 955 respectively.

Figure 12 illustrates a method in accordance with the present invention that will be discussed with reference to the system of Figure 10 and the accompanying Figures. In order to better understand the methods discussed herein, terminology and characteristics unique to the present invention are described. The term "projection/view plane" refers to a plane formed by the projection axis and at least one point of the view axis. The term projection/view plane is best understood with reference to Figure 3. Assuming that Figure 3 represents a cross section of the object 100. The projection axis illustrated is directed such that it lies entirely within the plane formed by the sheet of paper including Figure 3. Likewise, the view axis of Figure 3 is also lying entirely within the plane represented by the sheet of paper of Figure 3. In this example, the projection/view plane formed by the projection axis of Figure 3 and at least one point of the view axis of Figure 3 includes the sheet of paper on which the Figure is drawn.

However, if the view axis of Figure 3 was actually oriented such that the endpoint near the viewing device is on the plane of the paper, while the arrow end of the view axis representation is pointing out of the paper towards the reader, it would not be possible to form a plane that includes the entire view axis and projection axis. Therefore, the projection/view plane can be described

to contain substantially all of the projection axis and at least one point of the view axis, or all of the view axis and at least one point of the projection axis. For purposes of discussion herein, it will be assumed that the point of the view axis nearest the view device is the point to be included within that projection/view plane. For example, referring to prior art Figure 4, the projection/view plane described with reference to Figure 3 would be substantially orthogonal to the surface 104, and orthogonal to each of the lines 121-125. The projection/view plane is represented by line 99, which represents the plane from an edge view intersecting the lines 121-125.

At step 611 of Figure 12, an image is projected having an encoding (variable) feature with a component, or components, that varies orthogonal to the projection/view plane. With respect to Figure 13, the projection/view plane is illustrated by the line 936 indicating that the orientation of the view/ projection plane is on edge such the plane appears to be a line, and each of the shapes or patterns 931-935 represent an encoding feature.

Each of the individual features 931-935 has a component(s) that varies in a direction orthogonal to the projection/view plane. For example, feature 933 varies orthogonal to the projection plane such that three individual lines can be identified. By varying the thicknesses of the three individual lines a unique pattern is associated with each of the features 931-935. For example, the bar code feature 933 varies orthogonal between no line, thin line, no line, thick line, no line, thin line, and no line. The individual lines of the feature 933 are projected parallel to the projection/view plane. Projecting lines parallel to the

projection/view plane reduces, or eliminates, the viewed distortion affects of surface topology on the width of the lines. Therefore, because the viewed width of the individual lines making up the feature 933 do not distort substantially, the thickness, or relative thickness, of each individual line of the feature 933 can be readily identified independent of surface topology. As a result, the feature 933 can be identified substantially independent of surface topology.

Figure 13 displays a specific embodiment of an image having five separate lines (measuring features) 431-435. The lines 431-435 illustrated have lengths that run substantially orthogonal to the projection/view plane, and are uniformly spaced from each other in a direction parallel to the projection/view plane. By providing a plurality of lines which are detectable in the direction parallel to the projection/view plane, multiple measuring lines can be viewed and analyzed simultaneously. In one embodiment, the lines 431-435. In addition to the lines 431-435, five unique bar codes 931-935 are also illustrated. Each of the unique bar codes (variable features) 931-935 are associated with, and repeated along a respective measuring feature 431-435. In other implementations, each bar code can be repeated along a measuring feature more than the two times illustrated. Note that the bar codes illustrated are illustrated as repeating sets. In other implementations, the bar codes would not need to be grouped in sets.

In a specific embodiment, the lines 431-435 and bar codes 931-935 are generated using visible light that is low-intensity, such that the pattern is eye-tolerant and skin tolerant. For example, the lines 431-435 can be viewed as

white lines, and the bar codes 931-935 can be viewed as specific colors or combinations of colors. In another embodiment, high-intensity or laser light can also be used depending upon the application.

By associating bar codes to specific lines in the manner illustrated, it is possible to distinguish lines from one another even when they appear to be linearly coincident. For example, the lines 432 and 433 appear to be a continuous line at the edge of object 101. However, the lines 432 and 433 can be distinguished from each other by analyzing the (encoding feature) barcodes associated with each line. In other words, where line 432 and line 433 appear to the viewer to be a common line, it can now be readily determined that they are two different lines because the bar code associated with line 432 on the left would not be the same as the bar code associated with line 433 on the right.

In the specific example illustrated in Figure 13, the analysis of the retrieved images would determine that there is a discontinuity somewhere between the left most bar code 932 and the right most bar code 933 causing the line segments 432 and 433 to appear as a common line. In a specific embodiment, the location of such an edge can be determined with greater precision by providing repeating bar code patterns in relatively close proximity to one another. For example, the edge where surface 102 meets surface 101 can be determined only to an accuracy equal to the spacing between adjacent bar codes. This is because when the analysis encounters what appears to be a single line having two different bar codes it is unknown where between the two bar codes the discontinuity has occurred. Therefore, by repeating the bar code more

frequently along the measuring lines of Figure 13 the location of discontinuities can be more accurately identified.

The encoding features 931-935 of Figure 13 are non-repeating in that no two bar codes are the same. However, an encoding value, or sequence, can be repeated within a projected image as long as ambiguity is avoided. For example, if the image includes 60 lines (measuring features) using a binary encoding, 6 bits of data are needed to identify each line uniquely. However, due to the fact that the range of focus of the scanner is limited by the depth of field, each individual line of the 60 lines can show up as a recognizable image only within a certain range.

Figures 25 and 26 better illustrate how the depth of field affects the repeating of features. Figure 25 illustrates a projector projecting a SHAPE along a path 2540. When the SHAPE is projected onto a surface its image is reflected along a reflection path to a viewing device 2506. For example, reflection path 2544 results when the SHAPE is reflected off a surface at the location 2531, a reflection path 2541 results when the SHAPE is reflected off a surface at the location 2532, a reflection path 2542 results when the SHAPE is reflected off a surface at the location 2533, and a reflection path 2543 results when the SHAPE is reflected off a surface at the location 2534.

Figure 26 represents the SHAPE as the viewer 2506 would view it. Specifically, the image reflected off of the surface 2531, which is the surface closest to the projector, is viewed as the right most image in Figure 26, while the image reflected off of the surface 2534, which is the surface furthest from

the projector, is viewed as the left most image in Figure 26. However, it should be noted, that the left and right most images, which are furthest and closest to the projector 2505 respectively, are out of focus. Because they are out of focus they can not be accurately detected based upon the image received by the viewing device 2506.

Referring back to Figure 25, any surface closer to the projection device 2505 than plane 2525, or further from the projection device 2505 than the plane 2526 is not capable of reflecting a usable SHAPE because it is outside the viewable range 2610, or field of view. Therefore, the SHAPE can be repeated and still be uniquely identified, so long as the repeated SHAPE can not be viewed within the range 2610 of Figure 6.

In a specific embodiment, a projector projects approximately 80 lines. Each of the 80 lines have a color-coded encoding sequence. For example, if three colors are used (red, blue, Green), an encoding feature having three color locations could uniquely identify 27 different lines. This coding sequence of 27 lines can be repeated three times to cover all 80 lines, provided the field of view is such that lines having the same encoding can not be viewed at the same location. In another embodiment, five color locations can be added with or without increasing the number of lines in a sequence to provide recognition capability where a specific color location may be lost.

This means that coding features may be repeated, as long as the fields of view in which each of the repeating features may be viewed do not overlap. Thus, a sequence of 12 unique encoding features, requiring only four bits of

binary data, can be repeated five times to encode all 60 lines, provided there is no chance for features to be viewed at the same location.

By providing a pattern having a large number of measuring features with associated coding features reference independent scanning is achieved. Specifically, neither the object nor the scanner needs to be fixed in space, nor with reference to each other. Instead, on a frame by frame basis, the reference independent scanner retrieves enough measuring information (a 3D cloud), which is accurate due to the encoding feature, to permit registration to its adjacent frame. Registration is the process which determines the overlapping features on adjacent frames to form an integrated map of the object.

Figure 14 illustrates the object of Figure 13 whereby the measuring lines 431-435 have varying thickness. However, the thickness of lines 431-435 is subject to distortion. Thereby making identification of the individual lines 431-435 based upon their thickness alone prone to error. This is better illustrated with reference to Figure 15.

Figure 15 represents the object 700 of Figures 8 and 9 having a pattern in accordance with the present invention projected upon its surface. Figure 15 illustrates the projection of lines 721-723 having varying widths. As previously discussed, the lines 722 and 723, when projected onto the surfaces 711 and 712 respectively, appear to have the same line thickness as line 721. Therefore, merely having measuring lines of varying thickness will not allow an analysis of the images to determine which line is which. However, by further incorporating the encoding features 451-453, such that they have a component that varies

orthogonal to the projection/view plane, identification of the lines 721-723, and the subsequent mapping analysis, is improved over the prior art.

One skilled in the art will recognize that the specific implementations illustrated, whereby an encoding feature is projected to have a portion perpendicular to a projection/view plane, is advantageous over the prior art in that it allows for analysis of the received images to more accurately identify specific lines associated with the pattern. One skilled in the art will further recognize and understand that the specific implementation described herein has been described with reference to lines and bar codes. However, other patterns, shapes and features can also be used.

Referring to Figure 16, a table is illustrated where a specific set of shapes used in a direction orthogonal to the projection/view plane are illustrated. Column 1 of table 16 represents unique feature identifiers. The columns 2-4 of table 16 illustrate specific manners in which each feature identifier can be represented. Column 2 indicates bar codes. Column 3 indicates colors capable of being used either alone or with other encoding features. Note that some types of encoding features, including color features, can be implemented as an integral part of a measuring feature as well as an encoding feature separate from the measuring feature. Likewise, other types of encoding can be based upon the intensity at which a measuring and/or feature and its encoding feature is projected. Column 4 represents patterns that can be utilized either independently from the shape to identify the shape, or in combination as part of a shape. In other words, a line comprising a repeating

pattern sequence of the type illustrated in Column 4 can be provided. In this manner, the change of pattern in a direction orthogonal to the projection/view plane can be relative to the actual shape itself. In addition, one of ordinary skill in the art will recognize that many variations as to variable components would be anticipated by the present invention.

Figure 17 illustrates in tabular form, the use of unique non-repeating identifiers for each line. For example, referring to the first row of Figure 17 the sequence 0-F sequentially is presented. In one implementation, each of the values from 0 through F will represent a unique code associated with a specific line. One skilled in the art will recognize that in order to identify the specific codes, some type of spacer may need to exist between each individual code. For example, a long space, or a unique code can be used.

In a system used to project and analyze four lines, each with one of the sequences illustrated in Figure 17, it would be possible to identify which one of the four lines is being analyzed once a sequence of three codes has been retrieved. Generally, because the codes vary orthogonal to the projection/view plane missing codes may not pose a problem of misidentification.

Figure 18 illustrates four unique repeating code sequences. The letter S in table 18 is utilized to represent a spacer used between repeating sequences. A spacer can be some unique identifier specifying where each of the repeating codes of the encoding sequence begins and/or ends.

Returning to the flow of Figure 12, once the image has been projected having an encoding feature orthogonal the projection/view plane, a

representation of the surface image is received at a viewer. This is analogous to the discussion of Figure 10 whereby the viewer 970 receives the reflected image. Next, at step 613, the location of a point associated with an object is determined based upon the orthogonally varying feature. In a specific embodiment of the present invention, the point is based upon the variable component because each one of the shapes, e.g. lines is qualified to a unique code pattern prior to being used for object analysis.

Figure 19 illustrates sub steps to be associated with step 611 of Figure 12. At step 621, a first image is projected, while at step 622 a second feature is projected. Referring to Figure 14, the first image can be analogous to the combination of the measuring line 431 and its associated encoding features 931. In the similar manner, the second feature could be represented by the combination of the measuring line 432 and its encoding features 932. Note that in addition to being able to analyze line 431 with respect to the features 931, it would also be possible in another embodiment to determine the identity of line 431 based upon the encoding features 932. In other words, a specific line in a group of lines, such as illustrated in Figure 14, can be identified based on more than one of the various encoding features. However, in a specific embodiment, only the adjacent set of encoding features, or adjacent sets of encoding features, would be utilized. In addition, steps 621 and 622 can occur at different times as discussed with reference to Figure 23.

Figure 21 illustrates another method in accordance with the present invention. At step 631, a plurality of first features, and a plurality of second

features are projected. These features may be projected simultaneously, or at separate locations.

At step 632, one of the plurality of first features is determined, or identified, based upon the second features. Referring to Figure 14, the plurality of first features would include the lines measuring 431-435. By utilizing the second features, the bar code 931-935, a specific one of the lines 431-435 can be identified.

At step 633, the location of a point at the surface is determined based upon the specific one of the plurality of parallel first features.

This specific embodiment is an advantage over the prior art, in that a line identified by the analysis of the received shape is not utilized until its identity is verified based upon the encoding information.

Figure 22 illustrates another method in accordance with the present invention. At step 641 parallel first and second discrete shapes are projected. Examples of such discrete shapes would include the lines 431 and 432 of Figure 14. However, one of ordinary skill in the art will recognize that a variety of other parallel shapes could be projected.

At step 642, an encoding feature relative to the first discrete shape is projected. Again, referring to Figure 14, the encoding feature relative to the line 432 could include the encoding feature 932 or even an encoding feature 933.

At step 643, an encoding feature relative to the second discrete shape is projected.

At step 644 the first discrete shape is identified based upon the first encoding feature. This is accomplished in a manner similar to as discussed previously.

At step 645 a location of a specific point of an object is determined based upon the first discrete shape.

Figure 23 illustrates another embodiment of the present invention. Specifically, Figure 23 illustrates a series of images projected at times T1, T2, T3 and T4. At time T1, the image projected includes measuring features 1011 through 1013. During time T1, no encoding feature is projected. During time T2, an image containing encoding features 1021-1023 is projected. The patterns of times T1 and T2 are repeated during times T3 and T4 respectively. The result of alternating the projection of encoding and measuring features is that denser patterns can be used, allowing for more information to be obtained. Note that the image of time T4 shows the encoding features 1021-1023 overlying the measuring features 1011-1013. However, in one embodiment, the measuring features have been included for illustration purposes only, and would not generally be present at the same time as the encoding features.

In yet another embodiment of the present invention, Figure 24 illustrates an image having features with different characteristics. Specifically, Figure 24 illustrates an image 1100 having lines 1131 through 1134 with a distance X

between the individual lines, while the distance between lines 1134, 1135, and 1136 have a substantially greater distance Y separating the lines. By allowing for features having different isolation characteristics, it is possible to provide for a high-resolution feature. In other words, the line 1135 can be used to map surface features that otherwise may not be mappable. Note that the pattern 1100 could be used with or without the coding techniques described herein.

Once a scanner receives, or views, a projected frame pattern, the frame pattern is digitized into a plurality of 2D points (2D image frame). Because the projection and view axis of the scanner are fixed and known, each 2D point of the 2D image frame can be converted into a 3D point using conventional 3D imaging techniques, provided each 2D point of the 2D image frame can be correlated to a projected point. The use of a projected frame pattern that has encoding features enables correlation of the points of the 2D image to a respective projected point.

Multi-frame reference independent scanning is described herein in accordance with another aspect of the present disclosure. In a specific embodiment, multiple 3D image frames are received by using a hand-held scanner to scan an object one frame at a time to obtain a plurality of frames, where each frame captures only a portion of the object. With reference to multiple frames, reference independent scanning has a spatial position that is frame-by-frame variable relative to the object being scanned, and whose spatial position is not fixed, or tracked, relative to a reference point. For example, there is no fixed reference point relative to the object being scanned.

One type of reference independent scanner disclosed herein includes a hand-held scanner that projects a pattern in successive frames having measuring features and encoding features. This allows each viewed point of a frame to have a known corresponding projected point, thereby enabling the 2D frame data to be converted into 3D frame data.

Figures 27-28 are used to discuss multiple frame reference independent scanning.

Figures 27, 28, and 30 illustrate an object 2700 from different points of view. As illustrated in Figure 27, the object 2700 includes three teeth 2710, 2720, and 2730, and a gum portion 2740 that is adjacent to the three teeth.

The Figure 27 point-of-view is such that a plurality of non continuous surface portions are viewed. For example, from the Figure 27 point-of-view three noncontiguous surface portions 2711-2713 are viewed. The surface portion 2713 represents a side portion of the tooth 2710. The surface portion 2711 represents a portion of the tooth 2710 biting surface that is not continuous with surface portion 2713. The surface portion 2712 represents another portion of the tooth 2710 biting surface that is not continuous with either portion 2711 or 2713. In a similar manner, tooth 2720 has four surface portions 2721-2724, and tooth 2730 has four surface portions 2731-2734.

Figure 28 illustrates the object 2700 from a slightly different point-of-view (Figure 28 point-of-view). The point-of-view change from Figure 27 to Figure 28 is the result of the viewer, i.e. scanner, moving in a direction that

allows a greater portion of the upper teeth surfaces to be viewed. The change in point-of-view has resulted in variations to a plurality of viewed surface portions. With respect tooth 2710, tooth portion 2813 now represents a smaller 2D surface than did its corresponding tooth portion 2713; while tooth portions 2811 and 2812 now are viewed as larger 2D surfaces than their corresponding portions 2711 and 2712 of Figure 27.

With respect to tooth 2720, surface 2824 now is viewed as a smaller 2D surface than its corresponding tooth surface 2724 of Figure 27. With respect to tooth 2720; tooth surface 2821 represents a continuously viewed tooth surface that includes both of the surfaces 2721 and 2723 from the Figure 27 point-of-view.

With respect to tooth 2730, the viewed 2D surfaces 2832 and 2835 each include portions of surface 2732 and previously unviewed surface area. This is the result of a topographical feature of the tooth 2730, which resulted in the inability of the surface 2732 to be viewed continuously from the second frame point-of-view.

The relationship of the tooth portions of Figure 27 to the tooth portions of Figure 28 are better understood with reference to Figure 29. Specifically, Figure 29 is from the same point-of-view as Figure 28 with the viewed surface portions of Figure 27 indicated as shaded areas. For example, surface portion 2711 of Figure 27 is represented as a shaded portion within the surface portion 2811. As illustrated, the change in the point-of-view between Figure 27 and Figure 28 results in a viewed surface portion 2811 that encompasses the smaller

viewed surface portion 2711. Likewise, the change in perspective has resulted in different surface portions being viewed.

Figure 30 illustrates the object 2700 from another point-of-view. Specifically, the Figure 30 point-of-view is from directly over the teeth 2710-2730. Superimposed onto Figure 30 are the viewed surface portions of Figure 28. The object 2700 illustrated in Figure 27 will be referenced further herein to describe a specific embodiment of multiframe reference independent scanning.

Figure 31 illustrates a method 3100 in accordance with a specific embodiment of reference independent scanning. At step 3101 the object is scanned to obtain a 2D cloud of data. The 2D cloud of data includes a plurality of frames. Each of the frames has a plurality of 2D points, which, if viewed, would represent a 2D image.

At step 3102, a first frame of the 2D cloud of data is converted to 3D frame model. In one embodiment, a 3D frame model is a 3D point model, which includes a plurality of points in three-dimensional space. The actual conversion to a 3D frame point model is performed on some or all of the frame's 2D cloud of data using conventional techniques for converting a scanned 2D cloud of data into a 3D point model. In a specific embodiment using encoding features, as disclosed herein, surfaces with non continuous viewed surfaces, such as the teeth 2710-2730 of Figure 27, can be successfully scanned frame-by-frame.

Figures 32 and 33 further illustrate the object 2700 being scanned from the Figure 27 and Figure 28 points-of-view respectively. In Figure 32, the scan pattern includes scan lines 3221-3223. Any scan line portion outside the frame boundary 3210 is not capable of being properly scanned. Within the boundary 3210 each scan line, when sensed at the CCD (charge coupled diode) chip of the scanner, is converted to plurality of 2D points (cloud of data). Some or all points of a scan line can be used in accordance with the present invention. For example, every other, or every third point of a scan line can be used depending upon the desired resolution of a final 3D model. Figure 32 illustrates four points (A-D) of each line being identified. A 2D coordinate value, such as an X-Y coordinate, is determined for each of these points.

In a specific embodiment of scanning, a scan rate of 1 to 20 frames per second is used. Greater scan rates can be used. In a specific embodiment, the scan rate is chosen to allow for real-time viewing of a three-dimensional image. The pulse time during which each frame is captured is a function of the speed at which the scanner is expected to be moving. For dentition structures, a maximum pulse width has been determined to be approximately 140 micro-second, although much faster pulse widths, i.e. 3 micro-seconds, are likely to be used. In addition, in a specific embodiment the teeth 2710-2730 are coated with a substance that results in a surface that is more opaque than the teeth themselves.

In a specific embodiment, each point of the cloud of data is analyzed during the various steps and functions described herein. In another

embodiment, only a portion of the cloud of data may be analyzed. For example, it may be determined only every 3rd or 4th point needs to be analyzed for a desired resolution to be met. In another embodiment, a portion of the frame data can be a bounding box that is smaller than the entire frame of data such that only a specific spatial portion of the cloud of data is used for example, only a center portion of the cloud of data is included within the bounding box. By using a subset of the cloud of data, it is possible to increase the speed of various routines described herein.

Figure 33 illustrates the object 2700 being scanned from the Figure 28 point of view. As such, the viewed pattern including lines 3321-3323 are positioned differently on the teeth 2710-2730. In addition, the frame boundary 3310 has moved to include most of the tooth 2720.

Figure 34 illustrates another embodiment of a 3D frame model referred to herein as a 3D primitive model. A 3D primitive model includes a plurality of primitive shapes based upon the frame's 3D points. In the specific embodiment illustrated adjacent points from the 3D point model are selected to form triangles, including triangle PS1-PS3 as primitive shapes. Other implementations can use different or varied primitive shapes.

The use of primitive shapes to perform registration is advantageous over registration techniques that attempt to get the points of two point clouds as close as possible to each other, because using a primitive surface representation of one of the point clouds allows a lower resolution model to be used, resulting in a faster registration, without the disadvantage of undesirable offset error. For

example, if a scan resolution of 1mm is used for point-to-point registration, the best guaranteed alignment between two frames is 0.5 mm. This is due to the fact that the hand held scanner randomly captures which points of the surface are mapped. . Using point-to-surface registration provides a more accurate result since the registration can occur to any point of the surface, not just the vertices.

At step 3103 of Figure 31, a second 3D frame model is generated from the second frame of the cloud data. Depending upon the specific implementation, the second 3D frame model may be a point model or a primitive model.

At step 3104 a registration is performed between the first frame model and the second frame model to generate a cumulative model. "Registration" refers to the process of aligning the first model to the second model to determine a best fit by using those portions of the second model which overlap the first model. Those portions of the second model that do not overlap the first model are portions of the scanned object not yet mapped, and are added to the first model to create a cumulative model. Registration is better understood with reference to the method of Figure 35.

Figure 35 includes a registration method 3500 that, in a specific embodiment, would be called by one of the registration steps of Figure 31. At step 3501 of Figure 35 an entry point into registration is determined. The entry point into registration defines an initial guess of the alignment of the overlapping portions of the two models. The specific embodiment of choosing an entry point will be discussed in greater detail with reference to Figure 36.

At step 3502, a registration of the two shapes is attempted. If an overlap is detected meeting a defined closeness of fit, or quality, the registration is successful. When the registration is successful the flow returns to the calling step of Figure 31. When a registration is not successful the flow proceeds to the step 3598 were a decision whether to continue is made.

A decision to continue can be made based on a number of factors. In one embodiment, the decision to continue is made based upon the number of registration entry points that have been tried. If the decision at step 3598 is quit registration attempts, the flow proceeds to step 3503 where registration error handling occurs. Otherwise the flow continues at step 3501.

Figure 36 illustrates a specific method for choosing a registration entry point. At step 3699 a determination is made whether this is the first entry point for a specific registration attempt of a new frame. If so the flow proceeds to step 3601, otherwise the flow proceeds to step 3698.

At step 3601 the X and Y components of the entry point are determined based upon two-dimensional analysis of the 2D cloud of data for each of the two frames. In a specific embodiment, the two-dimensional analysis performs a cross-correlation of the 2D images. These 2D images do not have to be from the 2D cloud of data, instead, data associated with a plain video image of the object, with no pattern, can be used for cross correlation. In this way, a probable movement of the scanner can be determined. For example, the cross-correlation is used to determine how the pixels have moved to determine how the scanner has probably been moved.

In another embodiment, a rotational analysis is possible, however, for a specific embodiment this is not done because it tends to be time consuming, and having the correct entry point in the X and Y-coordinate direction allows the registration algorithm described herein to handle rotations.

At step 3602, a probable movement in the Z direction is determined.

In one specific embodiment, the previous frame's Z-coordinate is used, and any change in the Z-direction is calculated as part of the registration. In another embodiment, a probable Z coordinate is calculated as part of the entry point. For example, the optical parameters of the system can "zoom" the second frame in relationship to the first one until the best fit is received. The zoom factor that is used for that could tell us how far the two surfaces are away from each other in Z. In a specific embodiment, the X, Y and Z coordinates can be aligned so that the Z-coordinate is roughly parallel to the view axis.

At step 3606, the entry point value is returned.

At step 3698 a determination is made whether all entry point variations have been tried for the registration steps 3601 and 3602. If not the flow proceeds to step 3603, otherwise the flow proceeds to step 3697.

At step 3603 the next entry point variation is selected. Figure 37 illustrates a specific method for selecting the registration entry point variations. Specifically, Figure 37 illustrates the initial entry point E1 and subsequent entry points E2-E9. The entry points E2-E9 are selected sequentially in any predetermined order. The specific embodiment of Figure 37 illustrates the

registration entry points E2-E9 as various points of a circle 3720 having a radius 3710. In accordance with a specific embodiment, the dimensions of the entry point variations are two-dimensional, for example the X and Y dimension. In other embodiments, the entry points can vary in three dimensions. Note that varying number of entry points, i.e. subsets of entry points, can be used to speed up the registration process. For example, single frame registration as used herein could use fewer than the nine entry points indicated. Likewise, cumulative registration, described herein, could benefit by using more than the nine points illustrated.

Returning to step 3698 of Figure 36, the flow proceeds to step 3697 once all variations of the first identified entry point have been tried. At step 3697, all entry points associated with the first identified entry point have been tried, and it is determined whether a second identified entry point has been identified by step 3604. If not, flow proceeds to step 3604 where the second entry point is defined. Specifically, at step 3604 the scanner movement between two previous frame models is determined. Next, an assumption is made that the scanner movement is constant for at least one additional frame. Using these assumptions, the entry point at step 3604 is defined to be the location of the previous frame plus the calculated scanner movement. The flow proceeds to step 3606, which returns the entry point to the calling step of Figure 31. In another embodiment, an assumption can be made that the direction of the scanner movement remained the same but that it accelerated at a difference rate.

If the second identified entry point of step 3604 has been previously determined, the flow from step 3697 will proceed to step 3696. At step 3696, a determination is made whether an additional registration entry point variation for the second identified entry point exists. If so, the flow proceeds to step 3605, otherwise the flow returns to the calling step of Figure 31 at step 3607 and indicates that selection of a new entry point was unsuccessful. At step 3605 the next entry point variation of the second identified entry point is identified and the flow returns to the calling step of Figure 31.

Different entry point routines can be used depending upon the type of registration being performed. For example, for a registration process that is not tolerant of breaks in frame data, it will be necessary to try more entry points before discarding a specific frame. For a registration process that is tolerant of breaks in frame data, simpler or fewer entry points can be attempted, thereby speeding up the registration process.

Returning to Figure 31, at step 3105 the next 3D model portion is generated from the next frame's of cloud data.

At step 3106, registration is performed between the next 3D model portion and the cumulative model to update the cumulative model. In a specific implementation, the cumulative model is updated by adding all the new points from frame to the existing cumulative model to arrive at a new cumulative model. In other implementations, a new surface can be stored that is based on the 3D points acquired so far, thereby reducing the amount of data stored.

If all frames have been registered, the method 3100 is completed, otherwise the flow proceeds to steps 3105 through step 3199, until each frame's cloud of points has been registered. As result of the registration process described in method 3100, it is possible to develop a model for the object 2700 from a plurality of smaller frames, such as frames 3210 and 3310. By being able to register plurality of frames, highly accurate models of large objects can be obtained. For example, a model of a patients entire dentition structure, including gums, teeth, and orthodontic and prosthetic structures can be obtained. In another embodiment, a model of the patients face can be obtained.

Figure 38 illustrates a method 3800, which is an alternate method of registering an object using a plurality of frames from a reference independent scanner. Specifically, at step 3801 the object is scanned to receive a cloud data for the object. As previously described, the cloud of data includes data from a plurality of frames, with each frame including a plurality of points.

At step 3802 a single frame registration is performed. A single frame registration performs a registration between adjacent frames of the scanned image without generating a cumulative model. Instead, in a specific implementation, a cumulative image of the single frame registration process is displayed. The image formed by the single frame registration process can be used to assist in the scanning process. For example, the image displayed as a result of the single frame registration, while not as accurate as a cumulative model, can be used by the scanner's operator to determine areas where additional scanning is needed.

The single frame registration process is such that any error introduced between any two frames is "extended" to all subsequent frames of a 3D model generated using single frame registration. However, the level of accuracy is adequate to assist an operator during the scanning process. For example, the registration results, which describes the movement from one frame to another, can be used as an entry point for the cumulative registration process. Single frame registration is discussed in greater detail with reference to Figure 39.

At step 3803, a cumulative registration is performed. The cumulative registration creates a cumulative 3D model by registering each new frame into the cumulative model. For example, if 1000 individual frames were captured at step 3801 representing 1000 reference independent 3D model portions (frames), the cumulative registration step 3803 would combine the 1000 reference independent 3D model portions into a single cumulative 3D model representing the object. For example, where each of the 1000 reference independent 3D model portions represent a portion of one or more teeth, including frames 3210 and 3310 of Figures 32 and 33, the single cumulative 3D model will represent an entire set of teeth including teeth 2710-2730.

At step 3804, the results of the registration are reported. This will be discussed in further detail below.

Figure 39 describes a method 3900 that is specific to a single frame rendering implementation for step 3802 of Figure 38. At step 3903 a variable x is set equal to 2.

At step 3904 a registration between the current frame (3DFx) and the immediately, or first, previous adjacent frame (3DFx-1) is performed. Registration between two frames is referred to as single frame registration. A specific embodiment of registration between two models is discussed in greater detail with reference to the method illustrated in Figure 40.

At step 3999 it is determined whether or not the single frame registration of step 3904 was successful. In a specific implementation, a registration method, such as the method of Figure 40, provides a success indicator which is evaluated at step 3999. The flow proceeds to step 3905 when registration is successful, otherwise the flow proceeds to step 3907.

The flow proceeds to step 3905 when it is determined at step 3999 that the registration was successful. At step 3905 the current 3D frame (3DFx) is added to the current frame set of 3D frames. Note, that this set will generally be a set of transformation matrices. The current frame set of 3D frames is a sequential set of frames, where each frame in the sequence has a high degree of likelihood being successfully registered with [both] of its two adjacent frames. In addition, the newly registered frame can be displayed relative to the previous frame that is already being displayed.

At step 3998 a determination is made whether the variable x has a value equal to n, where n is the total number of frames to be evaluated. If x is equal to n, single frame registration is complete and the flow can return to Figure 38 at step 3910. If x is less than n, single frame registration continues at step 3906, where x is incremented before proceeding to step 3904.

Returning to step 3999, the flow proceeds to step 3907 if the registration of step 3904 was not successful. At step 3907 a registration is attempted between current frame (3DFx) and the second previously adjacent frame (3DFx-2). Step 3997 directs the flow to step 3905 if the registration of step 3907 was successful. Otherwise, step 3997 directs the flow to step 3908, thereby indicating an unsuccessful registration of the current frame (3DFx).

When the current frame cannot be registered, step 3908 saves the current frame set, i.e. set of matrices, and a new current frame set is begun. Flow from step 3908 proceeds to step 3905 where the current frame is added to the current frame set, which was newly created at step 3908. Therefore, it is possible for the single frame registration step 3802 to identify multiple frames sets.

Generation of multiple frame sets during cumulative registration is not desirable due to the amount of intervention required to reconcile multiple cumulative models. However, breaks in single frame registration are generally acceptable because the purpose of single frame registration is to assist the operator and define entry points to cumulative registration. One method of dealing with breaks during single frame registration is to merely display the first frame after the break at the same location as the last frame before the break, thereby allowing the operator to continue to view an image.

In accordance with step 4001 of Figure 40, a first model is a 3D primitive shape model, while the second model is a 3D point model. For reference purposes the primitive shapes in the first 3D model are referenced as S1..Sn, where n is the total number shapes in the first model; and, the points in

the second 3D model are references as P1..Pz, where z is the total number of points in the second model.

At step 4002, each individual point of the second model P1..Pz is analyzed to determine a shape closest to its location. In a specific embodiment, for a point P1, the shape S1-Sn that is the closest to P1 is the shape having the surface location that is the closest to P1 than any other surface location of any other shapes. The shape closest to point P1 is referred to as Sc1, while the shape closest to point Pz is referred to as Scz.

In another embodiment, only points that are located directly above or below a triangle are associated to a triangle, and points that are not located directly above or below a triangle surface are associated to a line formed between two triangles, or a point formed by multiple triangles. Note that in the broad sense that the lines that form the triangles and the points forming the corner points of the triangles can be regarded as shapes.

At step 4003, vectors D1..Dz are calculated for each of the points P1..Pz. In a specific implementation, each vector, for example D1, has a magnitude and direction defined by the minimum distance from its corresponding point, for example P1, to the closest point of its closest shape, for example Sc1. Generally, only a portion of the points P1..Pz overlap the cumulative image. The non-overlapping points, which are not needed for registration, have an associated vector having a comparatively large magnitude than an overlapping point, or may not reside directly above or below a specific triangle. Therefore, in a specific embodiment, only those vectors having a

magnitude less than a predefined value (an epsilon value) are used for further registration.

In addition to eliminating points that are not likely to be overlapping points, the use of epsilon values can also be used to further reduce risks of decoding errors. For example, if one of the measuring lines of the pattern is misinterpreted to be a different line, the misinterpretation can result in a large error in the Z-direction. For a typical distance between adjacent pattern lines of approximately 0.3 mm and an angle of triangulation of approximately 13°; an error in the X-direction of 0.3 mm results in a three-dimensional transformation error of approximately 1.3 mm (0.3 mm / tan 13°) in the Z-direction. If the epsilon distance is kept below 0.5mm we can be sure that there is no influence of surface areas further away from each other than 0.5mm. Note that in a specific embodiment, the epsilon value is first selected to be a value greater than 0.5mm, such as 2.0mm, and after reaching a certain quality the value is reduced.

At step 4004, in a specific embodiment, the vectors D1..Dz are treated as spring forces to determine movement of the second 3D model frame. In a specific embodiment, the second 3D model is moved in a linear direction defined by the sum of all force vectors D1..Dz divided by the number of vectors.

At step 4005, the vectors D1..Dz are recalculated for each point of the second 3D model.

At step 4006, the vectors D1..Dz are treated as spring forces to determine movement of the second 3D model. For a specific embodiment of

step 4004, the second 3D model frame is rotated about its center of mass based upon the vectors D1..Dz. For example, the second 3D model is rotated about its center of mass until the spring forces are minimized.

At step 4007, the quality of the registration is determined with respect to the current orientation of the second 3D model. One of ordinary skill in the art will recognize that various methods can be used to define the quality of the registration. For example, a standard deviation of the vectors D1..Dz having a magnitude less than epsilon can be used. In another embodiment quality is calculated using the following steps: square the distance of the vectors, sum the squared distances of all vectors within the epsilon distance, divide this sum by the number of vectors, and take the square root. Note, one of ordinary skill in the art will recognize that the vector values D1..Dz need to be recalculated after the rotation step 4006. In addition, one of ordinary skill in the art will recognize that there are other statistical calculations that can be used to provide quantitative values indicative of quality.

At step 4099, a determination is made whether the quality determined at step 4007 meets a desired quality level. If the quality is within a desired level, it indicates with a certain degree of confidence that a complete registration between the two frames models is achievable. By terminating the flow of method 4000 when a desired degree of quality is obtained, it is possible to quickly sort through all pairs of frames to provide an image to the user. By eliminating potential breaks in data at this point of the method, subsequent cumulative registration has a greater likelihood of producing a single

cumulative model, as opposed to multiple segments of the cumulative model. If the current quality level meets the desired level the flow returns to the appropriate calling step with a successful indicator. If the current quality level does not meet desired level, the flow proceeds to step 4098.

It is determined at step 4098 whether the current quality of registration is improving. In a specific embodiment, this is determined by comparing the quality of the previous pass through the loop including step 4003 with the current quality. If the quality is not improving the flow returns to the calling step with an indication that the registration was not successful. Otherwise, the flow proceeds to step 4003.

Upon returning to step 4003, another registration iteration occurs, using the new frame location. Note that once the frame data has been scanned and stored there is no need to do the registration exactly in the order of scanning. Registration could start other way round, or use any other order that could make sense. Especially when scanning results in multiple passes there is already a knowledge of where a frame roughly belongs. Therefore, the registration of adjacent frames can be done independently of the order of imaging.

Figure 41 illustrates a specific embodiment of a method 4100 for Figure 38. Specifically, the method 4100 discloses a cumulative registration which attempts to combine all of the individual 3D frame models into a single cumulative 3D model.

Steps 4101-4103 are setup steps. At step 4101 a variable x is to set equal to 1, and a variable x_last defines the total number of 3D model sets. Note, the number of 3D model sets is based upon the step 3908 of Figure 39.

At step 4102 a 3D cumulative model (3Dc) is initially defined to equal the first 3D frame of the current set of frames. The 3D cumulative model is modified to include that information from subsequent frame models that is not already represented by the 3D cumulative model.

At step 4103, Y is set equal to 2, and a variable Y_last is defined to indicate the total number of frames (3DF), or frame models, in the set Sx, where Sx represents the current set of frame models being registered.

At step 4104, the 3D cumulative model (3Dc) is modified to include additional information based upon the registration between the current 3D frame model being registered (Sx(3DFy)) and the 3D cumulative model (3DC). Note, in Figure 41 the current 3D frame model is reference as Sx(3Dy), where 3Dy indicates the frame model and Sx indicates the frame set. A specific embodiment for performing the registration of step 4104 is further described by the method illustrated in Figures 42-43.

At step 4199 it is determined whether the current 3D frame model is the last 3D frame model of the current step. In accordance with a specific implementation of Figure 41, this can be accomplished by determining if the variable Y is equal to the value Y_last. When Y is equal to Y_last the flow proceeds to step 4198. Otherwise, the flow proceeds to step 4106, where Y is

incremented, prior to returning to step 4104 for further registration of 3D frame models associated with current set Sy.

At step 4198 it is determined whether the current set of frames is the last set of frames. In accordance with the specific implementation of Figure 41, this can be accomplished by determining if the variable x is equal to the value x_last. The flow proceeds to step 4105 when x is equal to a x_last. Otherwise, the flow proceeds to step 4107, where x is incremented, prior to returning to step 4103 for further registration using the next set.

All frames of all sets have been registered when the flow reaches step 4105. Step 4105 reports results of the registration of the method 4100, as well as any other cleanup operations. For example, while ideally the method 4100 results in a single 3D cumulative model in reality multiple 3D cumulative models can be generated (see discussion at step 4207 of Figure 43). When this occurs step 4105 can report the resulting number of 3D cumulative models to the user, or to a subsequent routine for handling. As a part of step 4105, the user can have an option to assist in registering the multiple 3D models to each other. For example, if two 3D cumulative models are generated, the user can manipulate the 3D cumulative models graphically to assist identification of entry point, which can be used for performing a registration between the two 3D cumulative models.

In accordance with another embodiment of the present invention, a second cumulative registration process can be performed using the resulting matrices from the first cumulative registration as entry points for the new

calculations. In one embodiment, when the process encounters a point where frame(s) could not be successfully registered in the first attempt, an enlarged number of entry points can be used, or a higher percentage of points can be used.

Figures 42-42 illustrate a specific embodiment of registration associated with step 4104 of Figure 41.

Step 4201 is similar to step 4002 of Figure 40, where each point (P1..Pm) of the current frame Sx(3Dy) is analyzed to determine the shape of the cumulative model that is the closest shape.

Step 4202 defines vectors for each point of the current frame in a manner similar to that previously described with reference to step 4003 of Figure 40.

Steps 4203 through 4206 move the current 3D frame model in the manner described at steps 4004-4006 of Figure 40, where the first model of method 4000 is the cumulative model and a second model of method 4000 is the current frame.

At step 4299 a determination is made whether the current pass through registration steps 4202-4206 has resulted in an improved alignment between the cumulative model and the current frame model. One method of determining quality improvement is to compare a quality value based on the current position of the model register to the quality value based on the previous position of the model. As previously discussed with reference to Figure 40, the quality value

can be determined using the standard deviation, or other quality calculation based on the D vectors. Note, by default, a first pass through steps 4202-4206 for each model 3Dy results in an improved alignment. If an improved alignment has occurred, the flow returns to step 4202, otherwise, the flow proceeds to step 4298 of Figure 43.

Note that the flow control for the cumulative registration method of Figure 42 is different than the flow control for the single frame registration method of Figure 40. Specifically, the cumulative flow continues until no improvement in quality is realized, while the single frame flow stops once a specified quality is reached. Other embodiments of controlling the flow within the registration routines are anticipated.

In an alternate flow control embodiment, the registration iteration process continues as long as a convergence criteria is met. For example, the convergence criteria is considered met as long as an improvement in quality of greater than a fixed percentage is realized. Such a percentage can be in the range of 0.5-10%.

In another embodiment, even once a specific first criteria is met, such as convergence or no improvement in quality, additional stationary iterations can be used. A stationary iteration is a pass through the registration routine, once the quality level has stopped improving, or has met a predefined criteria. In a specific implementation, a number of stationary iterations can be fixed. For example, 3 to 10 additional iterations can be specified.

At step 4298 it is determined whether or not the current registration is successful. In a specific implementation success is based solely upon whether the calculated quality value of the current model placement meets a predefined criteria. If so, the registration has been successful and the routine 4200 returns to the calling step. If the criteria is not met, the flow proceeds to step 4207.

At step 4207, it has been determined that current frame model cannot be successfully registered into the cumulative 3D model. Therefore, the current cumulative 3D model is saved, and a new cumulative 3D model is started having the current frame. As previously described, because a new 3D cumulative model has been started, the current 3D frame model, which is a point model, is converted to a primitive model before returning to call step.

Many other embodiments of the present invention exist. For example, the movement of the frame during steps 4004, 4006, 4203, and 4205 may include an acceleration, or over movement, component. For example, an analysis may indicate that a movement in a specific direction needs to be 1mm. However, to compensate for the size of the sample being calculated or other factors, the frame can be moved by 1.5mm, or some other scaled factor. Subsequent movements of the frame can use a similar or different acceleration factor. For example, a smaller acceleration value can be used as registration progresses. The use of an acceleration factor helps compensate for local minima which result when no overlapping features happen to align. When this happens, a small movement value can result in a lower quality level. However,

by using acceleration it is more likely that the misalignment can be overcome. Generally, acceleration can be beneficial to overcome "bumpiness" in a feature.

It should be understood that the specific steps indicated in the methods herein, and/or the functions of specific modules herein, may generally be implemented in hardware and/or software. For example, a specific step or function may be performed using software and/or firmware executed on one or more a processing modules.

Typically, systems for scanning and/or registering of scanned data will include generic or specific processing modules and memory. The processing modules can be based on a single processing device or a plurality of processing devices. Such a processing device may be a microprocessor, microcontroller, digital processor, microcomputer, a portion of a central processing unit, a state machine, logic circuitry, and/or any device that manipulates the signal.

The manipulation of these signals is generally based upon operational instructions represented in a memory. The memory may be a single memory device or a plurality of memory devices. Such a memory device (machine readable media) may be a read only memory, a random access memory, a floppy disk memory, magnetic tape memory, erasable memory, a portion of a system memory, any other device that stores operational instructions in a digital format. Note that when the processing module implements one or more of its functions, it may do so where the memory storing the corresponding operational instructions is embedded within the circuitry comprising a state machine and/or other logic circuitry.

The present invention has been described with reference to specific embodiments. In other embodiments, more than two registration processes can be used. For example, if the cumulative registration process has breaks resulting in multiple cumulative models, a subsequent registration routine can be used to attempt registration between the multiple cumulative models.

Figures 44-52 illustrate a specific method and apparatus using three-dimensional scan data of an anatomical structure, which may be obtained in the specific manner described herein. The three-dimensional scan data is transmitted to a remote facility for further use. For example, the three-dimensional scan data can represent the anatomy of an anatomical structure which is used to design an anatomical device, manufacture an anatomical device, monitor structural changes of the anatomy, archive data pertaining to the anatomical structure, perform a closed-loop iterative analysis of the anatomical structure, perform an interactive consultation of the structure, perform simulations based upon the structure, make a diagnosis related to the anatomical structure, or determine a treatment plan based on the anatomical structure.

As used herein, an anatomical device is defined to include devices that actively or passively supplement or modify an anatomical structure. Examples of anatomical devices include orthotic and prosthetic devices, and anatomical appliances. Anatomical appliances include orthodontic appliances which may be active or passive, and can include, but is not limited to, such items as braces, retainers, brackets, wires and positioners. Examples of other anatomical appliances include splints, and stents. Examples of orthotic and prosthetic

anatomical devices include removable prosthetic devices, fixed prosthetic devices, and implantable devices. Removable prosthetic devices include dental structures such as dentures, partial dentures, and prosthetic structures for other body parts, such as prosthetic devices that serve as artificial body parts including limbs, eyes, implants, included cosmetic implants, hearing aids, and the like, such as spectacle frames. Fixed prosthetic anatomical devices include caps, crowns and other non-dental anatomical replacement structures. Implantable prosthetic devices include endosseous implants and orthodontic implants and fixture devices such as plates used for holding and reducing fractures.

Figure 44 illustrates a flow in accordance with the present invention. Specifically, Figure 44 illustrates the scanning of an anatomical structure 4400 by a scanning device 4401 at a facility 4441. In accordance with one aspect of the present invention, any scanner type or method capable of generating digital data for the purposes put forth herein can be used. Direct three-dimensions surface scanning indicates that some or all of the anatomical structure can be scanned directly. One embodiment of performing a direct three-dimensional surface scan is describe previously herein. In one embodiment, the scan is a surface scan, whereby the scanning device 4401 detects signals and/or patterns reflected from at or near the surface of the structure 4400. A specific surface scanning method and device has been described previously herein. Other scanning methods can be used as well.

Generally, the surface scan of the anatomical structure will be a direct scan of the anatomical structure. A direct scan refers to a scan of the actual anatomical structure (in-vivo). In an alternate embodiment, an indirect scan of the anatomical structure can also be made and integrated with the direct scan. An indirect scan refers to scanning a representation of the actual original anatomical structure (in-vitro).

Digital data 4405 is generated at the facility (location) 4441 based on the direct scan of anatomical structure 4400. In one embodiment, the digital data 4405 represents raw scan data, which is generally a two-dimensional cloud of points, generated by the scanning device 4401. In another embodiment, the digital data 4405 represents a three-dimensional point model, which is generally generated based upon a two-dimensional cloud of points. In yet another embodiment, the digital data 4405 represents a three-dimensional primitive model. Note that the digital data 4405 can be a composite of multiple independent scans, which may be performed at approximately the same or different points in times, as well as at the same or different locations.

The actual data type of digital data 4405 is determined by the amount of processing done to the raw scan data at the location 4441. Generally, the data received directly from the scanner 4401 is a two-dimensional cloud of points. Therefore, when no processing is performed at the facility 4441, the digital data 4405 is a two-dimensional cloud of points. Three-dimensional point models and three-dimensional primitive models are typically generated by further processing of the two-dimensional point cloud.

Facility 4441 represents a location where the physical scanning of the anatomical structure occurs. In one embodiment, facility 4441 is a location that is dedicated to, or primarily dedicated to, scanning anatomical structures. In this embodiment, the facility would be located where it is easily accessible by large numbers of clients (patients) needing scans. For example, a kiosk in a mall, or a location in a strip mall, can be dedicated to performing scans. Such a facility may perform a broad variety of scans, or may specialize in specific types of scans, such as scans of facial structures or dental structures. In an alternate embodiment, scans can be performed at home by a user. For example, a user can be provided with a portable scanner for remote use to scan the anatomical structure to generate scan data that can be used to monitor the progress of a treatment plan, for diagnostic purposes, or for surveillance or monitoring purposes.

In another embodiment the facility 4441 is a location that scans anatomical structures and performs other value-added services related to generating the digital data 4405. Examples of other value-added services include designing, or partially designing anatomical devices based upon the scan data to generate the digital data 4405, or installation of such anatomical devices. In one implementation, no value added services beyond the generation of the digital data 4405 are performed at the facility 4441.

Once the digital data 4405 is generated at the facility 4441, the digital data can be provided to the client. The connection 4406 represents the digital data being provided to a third party. This step of providing can be done by the

client, the facility 4441, or any other intermediate source. Generally, the client will specify the third party where the data is to be sent. The digital data 4405 can be provided to the facility 4442 either physically, i.e. by mail or courier, or remotely, i.e. by transmission. For example, the digital data 4405 can be physically provided on a non-volatile storage device, such as a portable magnetic media, a read-only fuse device, or a programmable non-violate device. In other embodiments, the digital data can be transmitted to the client or a third party by a direct connection, the internet, a local area network, a wide area network, a wireless connection, and/or any device that enables the transfer of digital information from one computing system to another. In specific embodiments, either all or some of the digital data need be transmitted. For example, where the scan is of a patient's teeth and associated structures, such as the gums, a portion of the teeth may be transmitted.

In the specific embodiment of Figure 44, the digital data 4405 received at the facility 4442 (receiving facility) is used to design an anatomical device at step 4415. Figure 45 illustrates a method having two alternate embodiments of step 4415. A first embodiment, which begins at step 4501 designs an anatomical structure using a physical model, while a second embodiment, which begins at step 4511, designs the structure using a virtual model of the anatomical device. A virtual model of the anatomical device will generally be a computer generated virtual model.

At step 4501, generation of a physical three-dimensional physical model of the anatomical structure occurs using the digital data 4405. In a specific

embodiment, the physical model of the scanned object is generated using numerically controlled processing techniques, such as three-dimensional printing, automated milling, laser sintering, stereo lithography, injection molding, and extrusion.

At step 4502, the three-dimensional physical model is used to design the anatomical device. For example, by using the physical model, practitioners will generate anatomical devices for use by the client. In one embodiment, anatomical devices are custom designed based upon the physical model. In another embodiment, standard orthodontic devices are selected based upon the physical model of the anatomical structure. These standard devices may be modified as required to form semi-custom devices.

At step 4503 of Figure 45, the manufacture of the anatomical device can be based upon the physical model. Where physical models are used, the step 4502 of designing and the step 4503 of manufacturing are often steps, whereby the design and manufacturing process are occurring simultaneously. In other embodiments, moldings or specifications of the desired anatomical device are made and sent to processing centers for custom design and/or manufacturing.

In an alternate embodiment, beginning at step 4511, a virtual three-dimensional model of the anatomical structure is used to design an anatomical device. A virtual three-dimensional model refers to a model generated by a numerically controlled device, such as a computer, and either includes the digital data 4405, or is generated based upon the digital data 4405. In one embodiment, the virtual three-dimensional model is included as part of the

digital data 4405 provided to a design center. In another embodiment, the three-dimensional model is generated using the digital data 4405 is received at step 4511. In another embodiment, an alternate-three-dimensional model is generated at step 4511 based on a three-dimensional model included as part of the digital data 4405. In another embodiment, multiple three-dimensional models can be stitched together from a plurality of scans. For example, data from multiple scan sessions can be used.

Furthermore, at step 4511, a virtual anatomical device is designed (modeled) using the virtual three-dimensional model. The virtual device can be designed using standard or custom design software for specifying virtual devices. Examples of such design software include commercially available products such as AutoCAD, Alias, Inc and ProEngineer. For example, the design software can be used to design a virtual crown using the three-dimensional virtual model of the anatomical structure, or to select a near-custom, standard or virtual devices from a library of devices that represents actual devices. Subsequent to selecting a standard device, customizations can be made.

At step 4512, the anatomical device can be manufactured directly based upon a virtual specification of the device. For example, the anatomical device can be generated using numerically controlled processing techniques, such as three-dimensional printing, automated milling, or laser sintering, stereo lithography, and injection molding, extrusion and casting techniques. It will be appreciated that the manufacture of the anatomical device includes partially

manufacturing the device, as well as manufacturing the device at multiple locations.

At step 4426, the manufactured anatomical device is scanned. By generating a virtual model of the manufactured anatomical device, a simulation can be performed to verify the relationship between the anatomical device as manufactured and the anatomical structure, thereby, providing closed loop feedback to assure proper manufacture of the device.

At step 4504, the completed anatomical device is sent to a specified location for installation. For example, returning to Figure 44, the anatomical device is sent to facility 4444, where installation occurs at step 4435. In one embodiment, the anatomical device is installed at step 4435 by a practitioner, such as a dentist, orthodontist, physician, or therapist. In another embodiment, the patient can install the anatomical device. For example, a patient can install some orthodontic devices, such as retainers or similar positioning devices.

In accordance with a specific embodiment of the present invention, the anatomical device is designed or manufactured at a remote location relative to where the digital data 4405 is received or generated. In one embodiment, the digital data is received at the location 4441. Specifically, the digital data is received by the scanning the anatomical structure 4400. Once received, the digital data is transmitted to location 4442, which is a remote location relative to the location 4441, where an anatomical device is at least partially designed.

A remote location (facility) is one that is disassociated in some manner from another location. For example, the remote location can be a location that is physically separate from the other location. For example, the scanning facility can be in a different room, building, city, state, country, or other location. In another embodiment, the remote location can be a functionally independent location. For example, one location can be used to perform one specific function, or set of functions, while another location can be used to perform a different function. Examples of different functions include scanning, designing, and manufacturing. Remote locations will generally be supported by separate infrastructures, such as personnel and equipment.

In another embodiment, the digital data 4405 at facility 4441 includes a partially designed anatomical device. The anatomical device is further designed at the remote facility 4442. Note that facility 4442 can represent one or more remote facilities that can be used in parallel or serial to determine a final anatomical device, make a diagnosis, form treatment plan, monitor progress, or design a device based upon cost, expertise, ease of transmission, and turn around time required. An example of parallel facilities is further illustrated in Figure 48.

Figure 46 illustrates another embodiment of the present invention. The flow of Figure 46 is similar to the flow of Figure 44, with an additional intermediate step 4615. The intermediate step 4615 indicates that the digital data 4405 does not need to be received directly from the facility 4441 where the data was scanned. For example, the digital data 4405 can be generated at the

first facility (sending facility) by scanning and provide the digital data to a second facility 4641 (receiving facility) where the intermediate step 4615 occurs. Once the intermediate step 4615 is completed, the digital data 4405, or a modified digital data that is a representation of the digital data, can be transmitted to a third facility (remote facility) that is remote relative to at least one of the first and second facilities. During the intermediary step 4615, other steps can modify the digital data 4405 before the data is sent to the third facility. For example, the scan data can be processed to provide a three-dimensional virtual model of the anatomical structure; data can be added to the digital data, including image data of the scanned anatomical structure 4400, video and/or photo data containing color information, diagnosis information, treatment information, audio data, text data, X-ray data, anatomical device design information, and any other data which may be pertinent to the design or manufacture of the anatomical device. In an alternate embodiment, the intermediary step 4615 need not alter the digital data 4405.

Figure 47 illustrates an alternate embodiment of the present invention where the digital data 4405 is received at facility 4742 for forensic evaluations at step 4741. An example of a forensic evaluation includes identification of victims based on the anatomical structure scanned. Such identifications will generally be made based upon matching a specific anatomical structure to an anatomical structure contained within a target data base, where the target data base can contain a single structure, a plurality of structures. In one embodiment, the target database could be a centrally located database containing archived data.

Figure 48 illustrates an embodiment of the present invention where digital data 4405, or its representation, is transmitted to one or more remote facilities 4843 for diagnostic purposes or treatment planning at steps 4844 and 4845. The ability to transmit the data for diagnostic purposes allows three-dimensional information of an anatomical structure to be provided to other practitioners, such as specialists, without the patient having to physically be present. This ability improves the overall speed and convenience of treatment, as well as accuracy when multiple diagnoses can be made in parallel. The ability to send the digital data 4405, or its representation, to multiple facilities for treatment planning and diagnosis allows multiple opinions to be obtained. Once a specific treatment plan is selected, any one of the devices specified as part of the treatment plan can be selected for manufacturing.

In a specific implementation of Figure 48, price quotes are obtained from each of the facilities. The price quotes can be based upon a specific treatment specified by a requesting party, where the treatment relates to the anatomical structure. Alternatively, the price quotes can be based upon a desired result specified by the requesting party, where the treatment definition and its associated implementation costs are determined by the facility providing the quotes. In this manner, a patient or a patient's representative can obtain competitive bids in an efficient manner.

Figure 49 illustrates an alternate embodiment of the present invention where the digital data 4405, or its representation, is received at facility 4942 so that the data can be used at the step 4941 for educational purposes. Because of

the deterministic nature of the embodiment described herein, educational techniques can be performed in a standardized manner not possible using previous methods. Examples of educational purposes include self learning purposes, education monitoring purposes, and the ability to provide standardized applied exams which were not possible before. Furthermore, case facts for a specific patient can be matched to previous, or present, case histories of other patients, where the case histories are stored or archived.

Figure 50 illustrates an embodiment where scan data can be archived at step 5001, which occurs at location 5002 for easy retrieval by authorized individuals. In a specific embodiment, such archives would be provided as a service, whereby that data would be commonly maintained, thereby allowing for a common site-independent "gold standard" copy of digital data to be obtained.

Figure 51 illustrates a specific embodiment of the present invention where the digital data obtained by scanning the anatomical structure is used in a closed-loop iterative system. The flow of Figure 51 may also be interactive. Specifically, changes in the anatomical structure, whether intentional or unintentional, can be monitored and controlled as part of the closed-loop system. The closed-loop system in accordance with the present invention is deterministic because the scan data is measurable in three-dimensional space, thereby allowing a standard reference, in the form of a three-dimensional model, to be used for analysis.

At step 5101 the three-dimensional scan data of the anatomical device is obtained.

At step 5102 the data from the scan of step 5001, or a representation of the data, is transmitted to a remote facility.

At step 5003, a design/evaluation of the transmitted data is performed. For example, a treatment plan, diagnosis, and a design for anatomical device are determined during a first pass through the loop including step 5103. During subsequent passes through step 5103, the status or progress of the treatment or device is monitored and changes are made as necessary. In one embodiment, the monitoring is performed by comparing the current scan data to an expected result, which has been simulated, or to the previous history, or against matched case histories.

At step 5104, the device or treatment plan is implemented or installed as appropriate. Any manufacturing of a device is also performed as part of step 5104.

It is determined whether an additional pass through the closed-loop system of Figure 50 is needed at step 5105. If so, the flow proceeds to step 5101. Otherwise, the flow terminates. As discussed with reference to Figure 51, a closed-loop feedback loop can exist between any of the steps illustrated in Figure 50

The ability to used feedback to verify progress is an advantage over the prior art, where practitioners relied upon one or more of text notes, visual

observations of models and other images. However, these observations where made without fixed three-dimensional models that would allow the practitioner to be assure the same perspective is being viewed. The use of the visual models described herein allows for a fixed reference to be obtained. For example, one method of obtaining fixed reference points for an orthodontic structure includes selecting orientation reference points based on physical attributes of the orthodontic structure. The orientation reference points can subsequently be used to map the digital image of the orthodontic structure into a three-dimensional coordinate system. For example, the frenum can be selected to be one of the orientation reference points and the rugae can be selected as the other reference point. The frenum is a fixed point in the orthodontic patient that will not change, or change minimally, during the course of treatment. The frenum is a triangular shaped tissue in the upper-portion of the gum of the upper-arch. The rugae is a cavity in the roof of the mouth 68 in the upper-arch. The rugae will also not change its physical position through treatment. As such, the frenum and the rugae are fixed physical points in the orthodontic patient that will not change during treatment. As such, by utilizing these as the orientation reference points, a three-dimensional coordinate system may be mapped thereto. Note that other physical attributes of the orthodontic patient including the incisive papilla, cupid's bow, the inter-pupillar midpoint, inter-commissural midpoint (e.g., between the lips), inter-alar midpoint (e.g., between the sides of the nose), the prone nasale (e.g., the tip of the nose), sub-nasale (e.g., junction of the nose and the lip), a dental mid-line point, a point on the bone, a fixed

bone marker such as an implant (e.g., a screw from a root canal, oral surgery) may be used as the orientation reference points.

Figure 52 illustrates that iterative feedback steps can take place within and between any combination of the steps illustrated herein. For example, an interactive and/or interactive loop can reside between the manufacturing step 4425 and the design step 4415, or within a single step as describe with reference to step 4426 of Figure 44.

In addition to the many methods of using the scanned data derived in the steps herein, many methods for financing the use of the data are possible. For example, fees for the use of such scan data 4405 may be fixed or variable fees based upon the use the data, the cost of a service provided, the anatomical device being generated, or the value added to a device or service based upon the data. In addition, it will be apparent that many other types of fees can be envisioned.

The steps and methods described herein may be executed on a processing module (not shown). The processing module may be a single processing device or a plurality of processing devices. Such a processing device may be a microprocessor, microcomputer, digital signal processor, central processing unit of a computer or work station, digital circuitry, state machine, and/or any device that manipulates signals (e.g., analog and/or digital) based on operational instructions. The processing module's operation is generally controlled by data stored in memory. For example, where a microprocessor is used, a bus of the microprocessor is connected to a bus of a

memory to access instructions. Examples of memory include single or multiple memory devices, such as random access memory, read-only memory, floppy disk memory, hard drive memory, extended memory, magnetic tape memory, zip drive memory, and/or any device that stores digital information. Such memory devices can be local (i.e. connected directly to the processing device), or at physically different locations (i.e. at a site connected to the Internet.) Note that when the processing module implements one or more of its functions, via a state machine or logic circuitry, the memory storing the corresponding operational instructions is embedded within the circuitry comprising the state machine or logic circuitry.

One of ordinary skill in the art will appreciate that the specific embodiments described herein provide advantages over the known art. For example, the anatomical structure being scanned may have one or more associated anatomical devices or appliances. In addition, the present invention provides a deterministic method for diagnosing, treating, monitoring, designing and manufacturing anatomical devices. In addition, the present embodiments can be used to provide an interactive method for communication between various parties designing and manufacturing the prosthetic device. Such an interactive method can be implemented in real-time. The methods describe herein permit data to be archived in such a manner that others can obtain the actual information and knowledge obtained from the experience of others. Multiple consultants can have access to identical deterministic copies of the information independent of location, allowing objective design, manufacturing, and or treatment-monitoring information to be obtained even when multiple

independent sites are being used. The present embodiments allow for the circumvention of traditional labs used to generate anatomical devices. Specifically, support facilities used for the generation of anatomical devices may now be numerous and remote relative to the patient. This can reduce the overall cost to the practitioner and patient. The patient does not have to visit the practitioner to have the status or progress of a device monitored, since the scanning location can be remote from other support locations. Overall, the fixed, archivable nature of the digital data of the present embodiments allows for a low cost of generating identical duplicate models from a gold standard model, thereby reducing the likelihood of lost and inaccurate data. By reducing the amount of time and travel required of a patient for analysis of specific anatomical structures, treatment costs are reduced. The accessibility of multiple opinions (quotes, treatment plans, diagnoses, etc.) increases without the additional inconvenience to the patient associated with the prior art methods. Competitive quoting is also readily obtainable using the specific embodiments indicated.

In the foregoing specification, the invention has been described with reference to specific embodiments. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the present invention as set forth in the claims below. For example, the digital data may be a composite of a direct scan of the anatomical structure and an indirect scan of the structure. This may occur when a portion of the anatomical structure is not viewable by the scanner 4401, so an impression of at least that portion of the anatomical structure that is not

viewable. The impression, or a model made from the impression, is then scanned and "stitched" into the direct scan data to form a complete scan. In other embodiments, the digital data 4405 can be used in combination with other traditional methods. In other embodiments, the digital data described herein can be compressed, or secured using an encryption method. When encrypted, one or more of the patient, the scanning facility, and archival facility or a representative of the patient can have encryption keys for the digital data. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present invention. In the claims, means-plus-function clause(s), if any, cover the structures described herein that perform the recited function(s). The mean-plus-function clause(s) also cover structural equivalents and equivalent structures that perform the recited function(s). Benefits, other advantages, and solutions to problems have been described above with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or element of any or all the claims.

One of ordinary skill in the art will recognize that the present invention is advantageous over the prior art, in that a reference independent scanner is disclosed that in a specific embodiment incorporates variable identifiers in a direction orthogonal to a projection/view plane. By providing variables in a direction orthogonal to the projection/view plane, the distortion of these

variables, which is less than distortion parallel to the projection/view plane, does not prohibit identification of specific shapes. As a result, greater accuracy, of mapping of objects can be obtained.

What is claimed is:

1. A method of creating a three-dimensional model of an object, the method comprising the steps of:

receiving a 3D primitive model of a first object portion, wherein the 3D primitive model includes a plurality of primitive shapes;

receiving a 3D point model of a second model portion, wherein the 3D point model includes a plurality of points;

determining a first set of points in the 3D point model that are likely to be valid and to overlap a portion of the 3D primitive model of the first object portions; and

aligning the 3D point model to the 3D primitive model based upon the first set of points.

2. The method of claim 1, wherein the step of determining includes the substeps of:

for x = 1 to n, where n is the number of points in the 3D point model:

determining a minimum distance Dx from a point Px to the primitive model; and

including the point Px in the first set of points if Dx is less than a predefined value.

3. An apparatus for scanning a surface of an object, an apparatus comprising in combination:

a scanning device wherein the scanning device includes a projecting device and a viewing device; and

a system controller operably coupled to the scanning device, wherein the system controller comprises a first controller to control the projecting device and a second controller to control the viewing device.

4. A method for generating a three-dimensional model of an object, the method comprising:

projecting an image having at least one encoded feature with at least one component that varies orthogonal to a plane formed by a projection axis and at least one point of a view axis;

receiving a representation of a surface image at a viewing device; and

determining a location of a point at the surface of the object based upon the at least one encoded feature.

5. A method for generating a three-dimensional model of an object from a reference independent scanning device, the method comprising:

a) scanning and receiving a first data representing two dimensional object data, the first data comprising a plurality of frames;

b) generating a first three-dimensional model from a first frame of the first data;

c) generating a second three-dimensional model from a second frame of the first data;

d) performing a process of aligning the first three-dimensional model to the second three-dimensional model to generate a cumulative model; and e) iterating the steps of b) through d) until the process of aligning and generating a cumulative model is complete for all frames of the first data.

6. A method of registering data, method comprising the steps of:

receiving reference independent data representing an object, wherein the reference independent data includes a plurality of frames F1 through Fn, where n is a positive integer greater than 1, and each of the frames F1 through Fn represent an object portion of the object; and

performing a registration between the object portions of frame Fx and frame Fx+1, where x is an integer between 1 and n-1.

7. The method of claim 6, wherein the spatial location of the object portion of frame Fx is unknown, and the spatial location of the object portion of frame Fx+1 is unknown.

8. The method of claim 6, wherein the spatial location of a scanner when frame Fx was captured is unknown, and the spatial location of the scanner when frame Fx+1 was captured is unknown.

9. The method of claim 8, wherein the spatial location of the object portion of frame Fx is unknown, and the spatial location of the object portion of frame Fx+1 is unknown.

10. A method of registering data, the method comprising the steps of:

receiving a first two-dimensional image representing a first portion of an object, wherein the first two-dimensional image is a reference independent image;

receiving a second two-dimensional image representing a second portion of an object, wherein the second two-dimensional image is a reference independent image ; and

determining an original entry point to be used for performing a three-dimensional registration of the second image to the first image.

11. The method of claim 10, further comprising the step of:

performing a three-dimensional registration based on the original entry point.

12. The method of claim 11, further comprising the step of:

defining an alternate entry point based upon the original entry point; and

performing a three-dimensional registration based on the alternate entry point.

13. A method of registering data, the method comprising the steps of:

receiving reference independent data representing an object, wherein the reference independent data includes a plurality of frames F1 through Fn, where n is a positive integer greater than 1, and each of the frames F1 through Fn represent an object portion of the object;

performing a first registration using the reference independent data to create a first three-dimensional model; and

performing a second registration using the reference independent data to create a second three-dimensional model.

14. The method of claim 13, wherein the first registration has a first characteristic and the second registration has a second characteristic.

15. The method of claim 14, wherein the first and second characteristics are accuracy characteristics.

16. The method of claim 15, wherein the first characteristic results in the second three-dimensional model having a greater accuracy than the first three-dimensional model.

17. The method of claim 16, wherein the step of performing the first registration takes less time than the step of performing the second registration.

18. The method of claim 13, wherein the first registration is a single frame registration that attempts to register each frame Fx to an adjacent frame Fx-1 for x = 2..n.

19. A method comprising the steps of:

receiving digital data, wherein the digital data is based upon a direct three-dimensional surface scan of an anatomical structure; and

transmitting a representation of the digital data to a remote location to have an anatomical device designed.

20. The method of claim 19, wherein the step of receiving further includes scanning the anatomical structure to directly receive the digital data.

21. The method of claim 19, wherein the step of receiving further includes receiving the digital data at a receiving facility from a sending facility, wherein the receiving facility, the sending facility, and the remote facility are different facilities.

22. The method of claim 19, wherein the step of transmitting to have an anatomical device designed includes having the device manufactured.

23. The method of claim 19, wherein the step of receiving includes the digital data being based upon a reference independent scan.

24. The method of claim 23, wherein the reference independent scan includes a multi-frame reference independent three-dimensional scan of an object.

25. The method of claim 19, wherein the step of receiving includes receiving the digital data at a facility that does not design the anatomical device.

26. A method comprising the steps of:

receiving digital data, wherein the digital data is based upon a direct three-dimensional surface scan of an anatomical structure; and

transmitting a representation of the digital data to a remote location for forensics.

27. A system comprising in combination:

a processing module having a bus;

a memory having a bus coupled to the bus of the processing module;

wherein the memory stores instructions that cause the processing module to:

receive digital data, wherein the digital data is based upon a three-dimensional surface scan of an anatomical structure; and

transmit a representation of the digital data to a remote location to have an anatomical device designed.

28. A method of mapping a surface, the method comprising:

during a first time period projecting a first image along a projection axis to an object to be mapped, the first image having a measuring feature; and

during a second time period projecting a second image along the projection axis to the surface, the second image having an encoding feature which is used to identify the measuring feature of the first image, wherein the first time period and the second time period are adjacent in time, and substantially mutually exclusive.

29. The method of claim 28, wherein the step of projecting the second image includes the encoding feature being at least partially substantially orthogonal to a plane formed by the projection axis and a point of a view axis.

30. An apparatus for mapping an object, the apparatus comprising:

a projector to transmit a first image having a measuring feature during a first time period along a projection axis to an object to be mapped, and to transmit a second image having an encoding feature during a second time period along the projection axis , the second image being at least partially orthogonal to the plane and is used to identify the measuring feature of the first image, wherein the first time period and the second time period are adjacent in time, and substantially mutually exclusive.

31. An apparatus for scanning an object, the system comprising:

a data processor for executing instructions;

a plurality of instructions capable of being executed on the data processor for executing the following operations:

specifying a first time period during which a first image is to be projected along a projection axis to an object to be mapped, the first image having a measuring feature which is detectable in a direction parallel to a plane formed by the projection axis and a point of a view axis; and

specifying a second time period during which a second image is to be projected along the projection axis to the surface, the second image having an encoding feature which is at least partially orthogonal to the plane and is used to identify the measuring feature of the first image, wherein the first time period and the second time period are adjacent in time, and substantially mutually exclusive.

32. A method of scanning, the method comprising the steps of:

providing a patient;

providing a scanner that uses a pattern with an encoding feature orthogonal to a plane of triangulation; and

scanning a portion of the patient using multi-frame reference independent scanning to receive scan data.

33. The method of claim 32, wherein the portion of the patient is a dentition structure.

34. The method of claim 33, wherein the portion of the patient includes a tooth portion.

35. The method of claim 32, wherein during the step of scanning, the portion of the patient is not fixed.

36. A method of scanning a portion of a patient's mouth, the method comprising the steps of:

receiving scan data having at images with undercuts of a dentition structure, wherein there is no known spatial reference associated with the scan data reference point; and

generating a three-dimensional model of the dentition structure using the scan data.

37. A method of mapping an object, the method comprising the steps of:

projecting a first image along a projection axis onto a surface of the object, wherein the first image includes a measuring feature to map a first set of surface features having a first characteristic; and

projecting a second image along a projection axis onto the surface of the object, wherein the second image includes a measuring feature to map a second set of surface features having a second characteristic.

38. The method of claim 37, wherein the step of projecting the second image further includes projecting the second image simultaneously with the first image.

39. The method of claim 38, wherein the first image further includes the first image having a plurality of parallel features, each of the plurality of parallel features separated by a predetermined distance X, and wherein the second image includes at least one feature separated from any other feature by a predetermined distance Y, where Y is greater than X.

40. The method of claim 37, further comprising the step of:

determining a the second set of surface features based upon projecting the first image feature, wherein the second set of surface features is not mapped using the first image feature.

41. An apparatus used to project an image for mapping an object, the method comprising a projector to project a first image and a second image along a projection axis onto a surface of the object, wherein the first image includes a measuring feature to map a first set of surface features having a first characteristic, and to project a second image along the projection axis onto the surface of the object, wherein the second image includes a measuring feature to map a second set of surface features having a second characteristic.

42. A method of mapping a surface, the method comprising:

projecting an image along a projection axis onto a surface to provide a surface image, wherein the image includes a variable feature which varies in a direction substantially orthogonal to a plane formed by the projection axis and a point of a view axis;

receiving a representation of the surface image along the view axis; and

determining a location at a point of the surface based at least partially upon the variable feature of the representation of the surface image.

43. The method of claim 42, wherein the image is a predefined pattern.

44. The method of claim 43, wherein the predefined pattern includes

a first image portion having a first feature that includes at least the location at the point of the surface, and a second feature which includes at least a portion of the variable feature;

a second image portion having a third feature, and a fourth feature; and

the step of determining further includes using the second feature to identify the first feature.

45. A method of mapping a surface, the method comprising:

projecting a pattern upon a surface, the pattern having a plurality of first features and a plurality of second features, wherein each of the plurality

of second features are uniquely identifiable independent of the topology of the surface; and

determining a specific feature of the plurality of first features based upon the plurality of second features.

46. The method of claim 45 further comprising the step of:

calculating a relative location of a point of the surface based upon the specific feature.

47. A method for scanning an object, the method comprising the steps of:

projecting a plurality of discrete shapes for scanning an object, wherein the plurality of discrete shapes include a first discrete shape and a second discrete shape; and

projecting a first encoding feature relative to the first discrete shape.

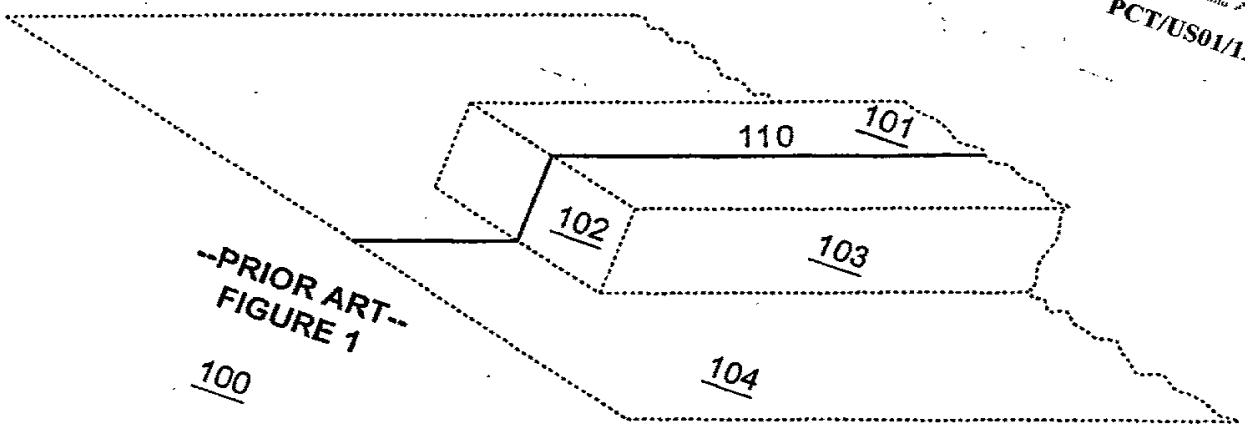
48. An apparatus for scanning an object, the apparatus comprising:

a data processor for executing instructions;

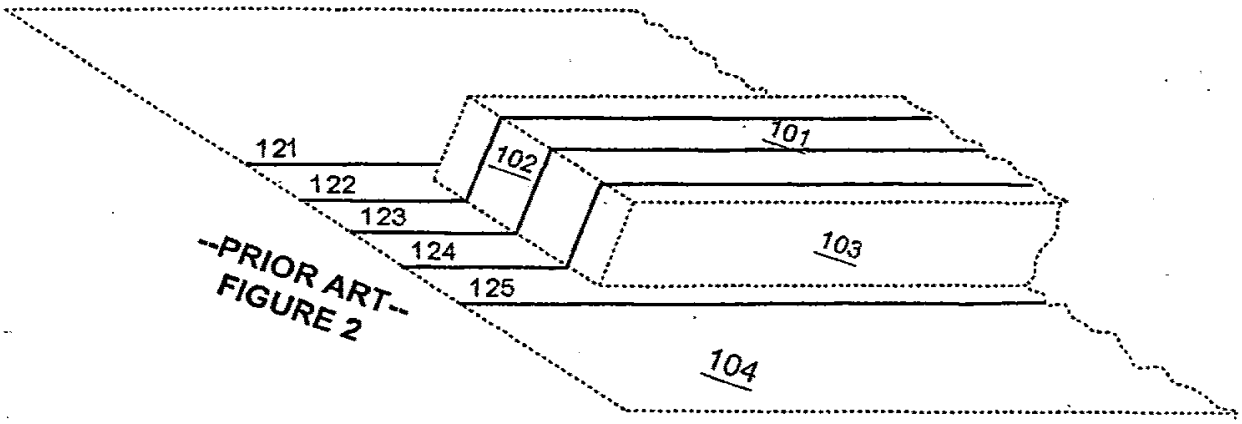
a plurality of instructions capable of being executed on the data processor to execute the following operations:

projecting a plurality of discrete shapes for scanning an object, wherein the plurality of discrete shapes include a first discrete shape and a second discrete shape; and

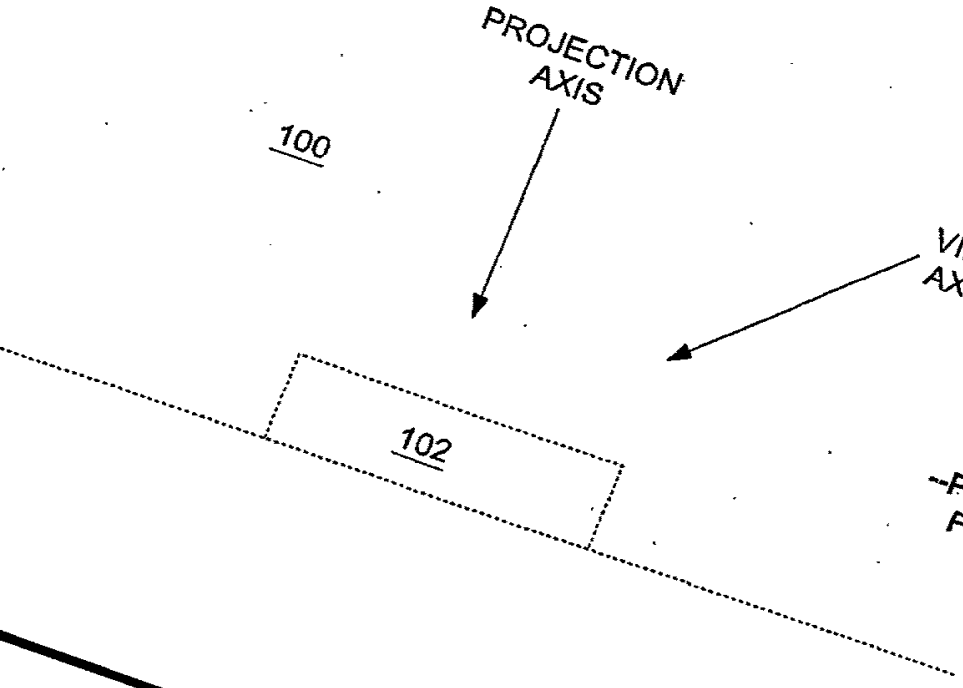
projecting a first encoding feature relative to the first discrete shape.



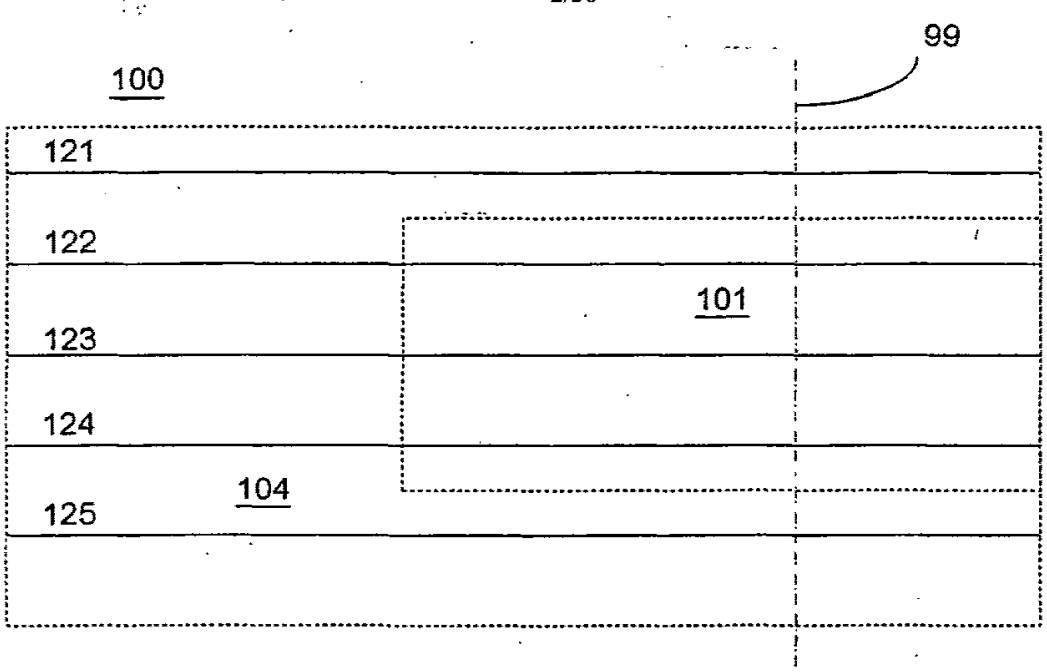
--PRIOR ART--
FIGURE 1



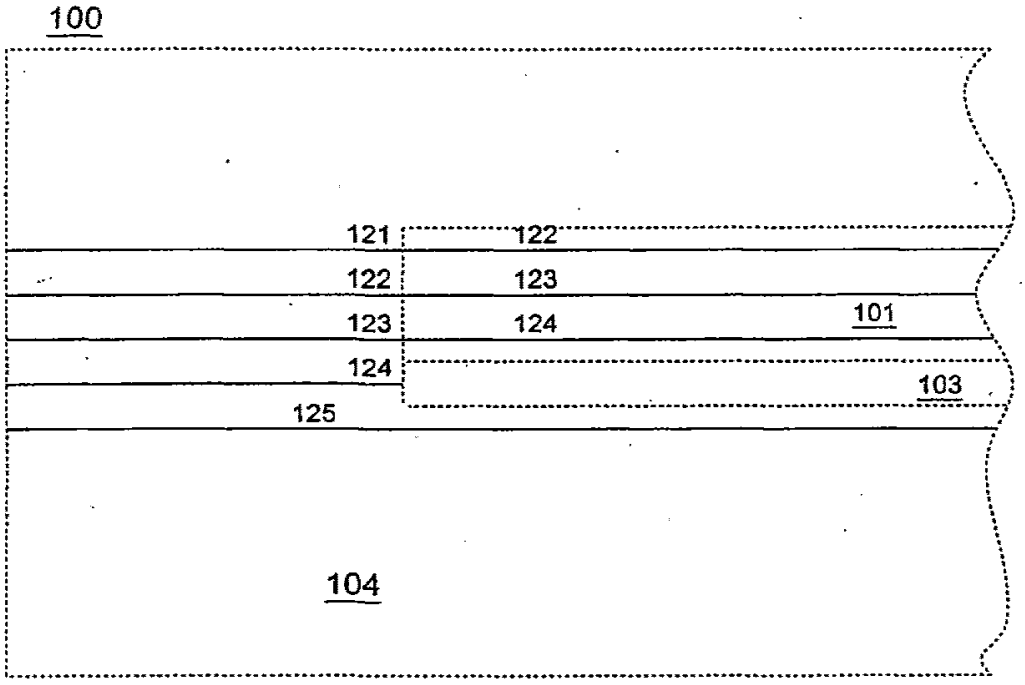
--PRIOR ART--
FIGURE 2



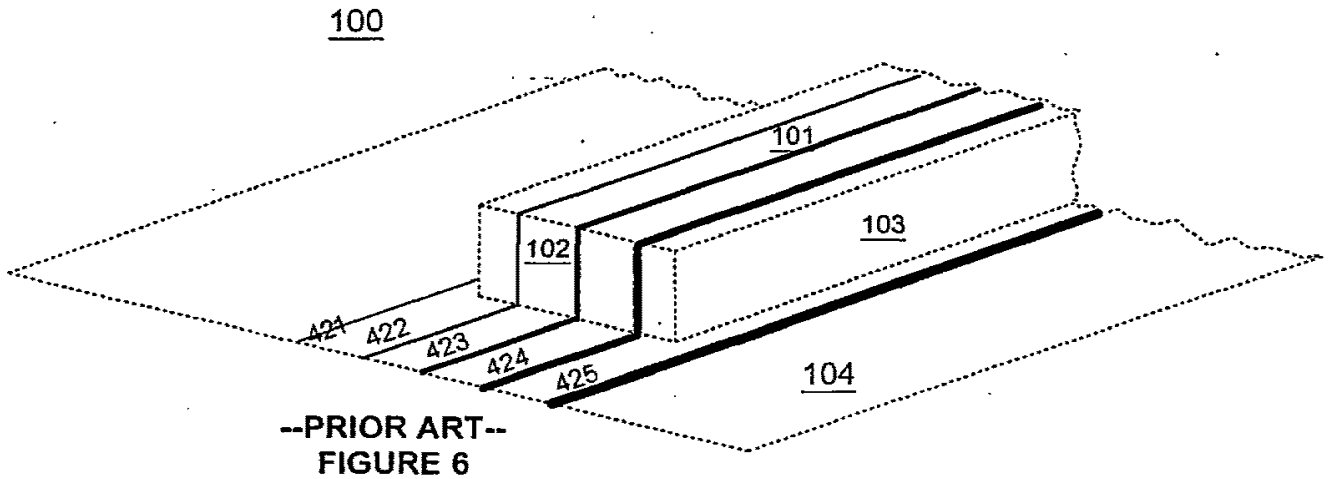
--PRIOR ART--
FIGURE 3



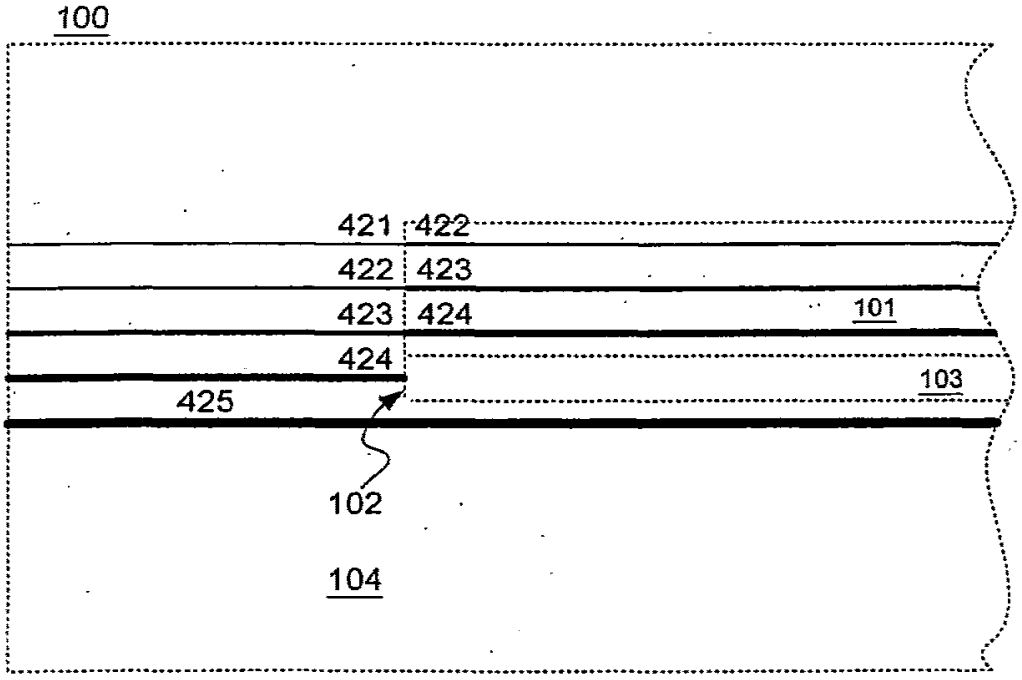
--PRIOR ART--
FIGURE 4



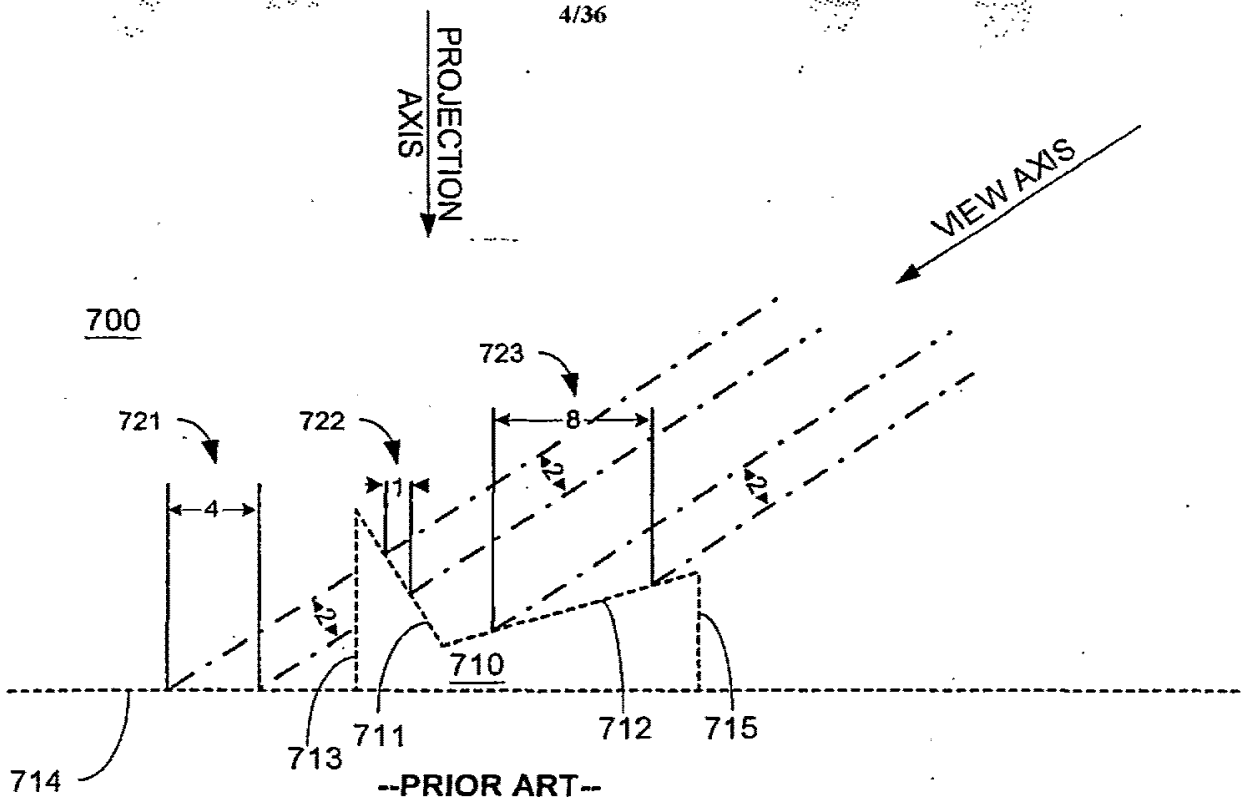
--PRIOR ART--
FIGURE 5



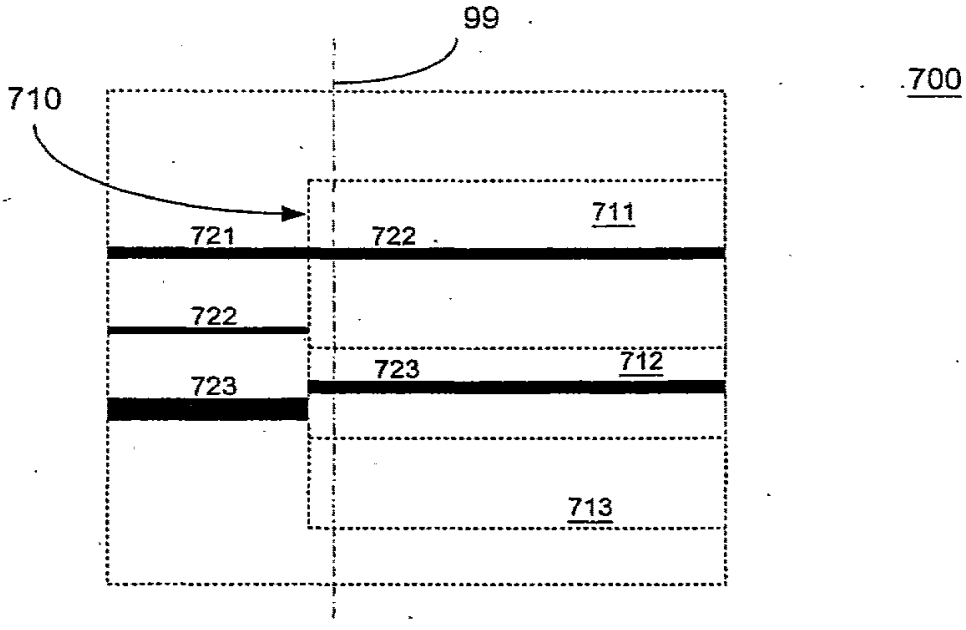
--PRIOR ART--
FIGURE 6



--PRIOR ART--
FIGURE 7



--PRIOR ART--
FIGURE 8



--PRIOR ART--
FIGURE 9

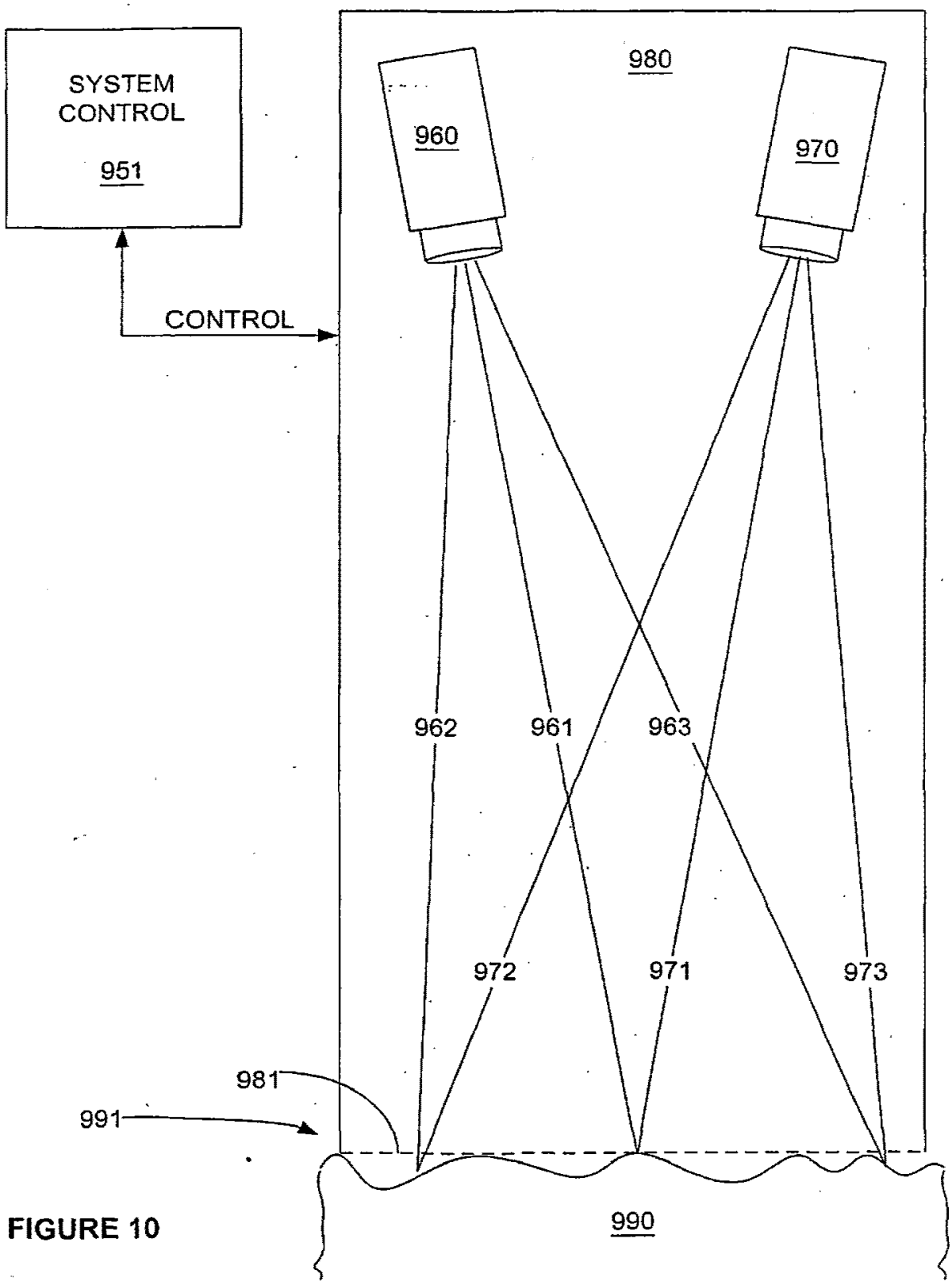

SYSTEM CONTROL
951
CONTROL
980
960
970
962
961
963
972
971
973
981
991
990

FIGURE 10

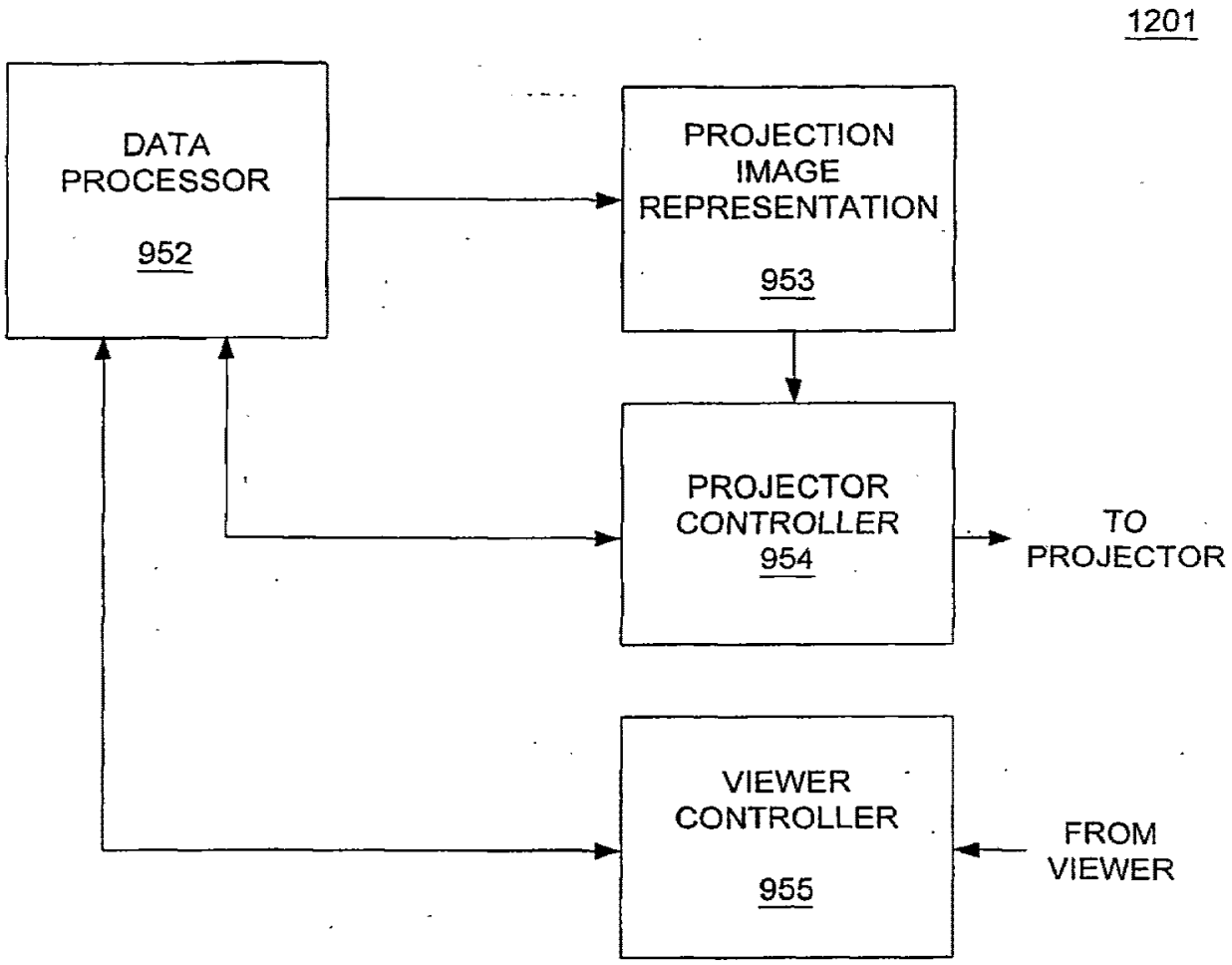

1201
DATA PROCESSOR
952
PROJECTION IMAGE REPRESENTATION
953
PROJECTOR CONTROLLER
954
TO PROJECTOR
VIEWER CONTROLLER
955
FROM VIEWER

FIGURE 11

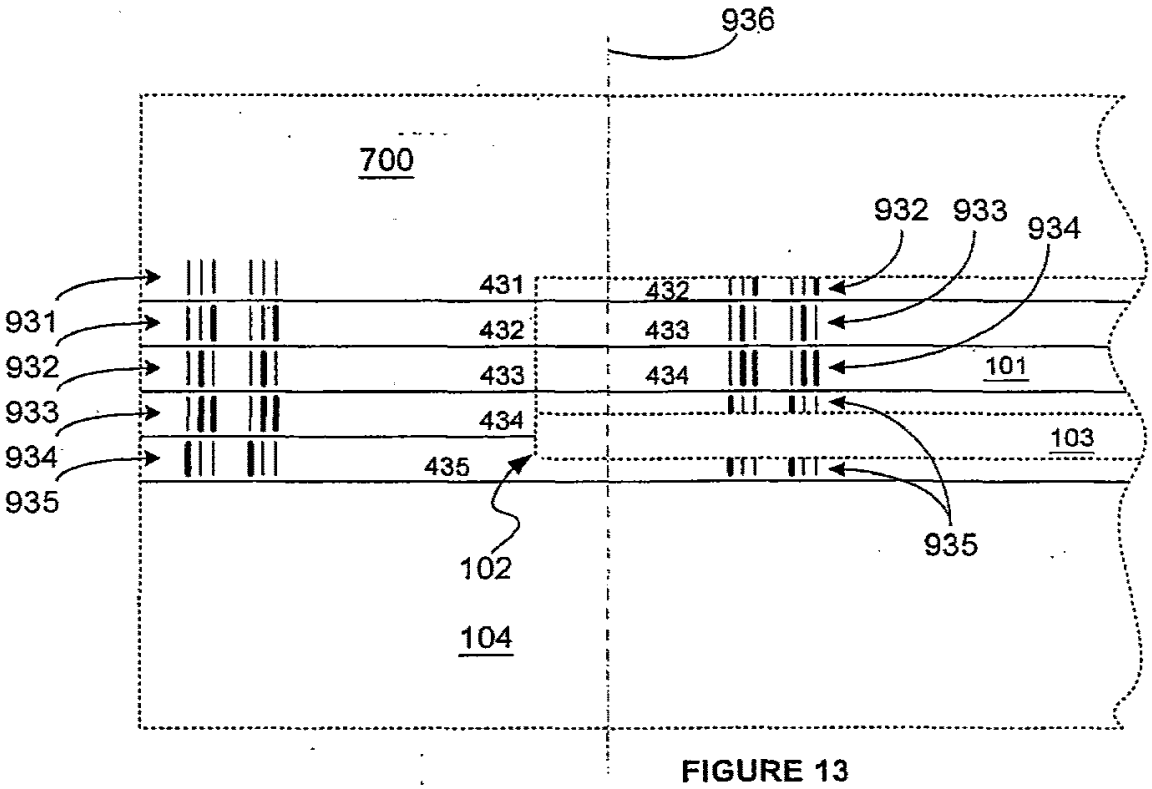


FIGURE 13

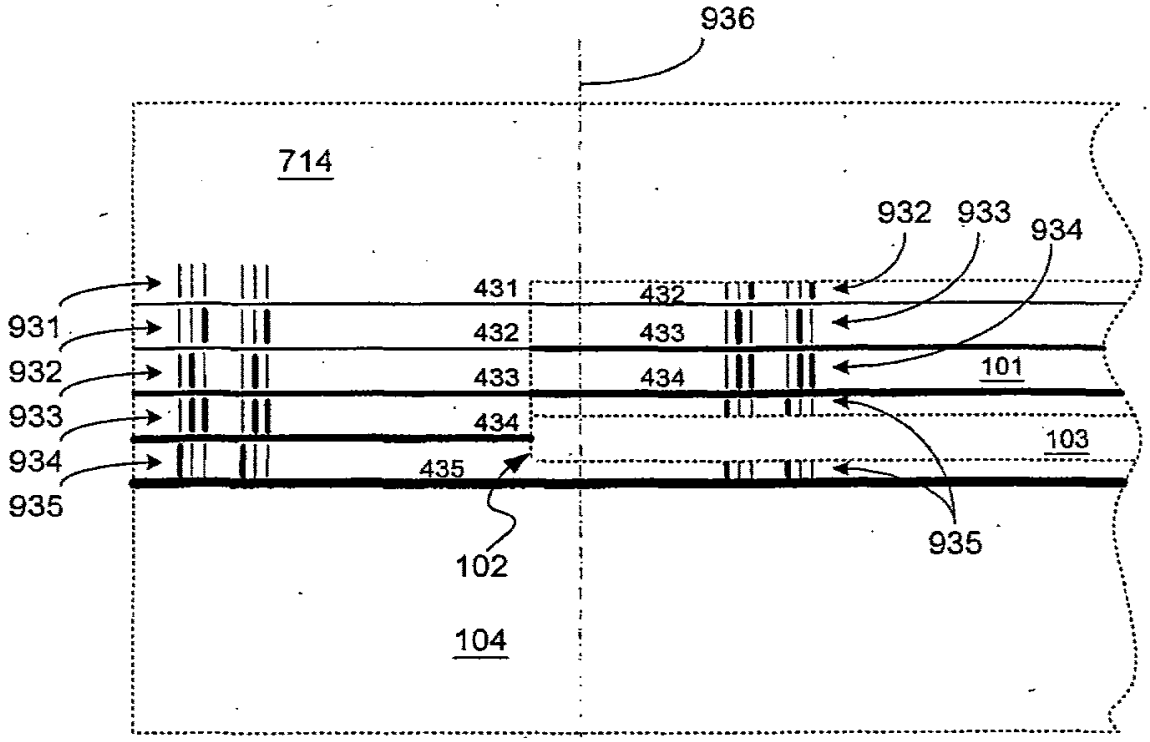


FIGURE 14

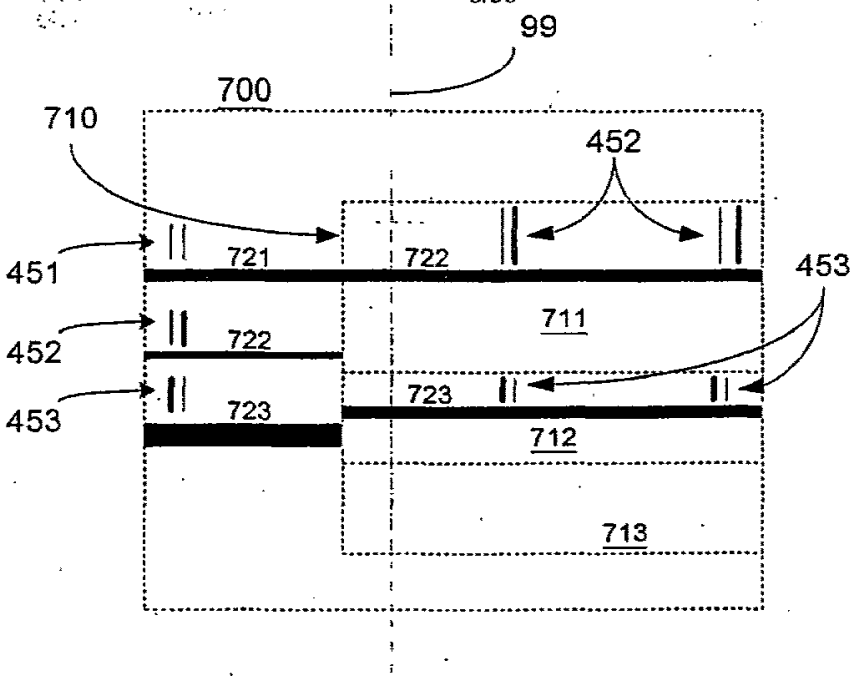


FIGURE 15

SHAPE NUMBER	BAR CODE	COLOR	PATTERN
0		RED	
1		ORANGE	
2		YELLOW	
3		GREEN	
4		BLUE	
5		INDIGO	
6		VIOLATE	
7		BROWN	

FIGURE 16

0 1 2 3 4 5 6 7 8 9 A B C D E F
0 1 2 7 4 5 6 3 8 9 A F C D E B
0 1 6 3 4 5 2 7 8 9 E B C D A F
0 5 2 3 4 1 6 7 8 D A B C 9 E F

FIGURE 17

S 0 1 2 3 S 0 1 2 3 S 0 1 2 3 S 0 1 2 3 S
S 0 1 3 2 S 0 1 3 2 S 0 1 3 2 S 0 1 3 2 S
S 0 3 1 2 S 0 3 1 2 S 0 3 1 2 S 0 3 1 2 S
S 3 1 2 0 S 3 1 2 0 S 3 1 2 0 S 3 1 2 0 S

FIGURE 18

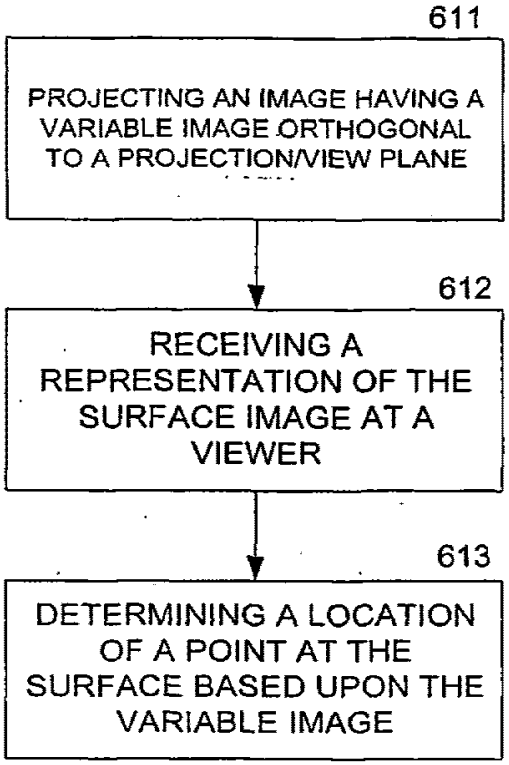


FIGURE 12

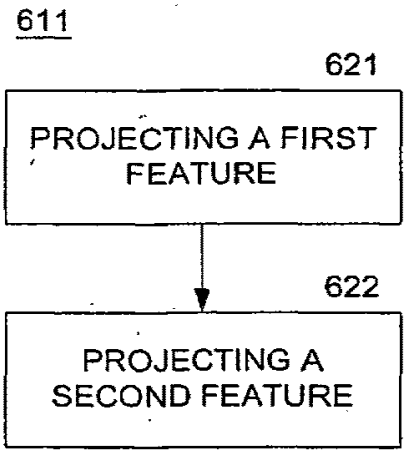


FIGURE 19

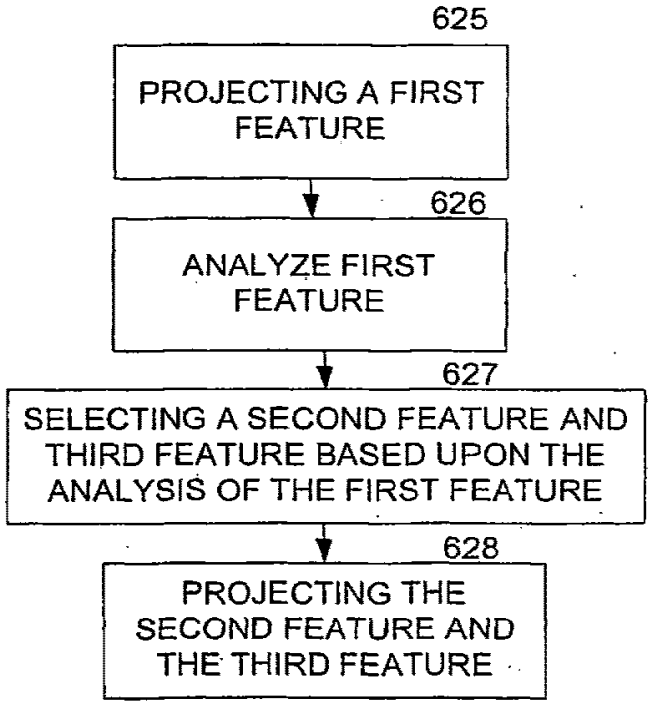


FIGURE 20

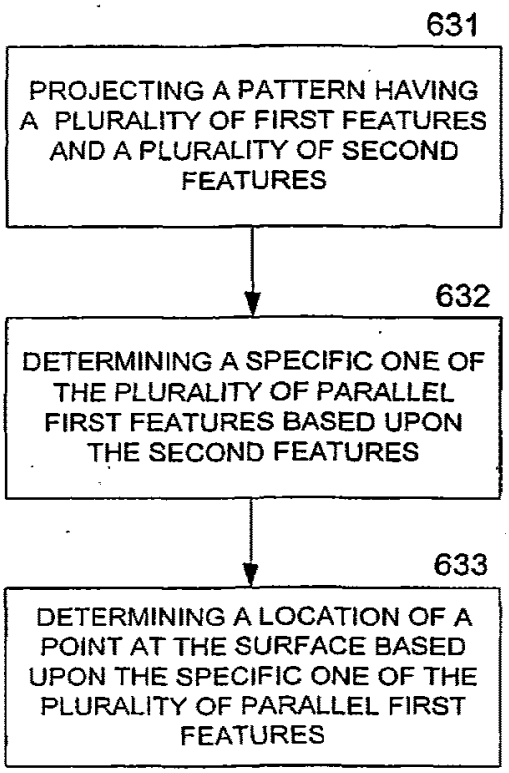


FIGURE 21

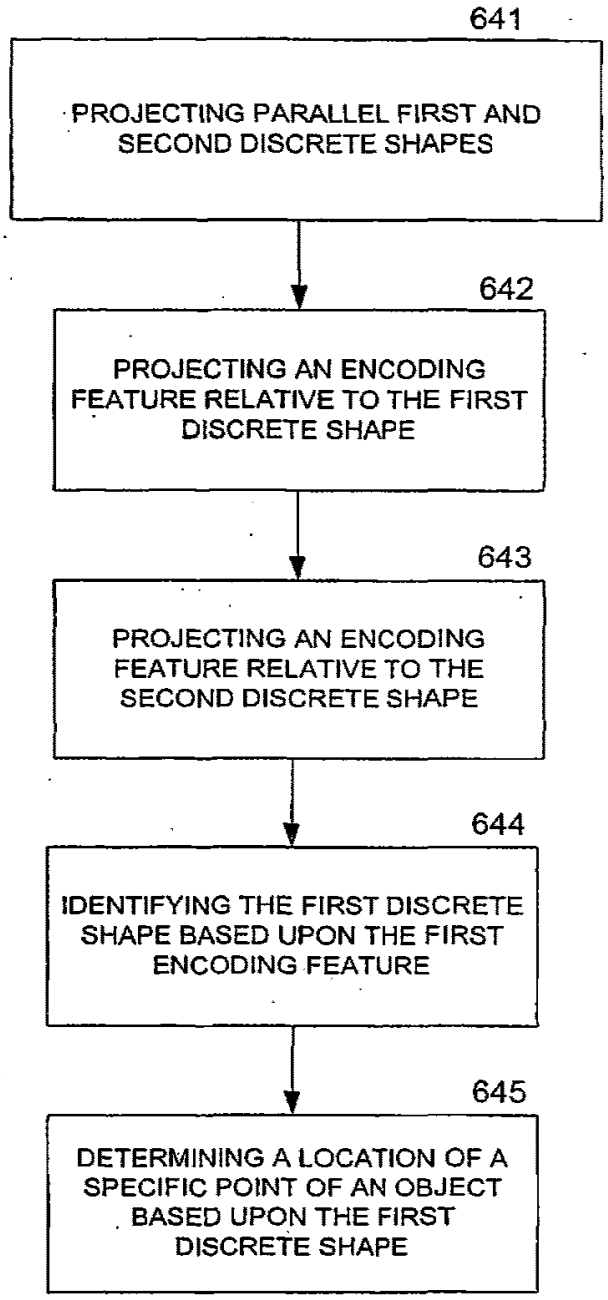


FIGURE 22

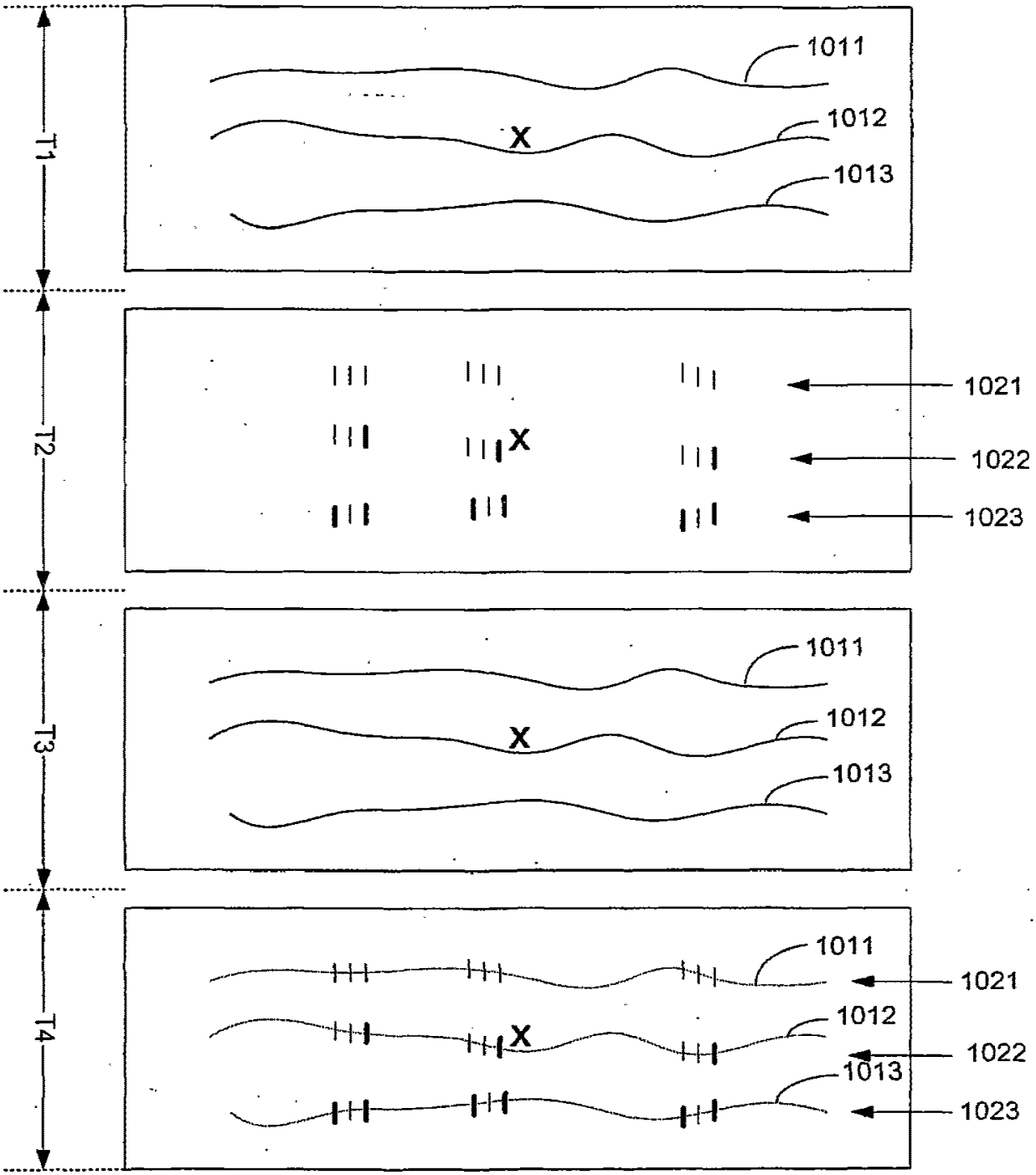

T1
1011
1012
X
1013
T2
1021
X
1022
1023
T3
1011
1012
X
1013
T4
1011
1021
1012
X
1022
1013
1023

Figure 23

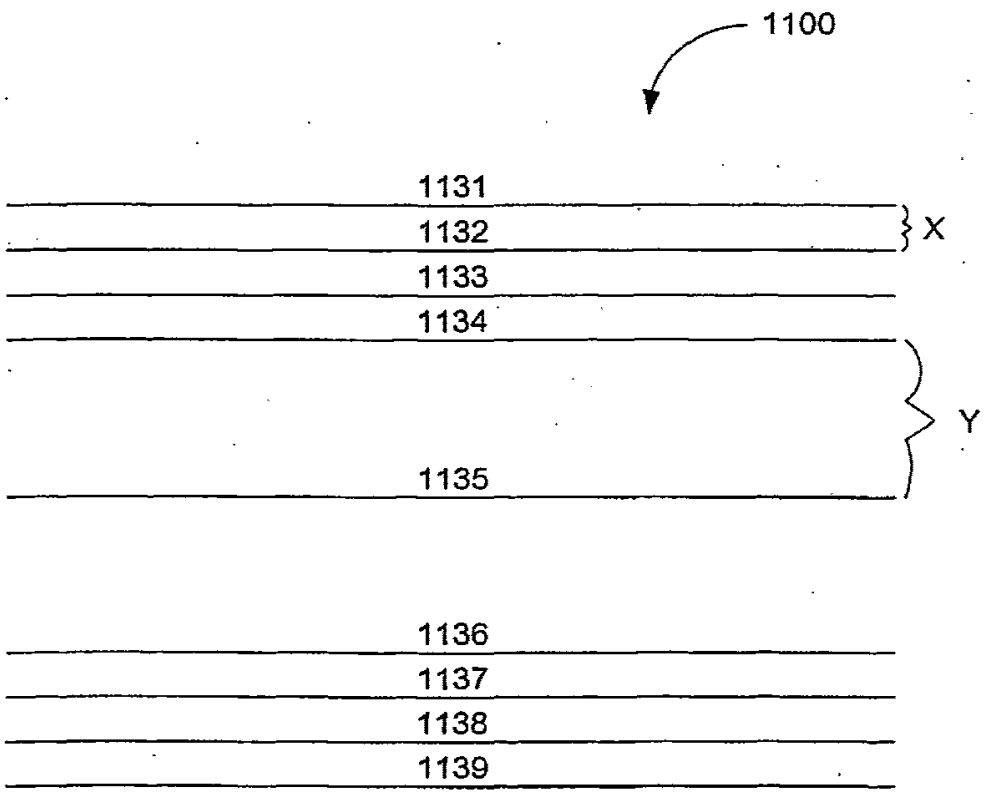


Figure 24

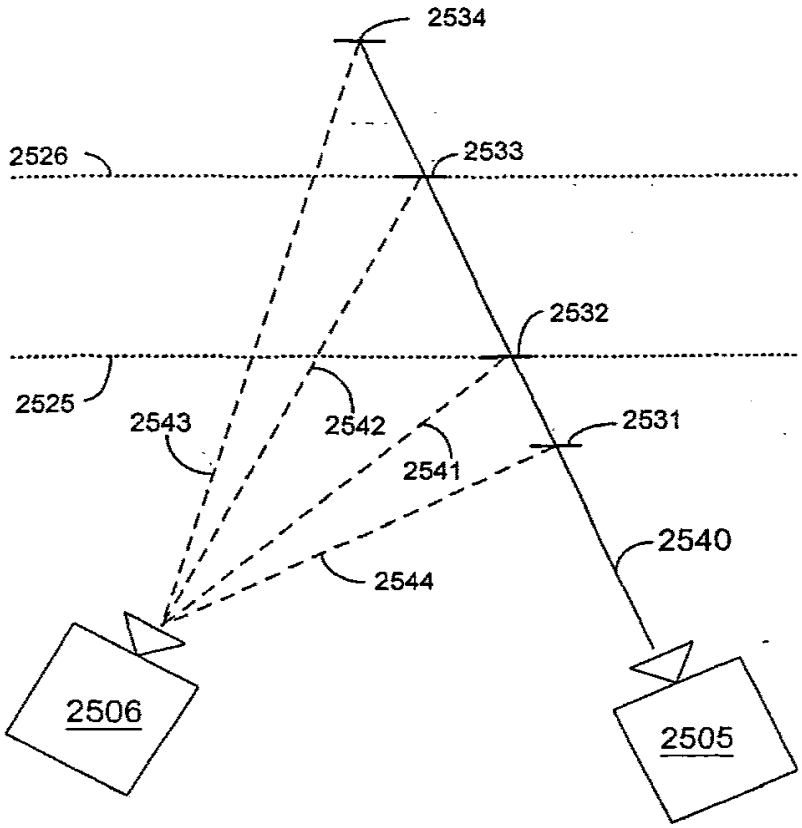


Figure 25

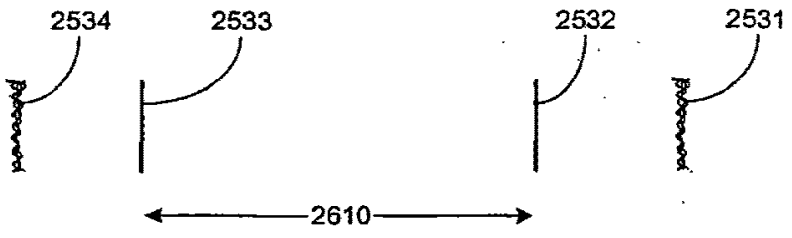


Figure 26

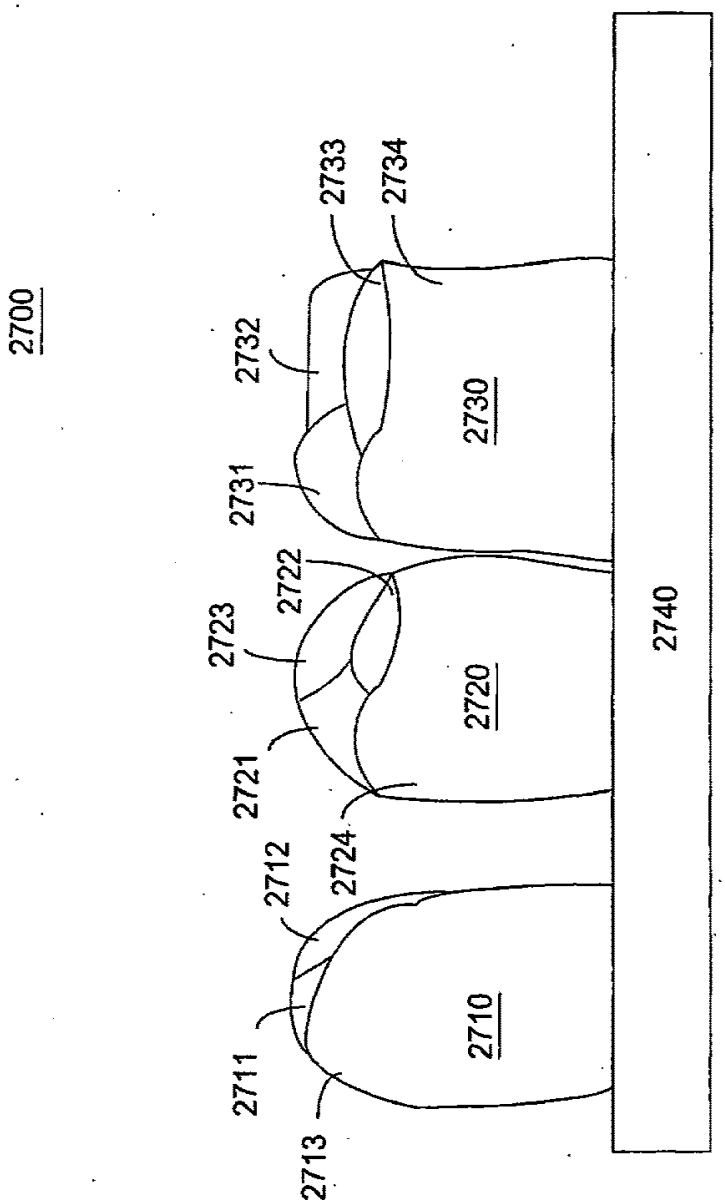

2700
2733
2734
2732
2730
2731
2722
2723
2720
2721
2724
2712
2740
2711
2710
2713

FIGURE 27

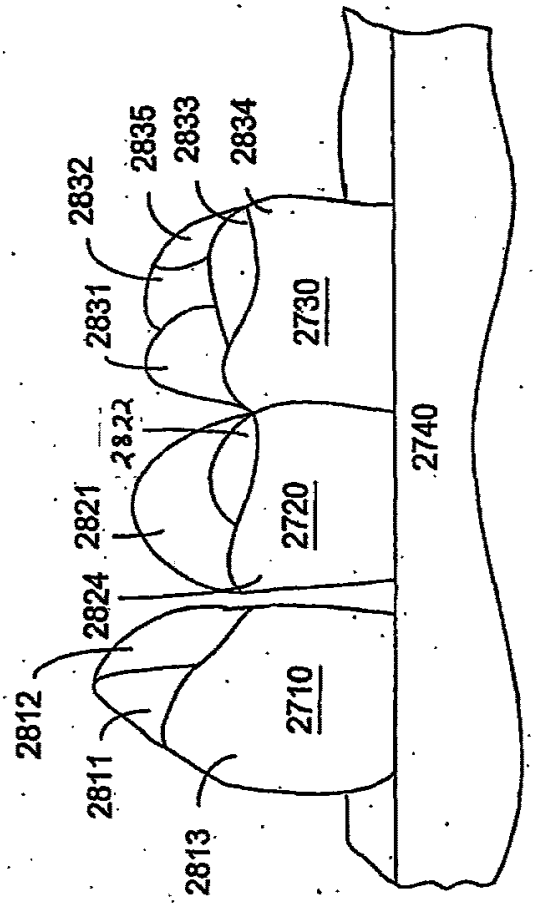

2832
2835
2833
2834
2831
2730
2822
2740
2821
2720
2824
2812
2710
2811
2813

FIGURE 28

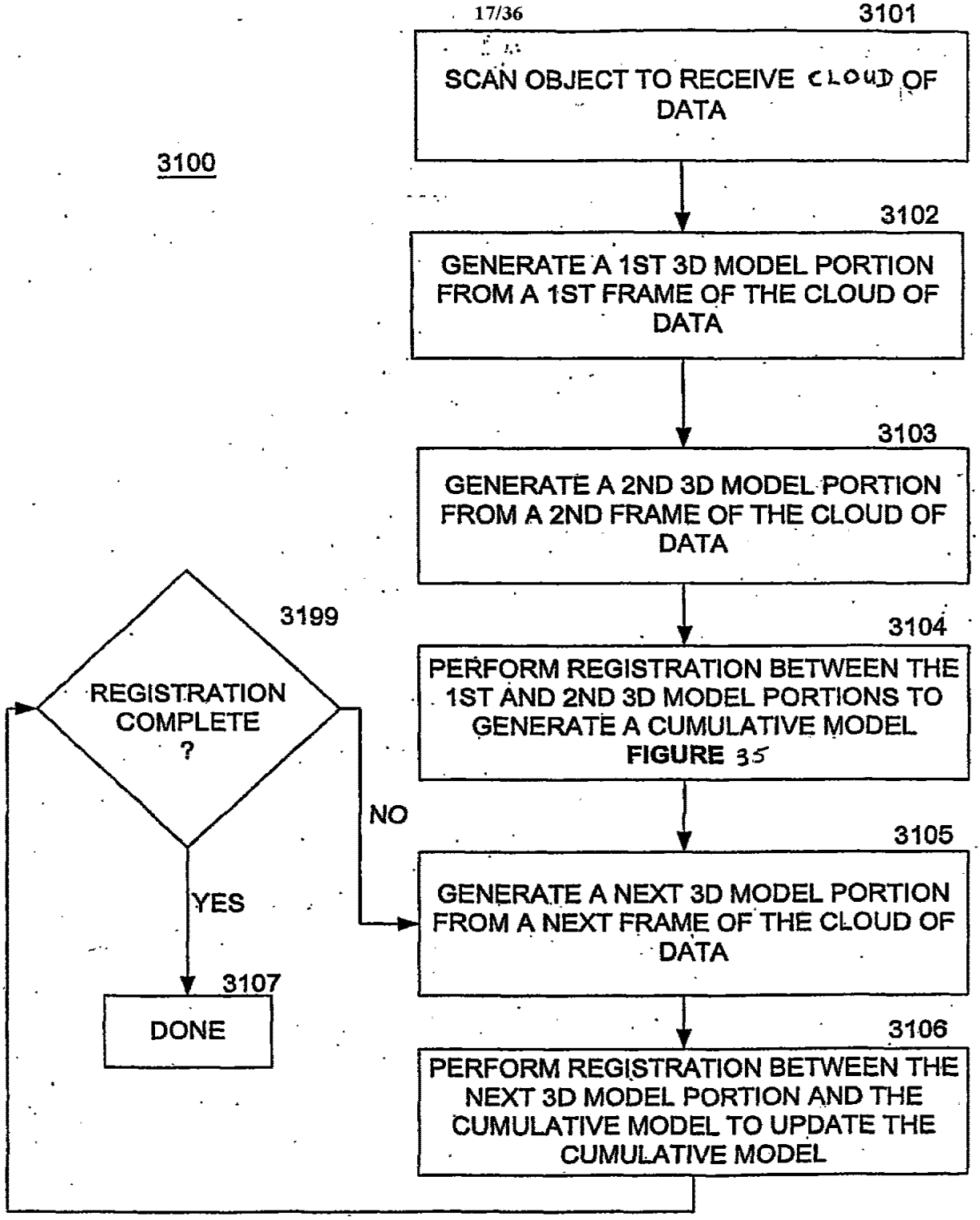

3100
3101
SCAN OBJECT TO RECEIVE CLOUD OF DATA
3102
GENERATE A 1ST 3D MODEL PORTION FROM A 1ST FRAME OF THE CLOUD OF DATA
3103
GENERATE A 2ND 3D MODEL PORTION FROM A 2ND FRAME OF THE CLOUD OF DATA
3104
PERFORM REGISTRATION BETWEEN THE 1ST AND 2ND 3D MODEL PORTIONS TO GENERATE A CUMULATIVE MODEL
FIGURE 35
3105
GENERATE A NEXT 3D MODEL PORTION FROM A NEXT FRAME OF THE CLOUD OF DATA
3106
PERFORM REGISTRATION BETWEEN THE NEXT 3D MODEL PORTION AND THE CUMULATIVE MODEL TO UPDATE THE CUMULATIVE MODEL
3199
REGISTRATION COMPLETE ?
NO
YES
3107
DONE

FIGURE 31

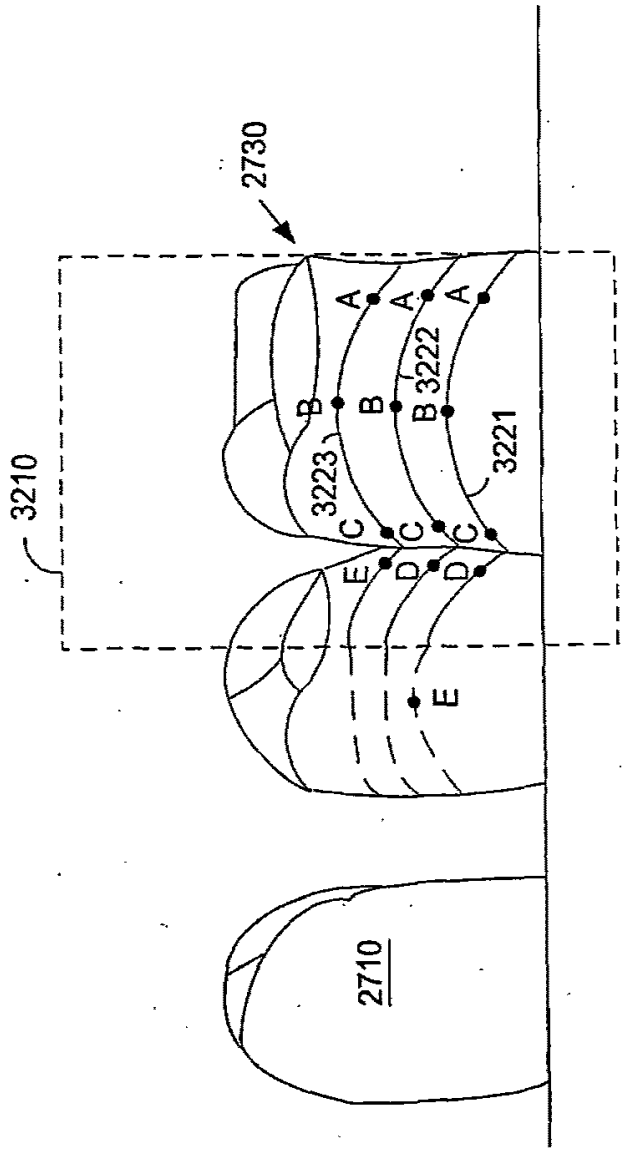


FIGURE 32

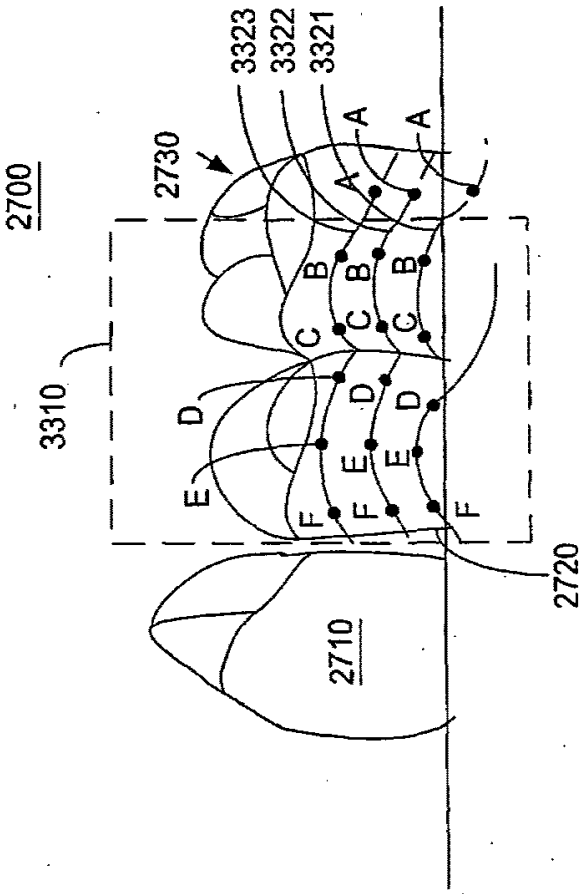

2700
2730
3323
3322
3321
A
A
A
B
B
B
C
C
C
D
D
D
E
E
E
F
F
F
3310
2720
2710

FIGURE 33

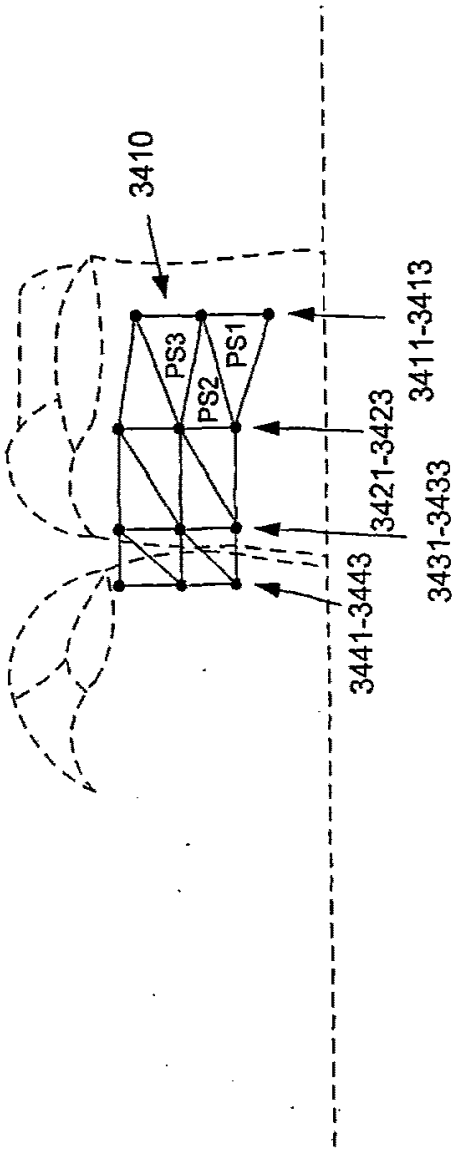


FIGURE 34

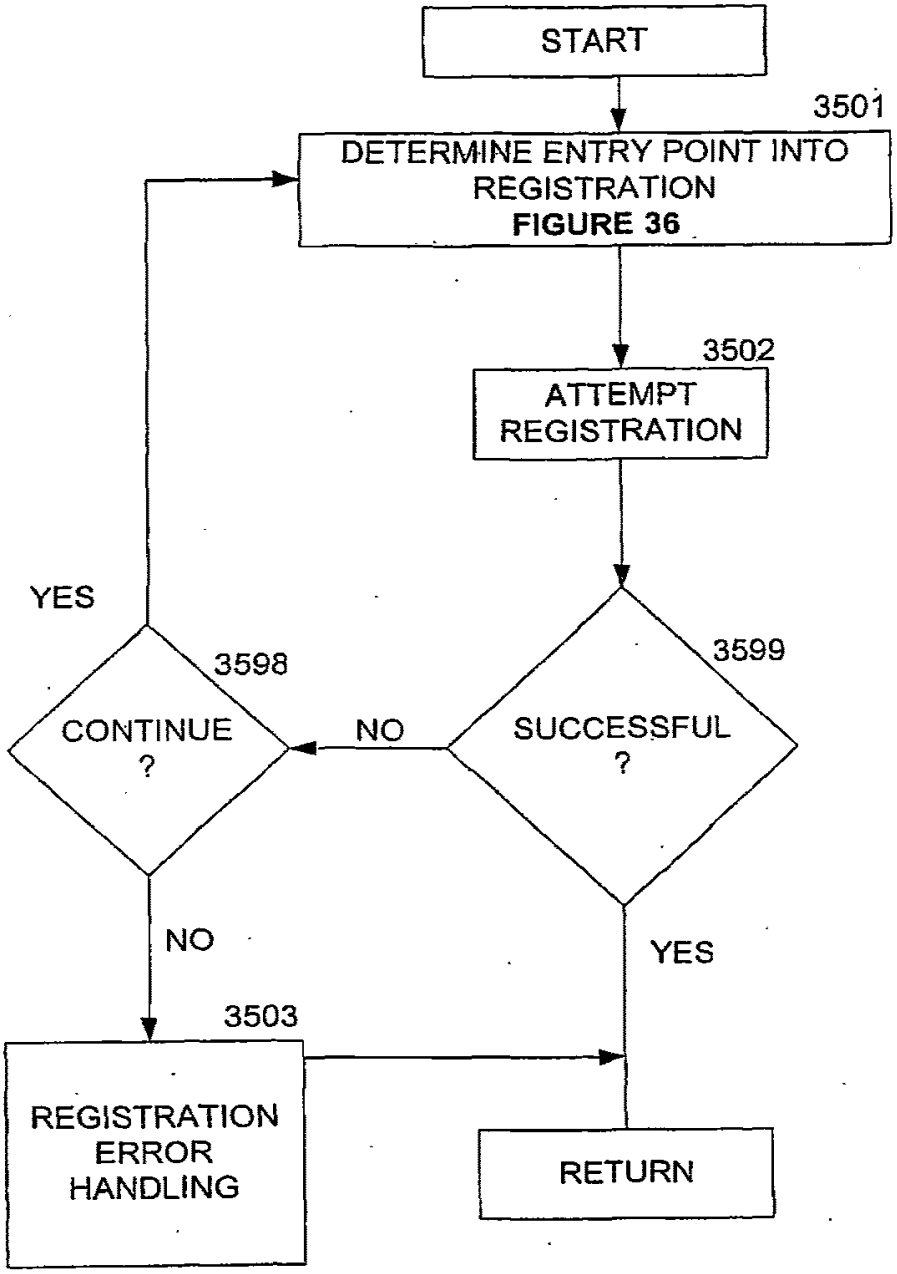

START
3501
DETERMINE ENTRY POINT INTO REGISTRATION
FIGURE 36
3500
3502
ATTEMPT REGISTRATION
YES
3598
CONTINUE ?
NO
3599
SUCCESSFUL ?
NO
YES
3503
REGISTRATION ERROR HANDLING
RETURN

FIGURE 35

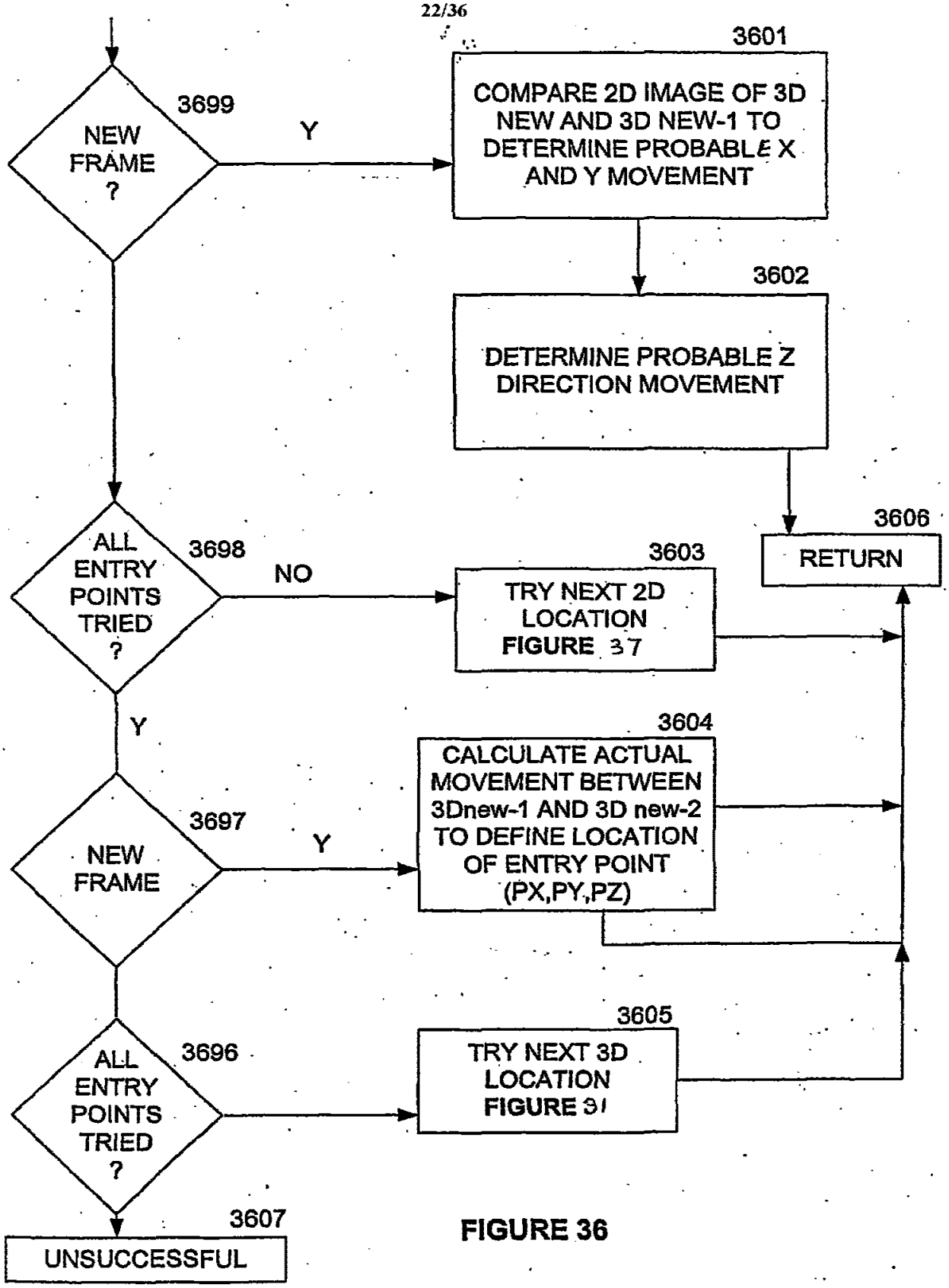

3601
COMPARE 2D IMAGE OF 3D NEW AND 3D NEW-1 TO DETERMINE PROBABLE X AND Y MOVEMENT
3699
NEW FRAME ?
Y
3602
DETERMINE PROBABLE Z DIRECTION MOVEMENT
3606
RETURN
ALL ENTRY POINTS TRIED ?
3698
NO
3603
TRY NEXT 2D LOCATION FIGURE 37
Y
3604
CALCULATE ACTUAL MOVEMENT BETWEEN 3Dnew-1 AND 3D new-2 TO DEFINE LOCATION OF ENTRY POINT (PX,PY,PZ)
NEW FRAME
3697
Y
3605
TRY NEXT 3D LOCATION FIGURE 37
ALL ENTRY POINTS TRIED ?
3696
3607
UNSUCCESSFUL

FIGURE 36

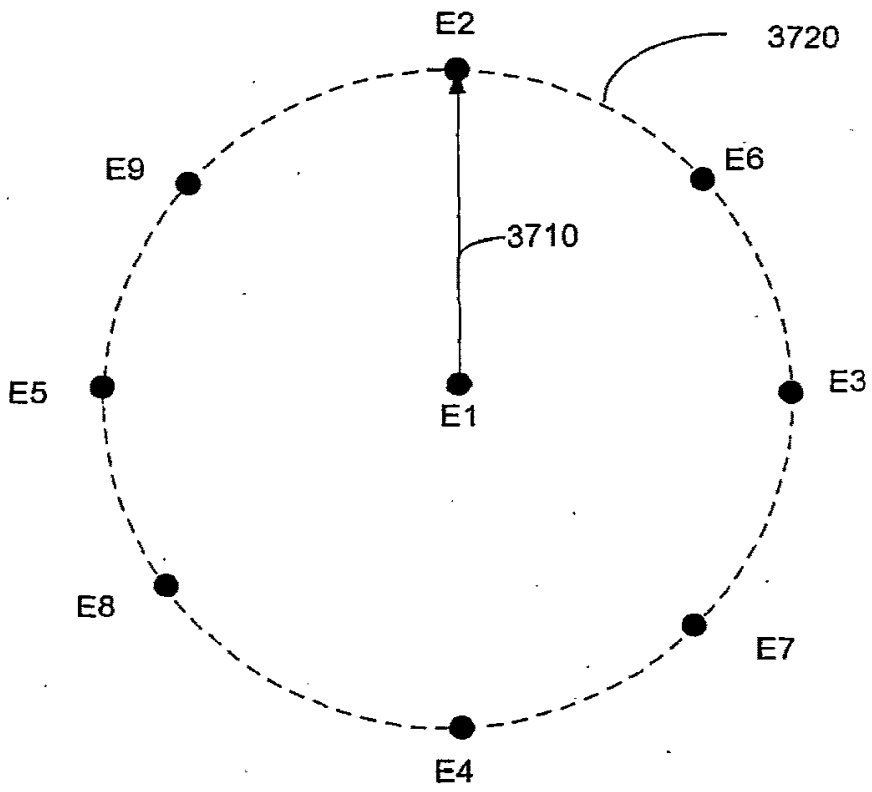


FIGURE 37

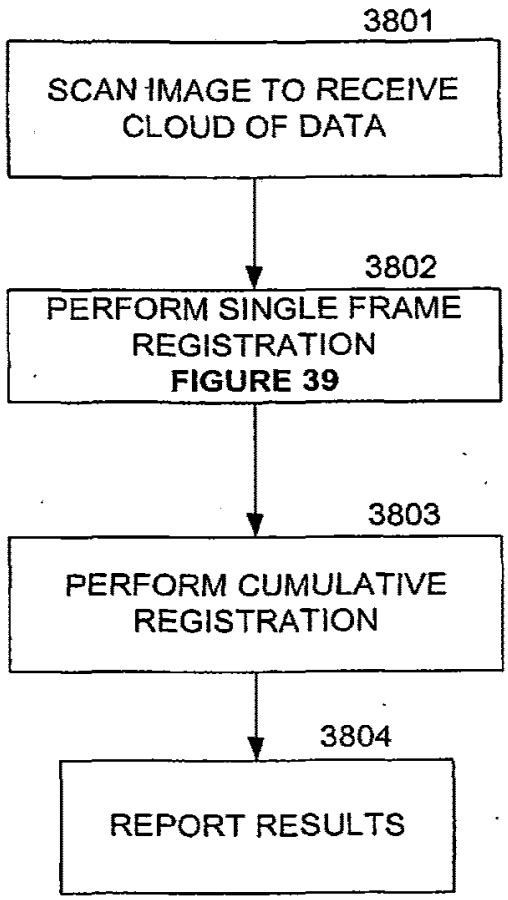

3801
3800
SCAN IMAGE TO RECEIVE CLOUD OF DATA
3802
PERFORM SINGLE FRAME REGISTRATION
FIGURE 39
3803
PERFORM CUMULATIVE REGISTRATION
3804
REPORT RESULTS

FIGURE 38

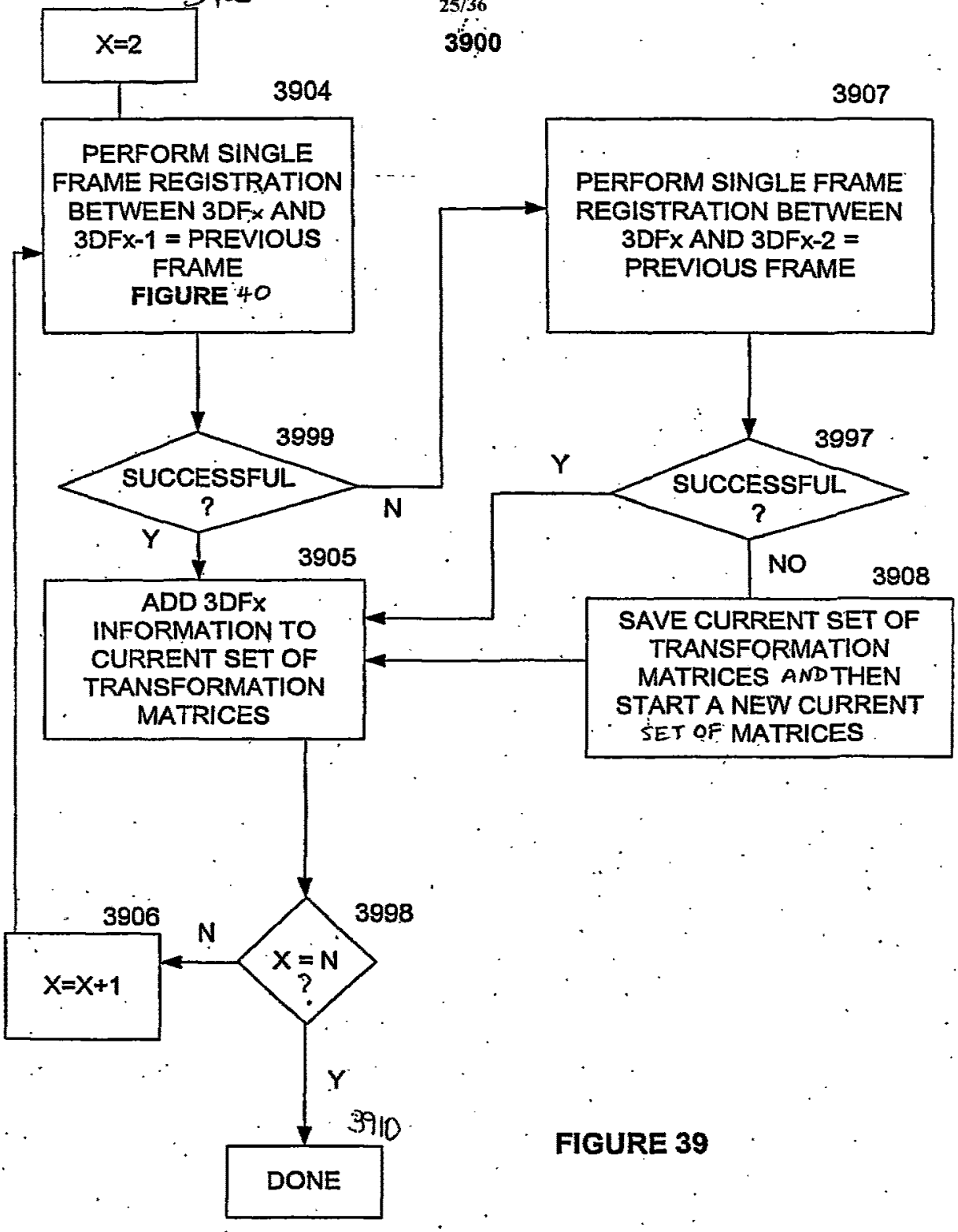

3900
3903
X=2
3904
PERFORM SINGLE FRAME REGISTRATION BETWEEN 3DFx AND 3DFx-1 = PREVIOUS FRAME
FIGURE 40
3907
PERFORM SINGLE FRAME REGISTRATION BETWEEN 3DFx AND 3DFx-2 = PREVIOUS FRAME
3999
SUCCESSFUL ?
N
Y
3997
SUCCESSFUL ?
Y
NO
3905
ADD 3DFx INFORMATION TO CURRENT SET OF TRANSFORMATION MATRICES
3908
SAVE CURRENT SET OF TRANSFORMATION MATRICES AND THEN START A NEW CURRENT SET OF MATRICES
3906
X=X+1
N
3998
X = N ?
Y
3910
DONE

FIGURE 39

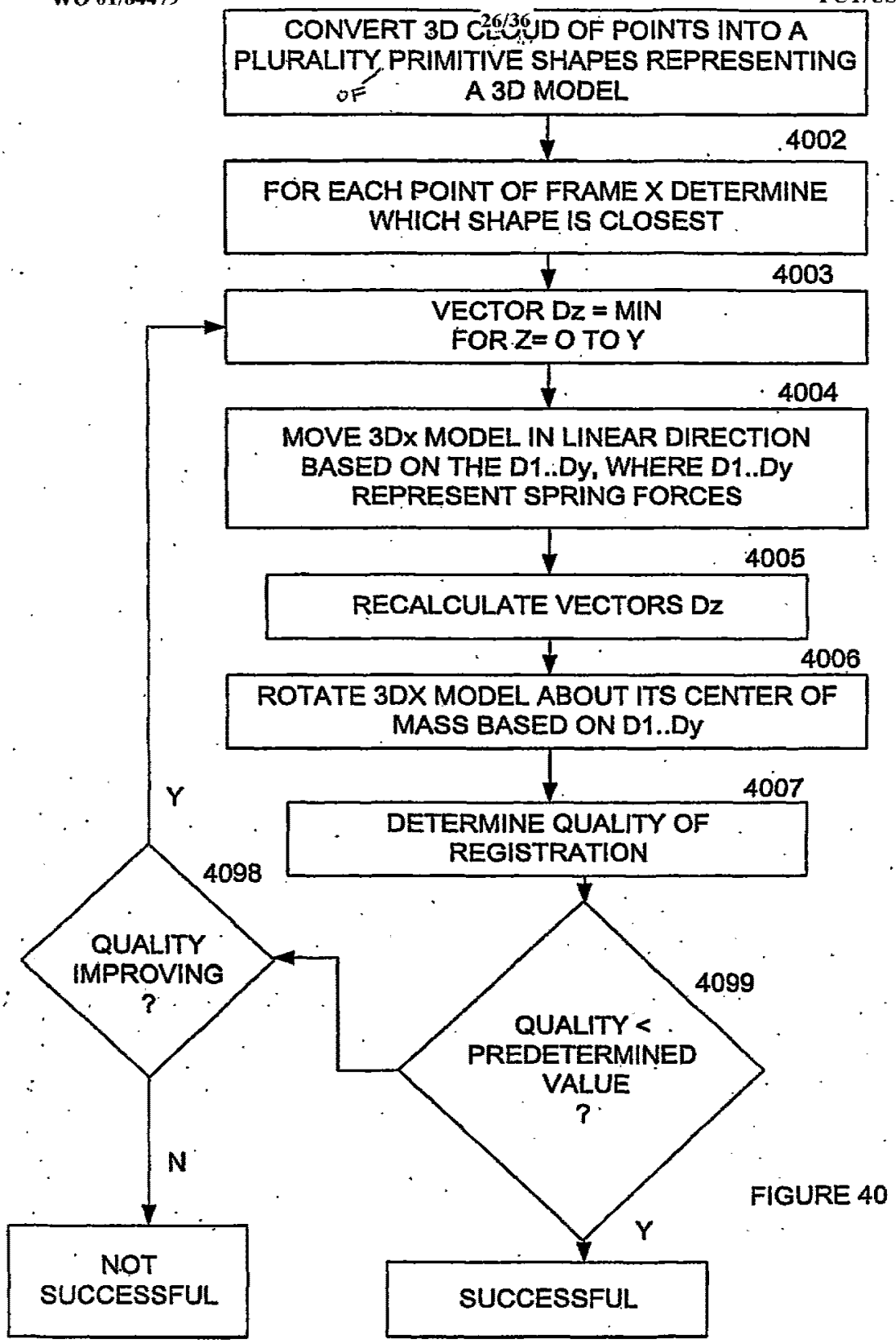

CONVERT 3D CLOUD OF POINTS INTO A PLURALITY OF PRIMITIVE SHAPES REPRESENTING A 3D MODEL
4002
FOR EACH POINT OF FRAME X DETERMINE WHICH SHAPE IS CLOSEST
4003
VECTOR Dz = MIN FOR Z= O TO Y
4004
MOVE 3Dx MODEL IN LINEAR DIRECTION BASED ON THE D1..Dy, WHERE D1..Dy REPRESENT SPRING FORCES
4005
RECALCULATE VECTORS Dz
4006
ROTATE 3DX MODEL ABOUT ITS CENTER OF MASS BASED ON D1..Dy
4007
DETERMINE QUALITY OF REGISTRATION
4098
QUALITY IMPROVING ?
4099
QUALITY < PREDETERMINED VALUE ?
Y
N
Y
NOT SUCCESSFUL
SUCCESSFUL

FIGURE 40

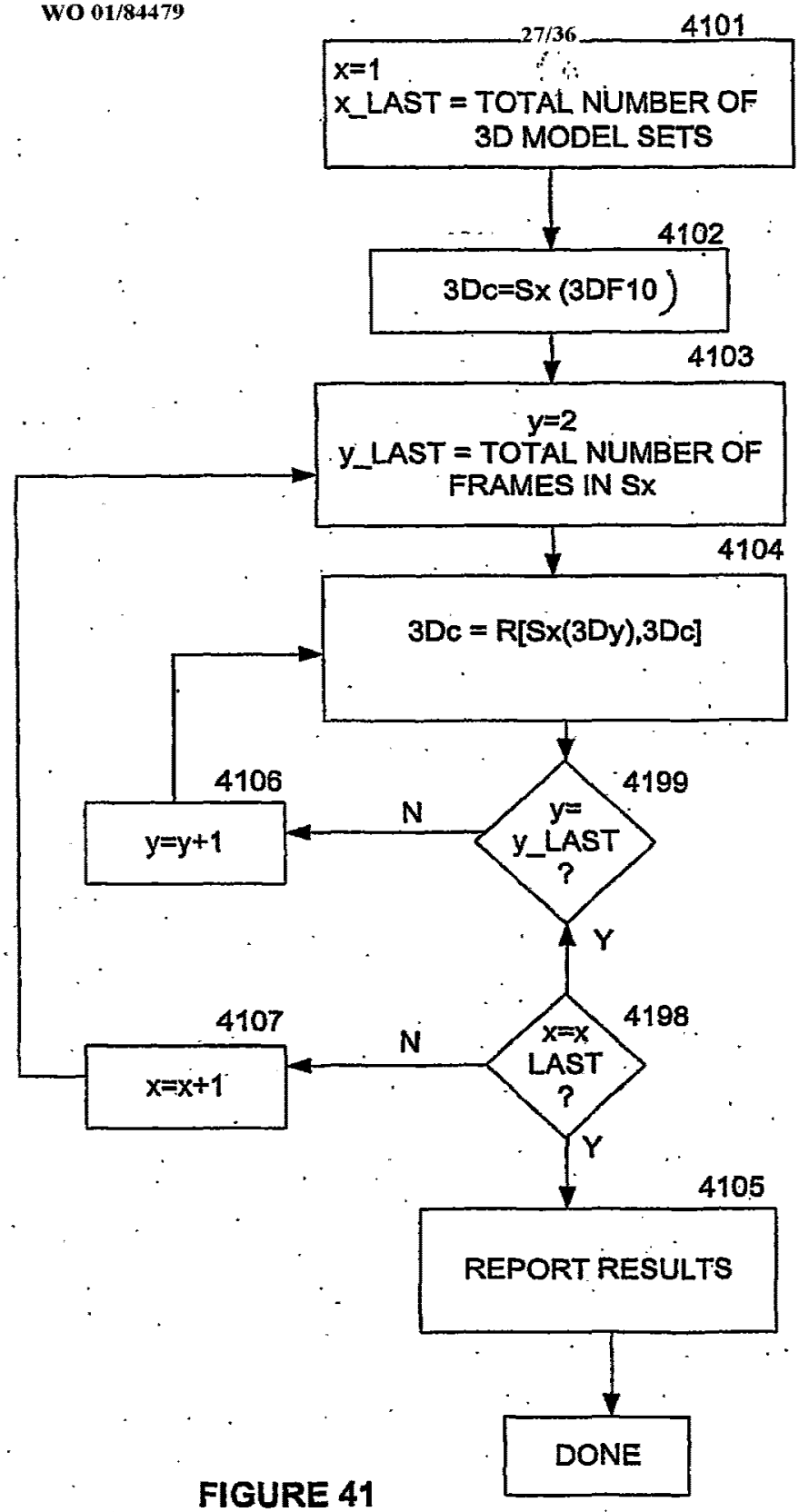

4100
4101
x=1
x_LAST = TOTAL NUMBER OF 3D MODEL SETS
4102
3Dc=Sx (3DF10)
4103
y=2
y_LAST = TOTAL NUMBER OF FRAMES IN Sx
4104
3Dc = R[Sx(3Dy),3Dc]
4199
y= y_LAST ?
N
4106
y=y+1
Y
4198
x=x LAST ?
N
4107
x=x+1
Y
4105
REPORT RESULTS
DONE

FIGURE 41

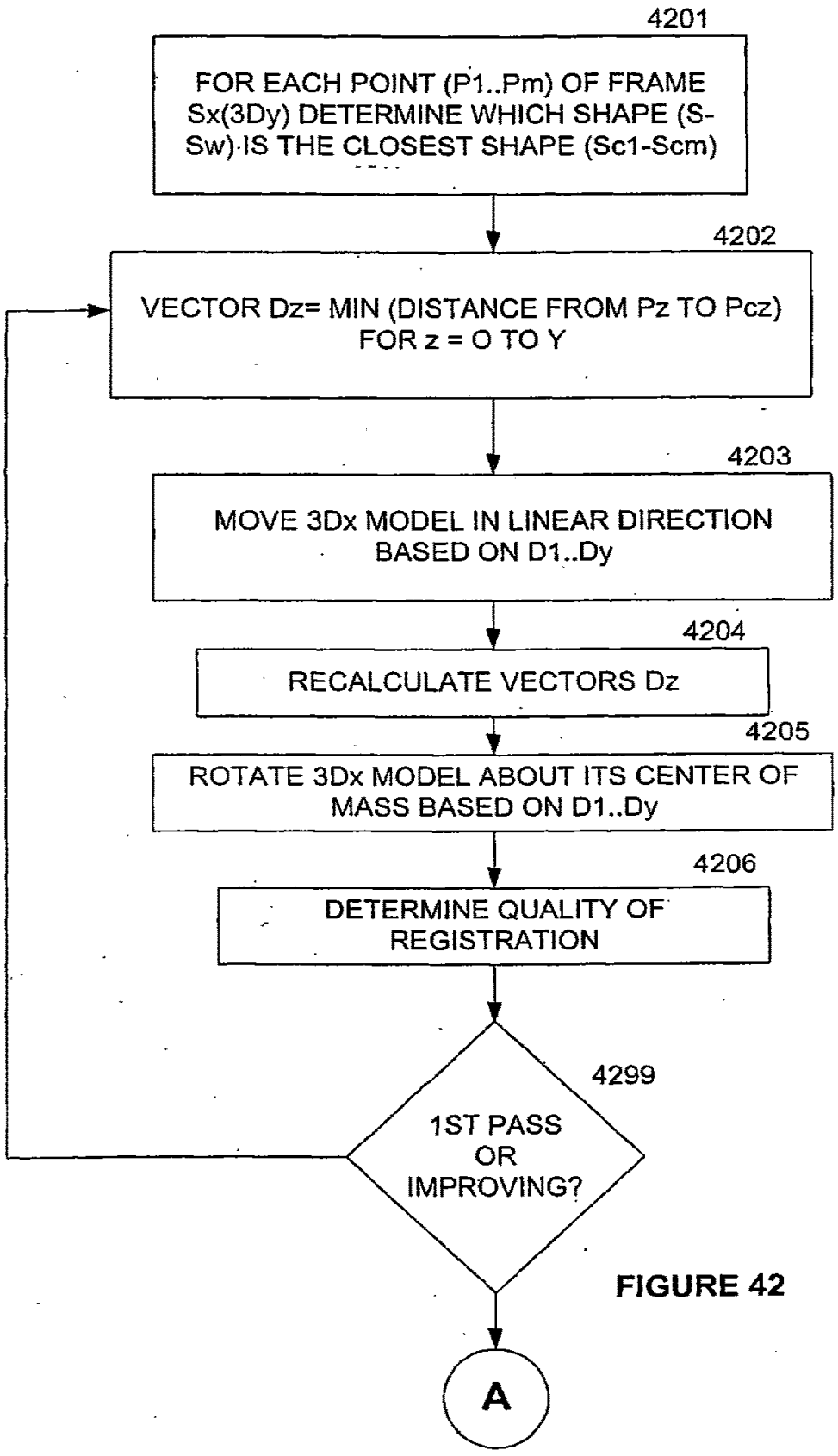

4201
FOR EACH POINT (P1..Pm) OF FRAME Sx(3Dy) DETERMINE WHICH SHAPE (S-Sw) IS THE CLOSEST SHAPE (Sc1-Scm)
4202
VECTOR Dz= MIN (DISTANCE FROM Pz TO Pcz) FOR z = O TO Y
4203
MOVE 3Dx MODEL IN LINEAR DIRECTION BASED ON D1..Dy
4204
RECALCULATE VECTORS Dz
4205
ROTATE 3Dx MODEL ABOUT ITS CENTER OF MASS BASED ON D1..Dy
4206
DETERMINE QUALITY OF REGISTRATION
4299
1ST PASS OR IMPROVING?
A

FIGURE 42

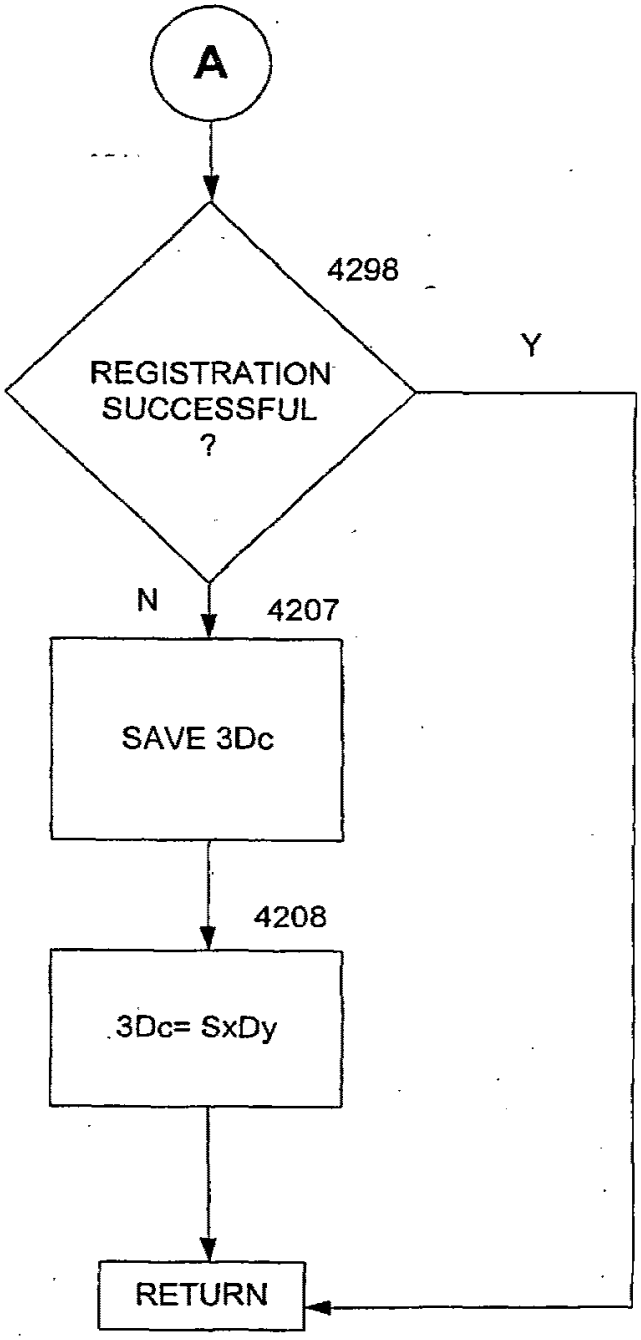

A
4298
REGISTRATION SUCCESSFUL ?
Y
N
4207
SAVE 3Dc
4208
3Dc= SxDy
RETURN

FIGURE 43

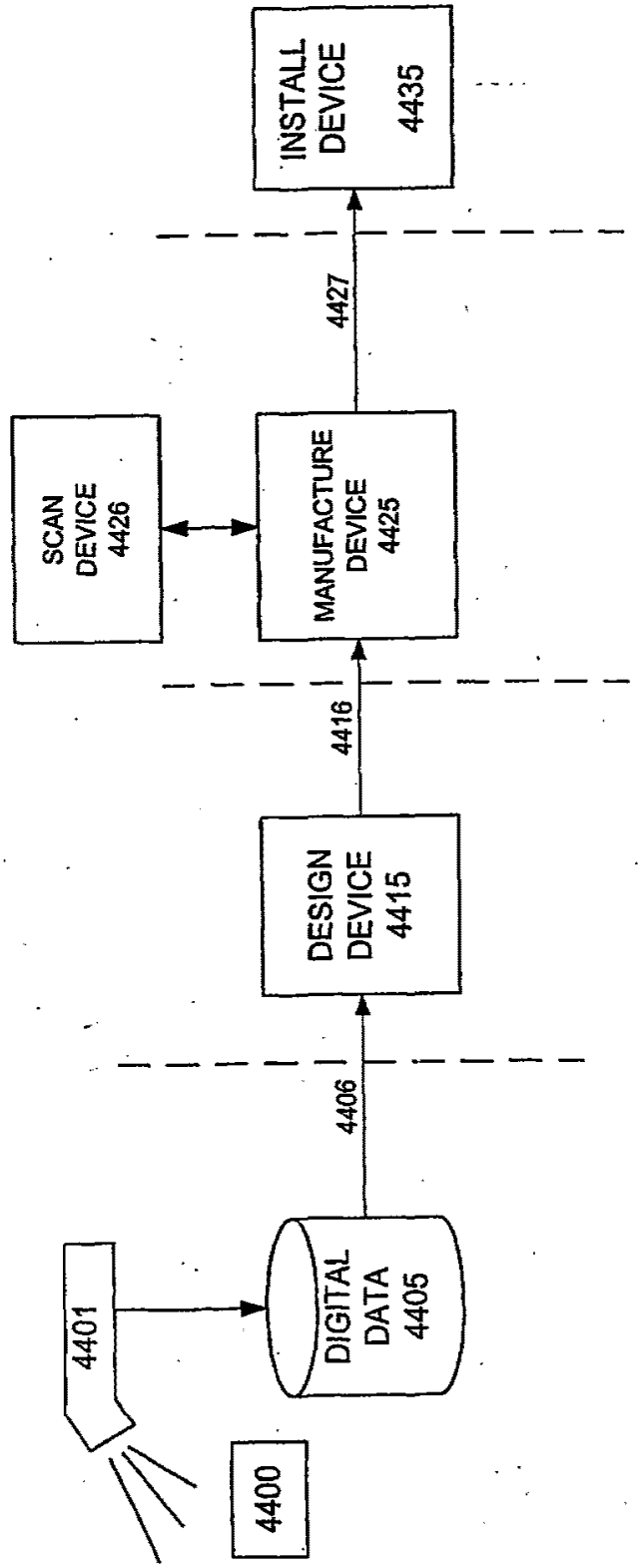

4400
4401
DIGITAL DATA 4405
4406
DESIGN DEVICE 4415
4416
SCAN DEVICE 4426
MANUFACTURE DEVICE 4425
4427
INSTALL DEVICE 4435
4441
4442
4443
4444

FIGURE 44

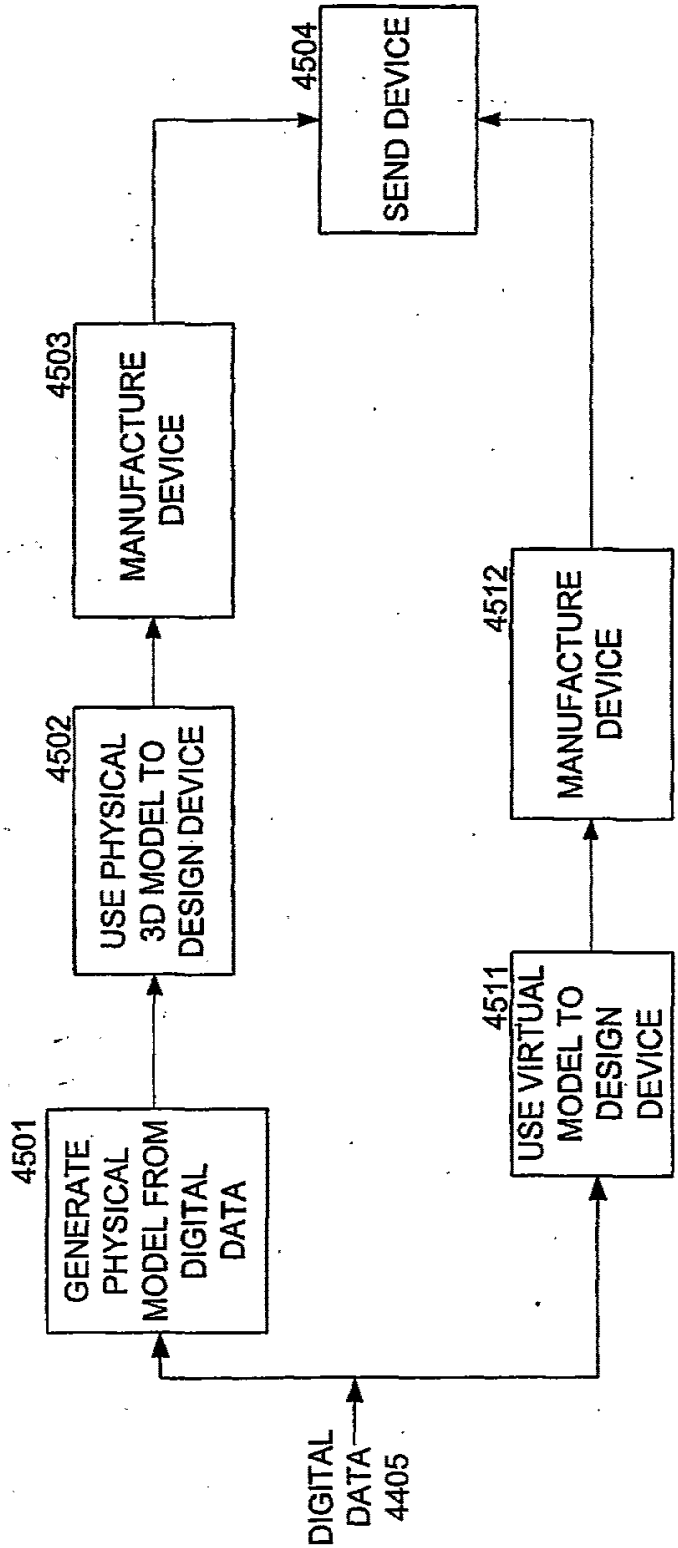

4504
SEND DEVICE
4503
MANUFACTURE DEVICE
4502
USE PHYSICAL 3D MODEL TO DESIGN DEVICE
4501
GENERATE PHYSICAL MODEL FROM DIGITAL DATA
4512
MANUFACTURE DEVICE
4511
USE VIRTUAL MODEL TO DESIGN DEVICE
DIGITAL DATA 4405

FIGURE 45

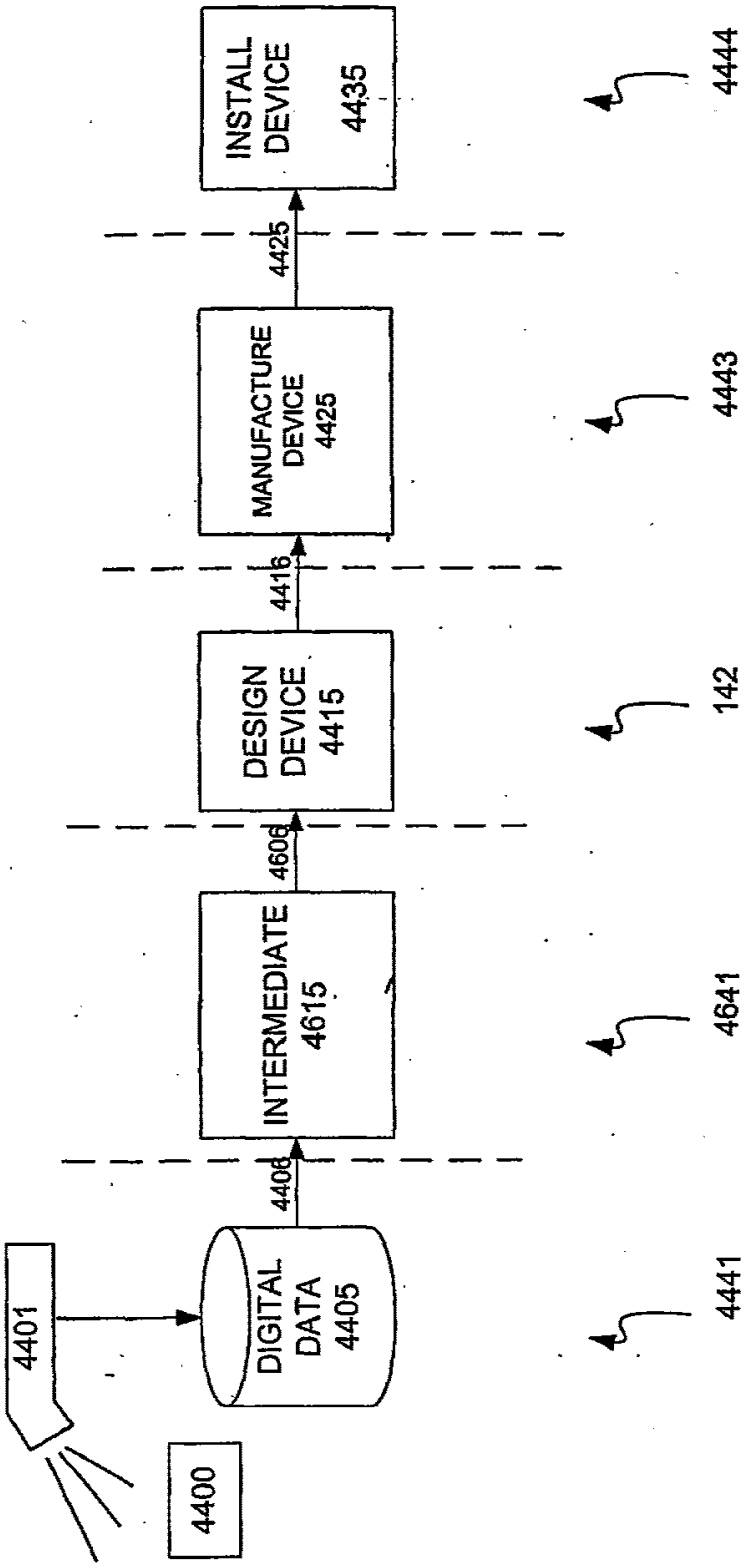

4401
4400
DIGITAL DATA 4405
4406
INTERMEDIATE 4615
4606
DESIGN DEVICE 4415
4416
MANUFACTURE DEVICE 4425
4425
INSTALL DEVICE 4435
4441
4641
142
4443
4444

FIGURE 46

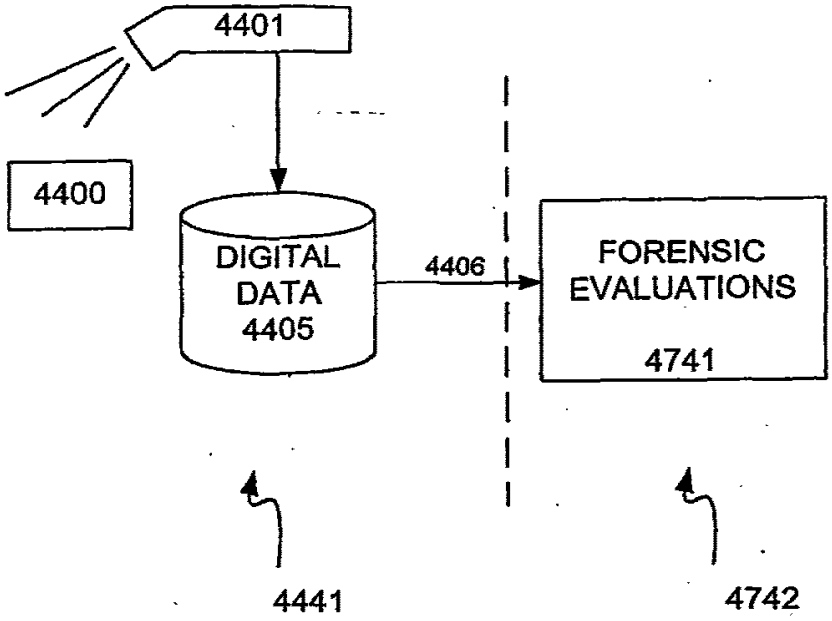


FIGURE 47

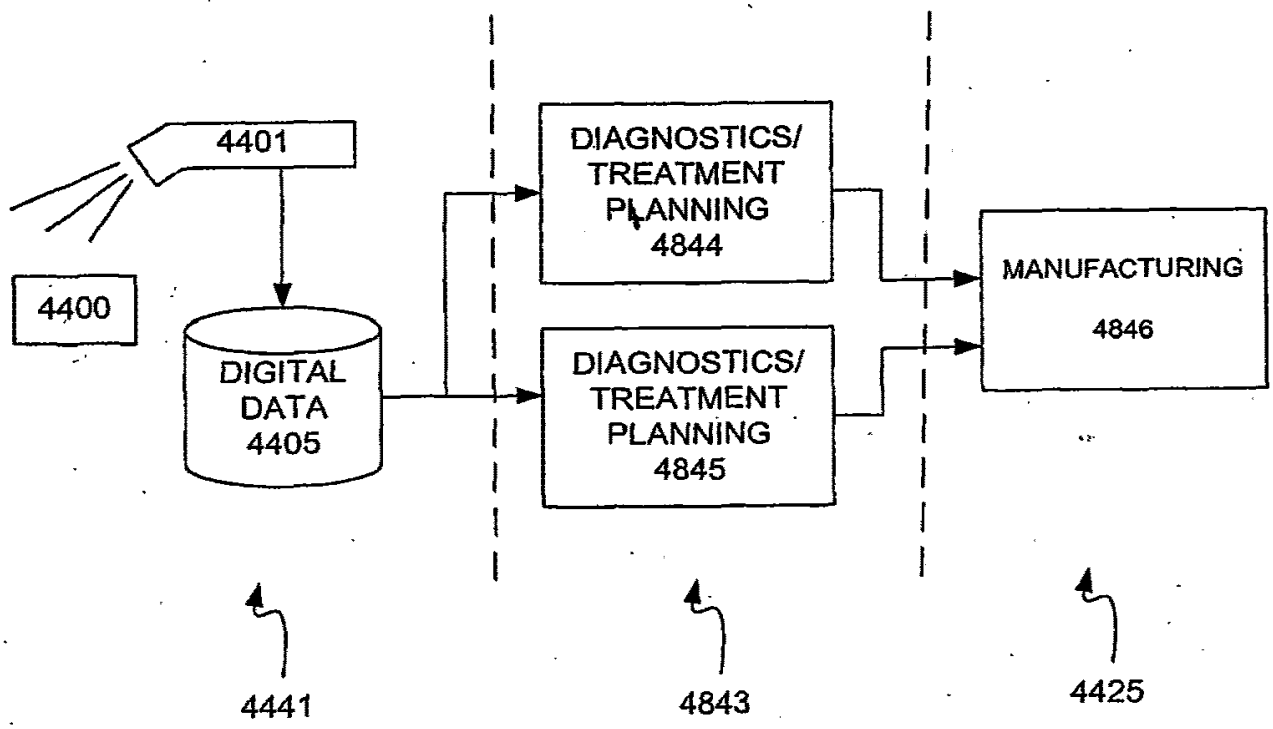


FIGURE 48

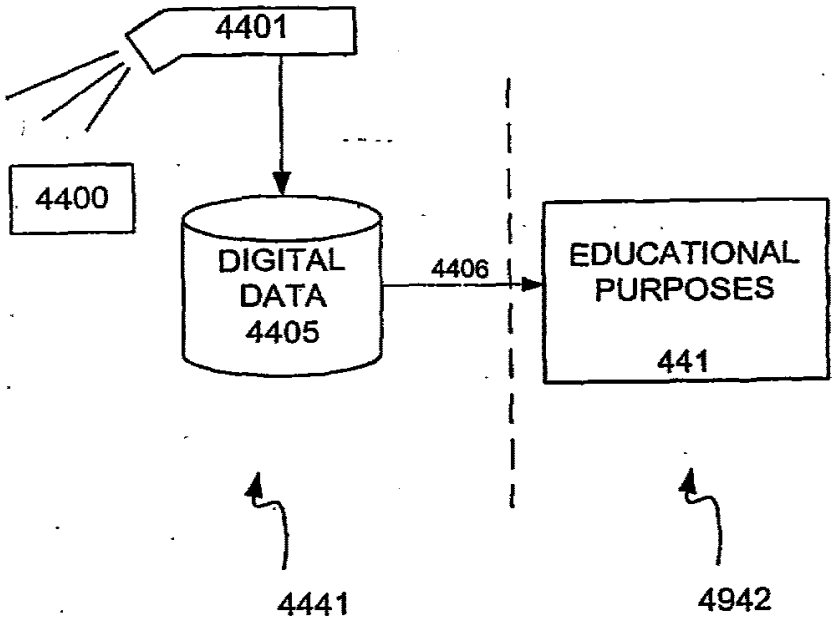


FIGURE 49

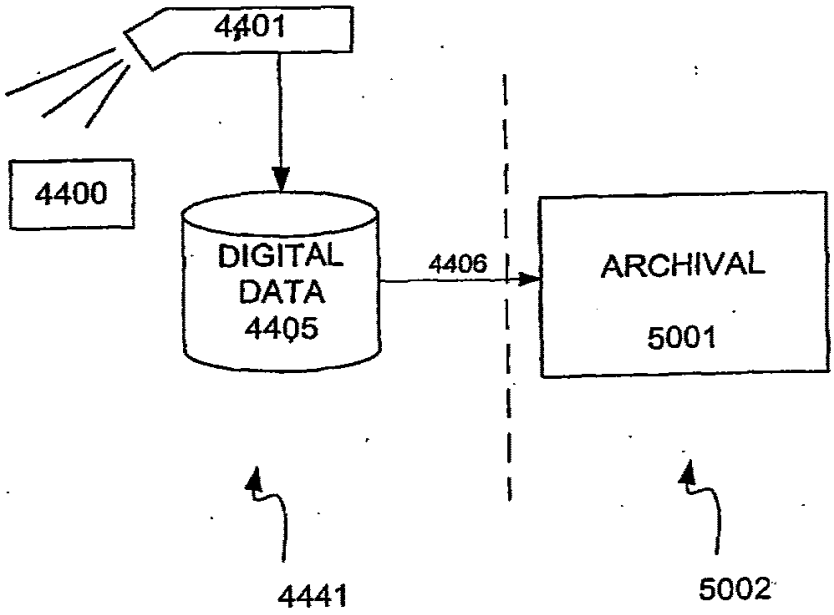


FIGURE 50

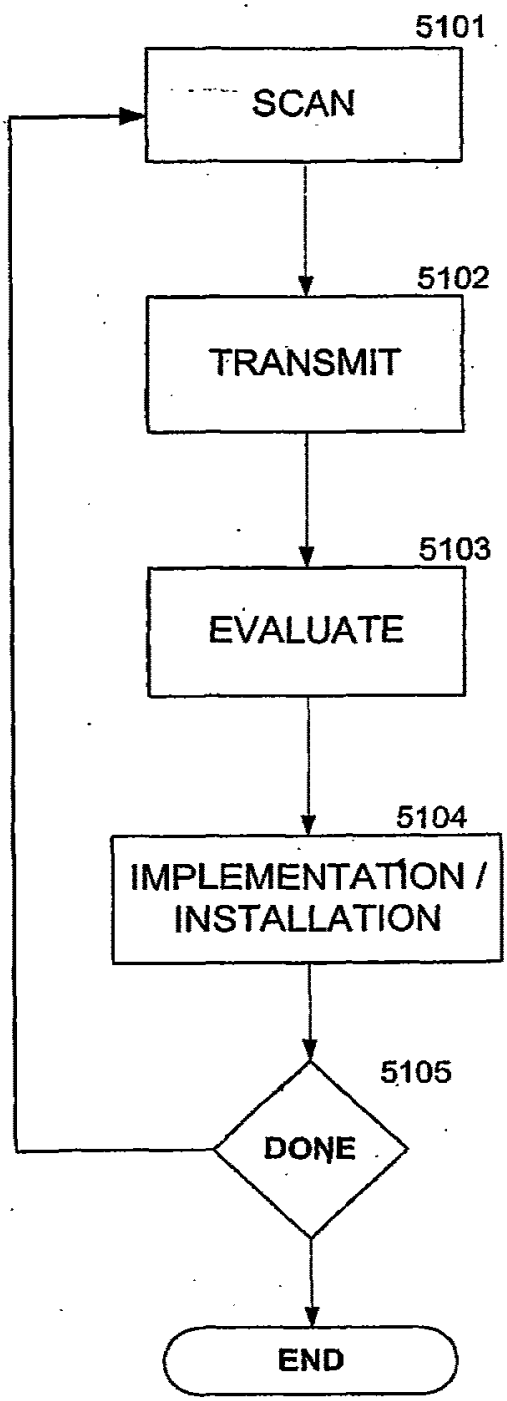

5101
SCAN
5102
TRANSMIT
5103
EVALUATE
5104
IMPLEMENTATION / INSTALLATION
5105
DONE
END

FIGURE 51

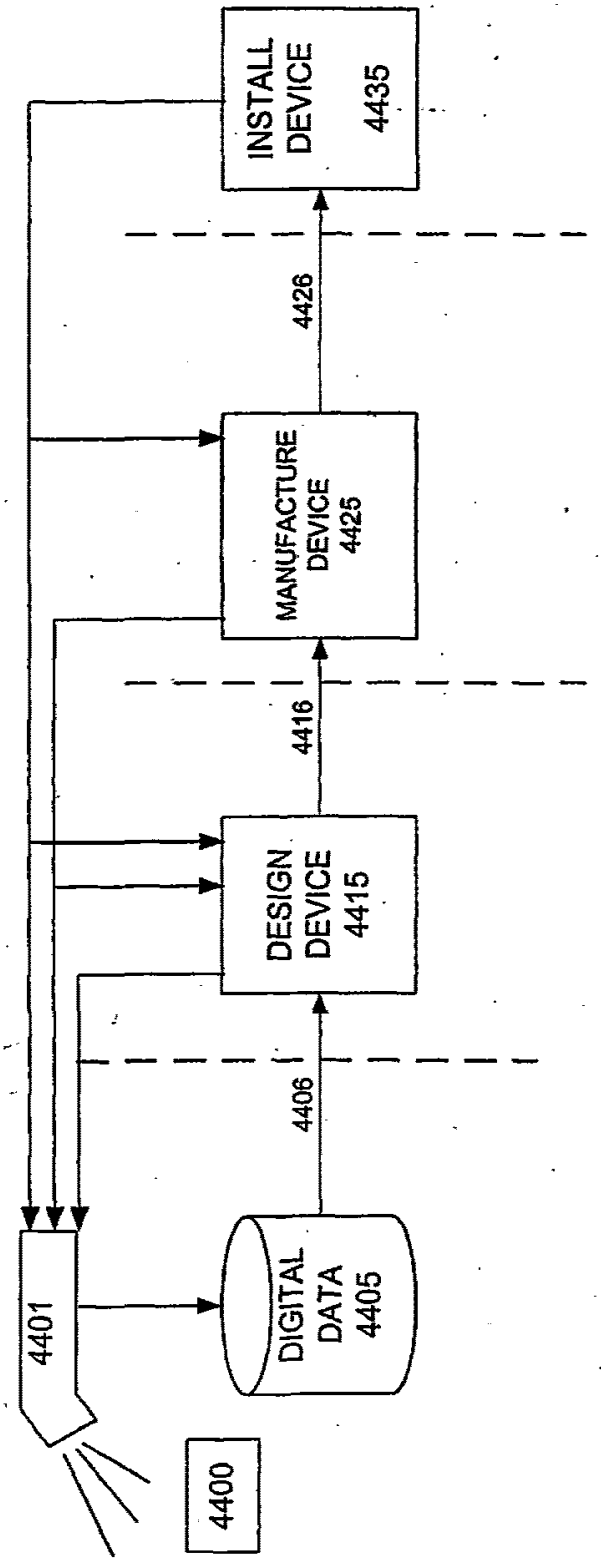

INSTALL DEVICE 4435
4444
4426
MANUFACTURE DEVICE 4425
4443
4416
DESIGN DEVICE 4415
4442
4406
DIGITAL DATA 4405
4441
4401
4400

FIGURE 52

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/12107

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G06K 9/00, 9/46, 9/50; G03B 21/32, 19/18, 35/00, 41/00; G06T 15/00, 15/40; G01V 8/00; G01C 3/00; G05B 11/01, 13/02, 19/18; G06F 19/00

US CL : 382/100, 108, 109, 141, 181, 190, 193, 201, 203, 204, 282, 285, 286, 287, 294; 352/41, 47, 57, 68, 89;

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : Please See Continuation Sheet

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,724,435 A (MALZBENDER) 03 March 1998 (03.03.1998), the whole document .	1-2, 5-18
X	US 5,880,961 A (CRUMP) 09 March 1999, (09.03.1999), the whole document.	1-2, 5-18
X	US 5,886,775 A (HOUSER ET AL.) 23 March 1999, (23.03.1999), the whole document.	1-2, 5-18
X	US 5,988,862 A (KACYRA ET AL.) 23 November 1999, (23.11.1999), the whole document.	1-2, 5-18
X,P	US 6,100,893 A (ENSZ ET AL.) 08 August 2000, (08.08.2000), the whole document.	1-2, 5-18
X,P	US 6,167,151 A (ALBECK ET AL.) 26 December 2000, (26.12.2000), the whole document.	1-2, 5-18
X,P	US 6,201,546 B1 (BODOR ET AL.) 13 March 2001, (13.03.2001), the whole document.	1-2, 5-18
X,E	US 6,253,164 B1 (ROHM ET AL.) 26 June 2001, (26.06.2001), the whole document.	1-2, 5-18
X	US 4,286,852 A (STERN ET AL.) 01 September 1981, (01.09.1981), the whole document.	3-4, 42-44, 47-48
X	US 4,508,452 A (DIMATTEO ET AL.) 02 April 1985, (02.04.1985), the whole document.	3-4, 28-31, 37-48
X	US 4,616,121 A (CLOCKSIN ET AL.) 07 October 1986, (07.10.1989), the whole document.	3-4, 42-44, 47-48
X	US 5,028,799 A (CHEN ET AL.) 02 July 1991, (02.07.1991), the whole document.	3-4, 28-31, 37-48
X	US 5,098,426 A (SKLAR ET AL.) 24 March 1992, (24.03.1992), the whole document.	3-4, 42-44, 47-48

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
29 June 2001 (29.06.2001)

Date of mailing of the international search report
15 AUG 2001

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Authorized officer
Shervin Nakhjavan
Telephone No. 703 305-3900

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/12107

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,243,665 A (MANEY ET AL.) 07 September 1993, (07.09.1993), the whole document.	3-4, 28-31, 37-48
X	US 5,991,437 A (MIGDAL ET AL.) 23 November 1999, (23.11.1999), the whole document.	3-4, 42-44, 47-48
X,P	US 6,211,506 B1 (PRYOR ET AL.) 03 April 2001, (03.04.2001), the whole document.	3-4, 42-44, 47-48
X	US 4,294,544 A (ALTSCHULER ET AL.) 13 October 1981, (13.10.1981), the whole document.	19-27, 32-36
X	US 4,935,635 A (O'HARRA) 19 June 1990, (19.06.1990), the whole document.	19-27, 32-36
X	US 5,131,844 A (MARINACCIO ET AL.) 21 July 1992, (21.07.1992), the whole document.	19-27, 32-36
X	US 5,214,686 A (WEBBER) 25 May 1993, (25.05.1993), the whole document.	19-27, 32-36
X	US 5,347,454 A (MUSHABAC) 13 September 1994, (13.09.1994), the whole document.	19-27, 32-36
X	US 5,823,778 A (SCHMITT ET AL.) 20 October 1998, (20.10.1998), the whole document.	19-27, 32-36
X	US 5,848,115 A (LITTLE ET AL.) 08 December 1998, (08.12.1998), the whole document.	19-27, 32-36
X	US 6,088,695 A (KARA) 11 July 2000, (11.07.2000), the whole document.	19-27, 32-36
X,P	US 6,139,499 A (WILK) 31 OCTOBER 2000, (31.10.2000), the whole document.	19-27, 32-36
X,P	US 6,205,716 B1 (PELTZ) 27 March 2001, (27.03. 2001), the whole document.	19-21, 32-36
X,E	US 6,217,334 B1 (HULTGREN) 17 April 2001, (17.04.2001), the whole document.	19-27, 32-36
X,E	US 6,227,850 B1 (CHISHTI ET AL.) 08 May 2001, (08.05.2001), the whole document.	19-27, 32-36
X	US 5,513,276 A (THEODORACATOS) 30 April 1996, (30.04.1996), the whole document.	28-31, 37-41, 45-46
X	US 4,745,469 A (WALDECKER ET AL.) 17 May 1988, (17.05.1988), the whole document.	28-31, 37-41, 45-46
X	US RE. 35,816 E (SCHULZ) 02 June 1998, (02.06.1998), the whole document.	28-31, 37-41, 45-46
X	US 5,985,495 A (OKUMURA ET AL.) 16 November 1999, (16.11.1999), the whole document.	28-31, 37-41, 45-46
X,P	US 6,124,934 A (SHAHAR ET AL.) 26 September 2000, (26.09.2000), the whole document.	28-31, 37-41, 45-46

Form PCT/ISA/210 (continuation of second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

Internati	lication No.
PCT/US01/12107	

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/12107

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-2, and 5-18, drawn to method of three dimensional image modeling of an object and aligning or registering of the model images onto one another.

Group II, claim(s) 3-4, 42-44, and 47-48, drawn to projection of an image onto an object and finding location of a point at the surface of an object.

Group III, claim(s) 19-27, and 32-36, drawn to remote communication of digital anatomical data.

Group IV, Claim(s) 28-31, 37-41, and 45-46 drawn to projection of patttern upon a surface and specific timing and pattern characteristics of projection step.

Continuation of B. FIELDS SEARCHED Item 1: 382/100, 108, 109, 141, 181, 190, 193, 201, 203, 204, 282, 285, 286, 287, 294; 352/41, 47, 57, 68, 89; 345/419, 421; 250/559.2, 559.29, 559.3, 559.31, 559.32; 356/3.01, 3.02, 3.03, 3. 09, 3.12; 700/28, 29, 30, 31, 51, 57, 58, 59, 95, 97, 98, 108, 117, 118, 119, 120, 145, 146, 151, 163, 201, 203, 285, 303

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [4] : G02B 21/00, 21/06, 26/10	A1	(11) International Publication Number: WO 88/ 07695
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(33) Priority Country: US

(71) Applicant: THE BOARD OF TRUSTEES OF THE LELAND STANFORD JUNIOR UNIVERSITY [US/US]; Stanford, CA 94305 (US).

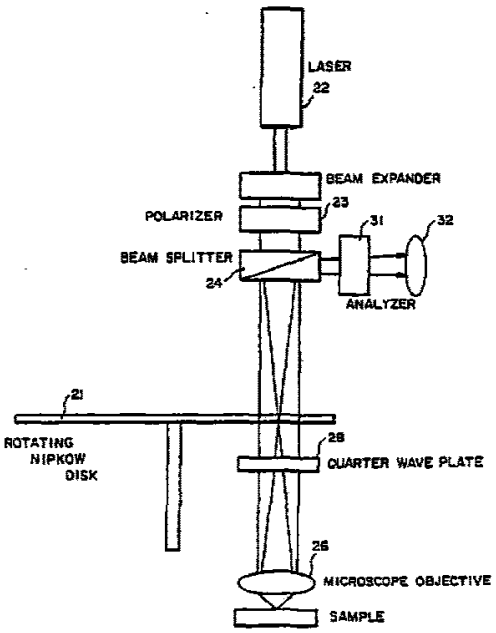
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(74) Agents: BREZNER, David, J. et al.; Flehr, Hohbach, Test, Albritton & Herbert, Four Embarcadero Center, Suite 3400, San Francisco, CA 94111-4187 (US).

(81) Designated States: AT (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: SCANNING CONFOCAL OPTICAL MICROSCOPE



(57) Abstract

A scanning confocal optical microscope using a Nipkow disc (21) having a plurality of pinholes to project light and an objective lens (26) to receive the light and illuminate points on an object to be viewed. Rotation of the disc scans the points across the object. The object is viewed by viewing the reflected light focused on the pinholes by the objective lens (26).

Exhibit 1004 page 312 of 1621
DENTAL IMAGING

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SCANNING CONFOCAL OPTICAL MICROSCOPE

This invention relates generally to confocal optical microscopes and more particularly to a scanning confocal optical microscope.

Conventional confocal optical microscopes are known for their extremely short depth of focus and improved transverse resolution. The main drawback with conventional confocal scanning optical microscopes is that they illuminate only one point on the object at a time. To scan the object either the sample or beam must be mechanically moved to form a raster image of the object. Mechanical scanning is time consuming.

In a paper appearing in The Journal of the Optical Society of America, Vol.58, No.5, May 1968, there is described a tandem-scanning reflected-light microscope. In the described microscope both the object plane and the image plane are scanned in tandem so that only light reflected from the object plane is included in the image. The object to be viewed is illuminated with light passing through a plurality of holes in a rotating disc which are focused onto the object by an objective lens. Thus, a large number of points on the object, corresponding to the holes which are illuminated, are illuminated at one time. The holes themselves are located along spiral paths. By rotating the disc a raster scan of the object is obtained. Reflected light from the illuminated spots is directed to the opposite side of the same apertured disc and passes

through optically congruent holes on diametrically opposite sides of the rotating disc. The image obtained had better contrast and sharpness than possible with the usual reflected-light microscope. This is due to the fact that reflected light from within the microscope and other stray light coming from other points is intercepted by the opaque portions of the disc and the image only comprised reflection from the illuminated spots. The system of the prior art is extremely complex and difficult to align because of the necessity of assuring that the light reflected from the illuminated spots must pass through congruent holes on the opposite side of the rotating disc. Therefore, despite its obvious advantages, only two or three microscopes of this type have been constructed in the last 20 years.

The present invention employs the principals of a confocal optical microscope such as illustrated schematically in Figure 1. Light input from a laser, arc lamp or other light source impinges upon a plate 11 which includes a pinhole 12. The light travels through the pinhole to the objective lens 13 and is focused on the object plane 14. Light reflected from the object plane travels back through the pinhole as shown and can be viewed. Reflection from out of focus planes such as plane 16 does not converge at the pinhole and is therefore blocked by the plate 11. In operation the reflected light passing through the pinhole impinges upon an associated detector. The detector output is maximum when the object is located at the focus of the lens, otherwise the light received at the pinhole is defocused and the amplitude of the signal falls off rapidly as the position of the object is changed on either side of the object plane. The system has a very short depth of focus in addition to excellent transverse definition.

As previously described, such a microscope can be mechanically scanned to form a raster image by moving the object or pinhole in a raster pattern.

It is a general object of the present invention to provide a scanning confocal microscope which overcomes the mechanical alignment problems of the prior art Tandem Scanning Microscope and which presents a total image of the object without the necessity of mechanical scanning of the light beam or object.

In accordance with the invention there is provided a scanning microscope for viewing an object which comprises a scanning disc with a plurality of holes arranged in a predetermined pattern and a light source for illuminating a portion of said disc. A polarizer receives the light from the source and polarizes the light prior to the light illuminating the disc. An objective lens focuses light diffracted through said plurality of illuminated holes onto an objective lens which focuses a plurality of spots on the object. The objective lens receives light reflected from the object spots and focuses the light on the corresponding pin hole. A quarter wave plate is interposed between the objective lens and the disc.

A beam splitter receives the reflected light traveling through the holes and directs the light to a polarizer. Means are provided for rotating the disc to scan the spots across the object in a raster scan to provide an image of the region of the object illuminated by the spots.

The foregoing and other objects of the invention will be more clearly understood from the following description taken in connection with the drawings of which:

Figure 1 shows a prior art confocal optical microscope.

Figure 2 shows a scanning confocal optical microscope in accordance with the present invention.

Figure 3 shows another embodiment of the scanning confocal microscope in accordance with the invention.

Referring to Figure 2, the microscope includes a circular disc 21, known as a Nipkow disc which has holes disposed in a pattern of several interleaved spirals of several turns each. The holes are spaced approximately ten hole diameters apart. In one example the average radius of the spiral was five centimeters and the spiral extended over a radial distance of 1.8 centimeters with a total of 200,000 holes of 20 micrometer diameter formed in the periphery of the disc. Preferably the disc is of transparent material with a layer of black emulsion or black chrome in which the holes are formed by photo masking techniques.

A suitable light source, for example, either a mercury arc lamp or a laser 22, is used to illuminate an area of 1.8 centimeters by 1.8 centimeters containing about 4,000 holes. The light from the light source is polarized by a polarizer 23 and passes through a beam splitter 24 before striking the disc 21. The holes diffract the impinging light and the incident beam converges on objective lens 26. For example, the incident beam converges to a five millimeter diameter on the back of the objective lens 26 so that 4,000 points on the object 27 are simultaneously illuminated. Because of the spacing of the image points there is negligible interference between the different illuminated points.

The disc is rotated, for instance, at 2,000 rpm and since

the holes are arranged along the spiral path the rotation of the disc forms a raster scan across the object, thus forming 7,000 lines 500 frames per second.

The light focused on the object is reflected and focused at the same pinholes by the objective lens after traveling through a quarter wave plate 28. The light passing through the holes strikes a beam splitter 29 and is directed at right angles there from to an analyzer 31 and thence can be viewed by the naked eye through a transfer lens 32 which focuses on the pinholes.

In the embodiment of Figure 3, where like reference numerals are applied to like parts, the image travels through a relay lens to a camera 33 and to a TV monitor 34 which provides a display. Alternately the camera may be a photographic camera which takes a picture of the object. It is to be noted that no precise alignment is needed. The same holes are used for transmission and reception of the light making it relatively simple to align the microscope. The eyepiece, or camera, is focused on the pinholes illuminated by reflected light from behind the pinholes. Centering of the spiral is not critical. Vibration is not a severe problem provided that disc vibration has an amplitude much less than the depth of focus of the lenses at the pinholes, typically a distance greater than 1 millimeter.

The use of the polarizers and a quarterwave plate reduces interference from reflections from the disc as well as as the surfaces of the microscope elements by a factor of the order of 10^{-6} intensity and provide a clear visual image.

With reference to Figure 3 the apparatus also includes a

light stop which is located at the focal point of the incident light reflected from the surface of the Nipkow disc.

The purpose of this stop is to completely remove all remaining reflected light from the disc. When a laser source is employed, the stop is placed at the focus of the reflected converging beam. With a lamp source, an image of the source is focused on the stop. With an incoherent light source of finite diameter, the stop must be larger than it would need to be with a coherent light source. Nevertheless the stop would only intercept a very small fraction of the area of the beam passing through the pinholes to the observer. The microscope can be constructed with solely a light stop, and this may be advantageous when an object having a low reflectivity is being viewed.

The object or the objective lens can be moved up or down in order to focus on various planes in a translucent object such as a biological material like bone, or at various levels of a sample such as an integrated circuit. A very similar system can be used as a range sensor in robotic applications.

The Nipkow disc is illuminated by a collimated laser beam with, perhaps, as much as several watts in the beam. The pinholes in the disc are viewed as described in Figure 3. Images of the pinhole are focused on a distant plane by a camera lens. The beam, after leaving the pinhole, may be expanded by a telescope to give a larger beam at the lens pupil. This is to make it possible to use a lens of larger aperture so as to obtain the optimum transverse and range definitions.

When the Nipkow disc is rotated a region at the focal plane of the lens is imaged. Thus a direct real time image of a plane at a fixed distance from the lens is obtained in real time. Images of other cross sections are easily obtained by moving the lens back and forth. This can be used to control a robot.

What is claimed is:

1. A scanning microscope for viewing an object comprising a scanning disc with a plurality of pinholes arranged in a predetermined pattern, a light source on one side of said disc for illuminating an area of said disc, a first polarizer for polarizing the light which illuminates the disc, an objective lens on the opposite side of said disc for focusing light diffracted by said pinholes onto the object to illuminate a plurality of points on said object, means for rotating said disc to scan the points across the object, said objective lens serving to receive light reflected from the object and focus the light on corresponding pinholes, a quarterwave plate interposed between said objective lens and disc to intercept the light travelling to and reflected from said object, a beam splitter on said one side of said disc between said first polarized and said quarterwave plate for receiving reflected light travelling through said pinholes and said quarterwave plate and directing it at an angle, and a polarizer for receiving the directed light.

2. A scanning microscope as in Claim 1 including a light stop disposed to stop light reflected from the disc.

3. A scanning microscope as in Claim 1 in which the holes are disposed in a pattern of several interleaved spirals of several turns each.

4. A scanning microscope as in Claim 1 in which the disc includes an apertured dark layer on the surface of a transparent disc.

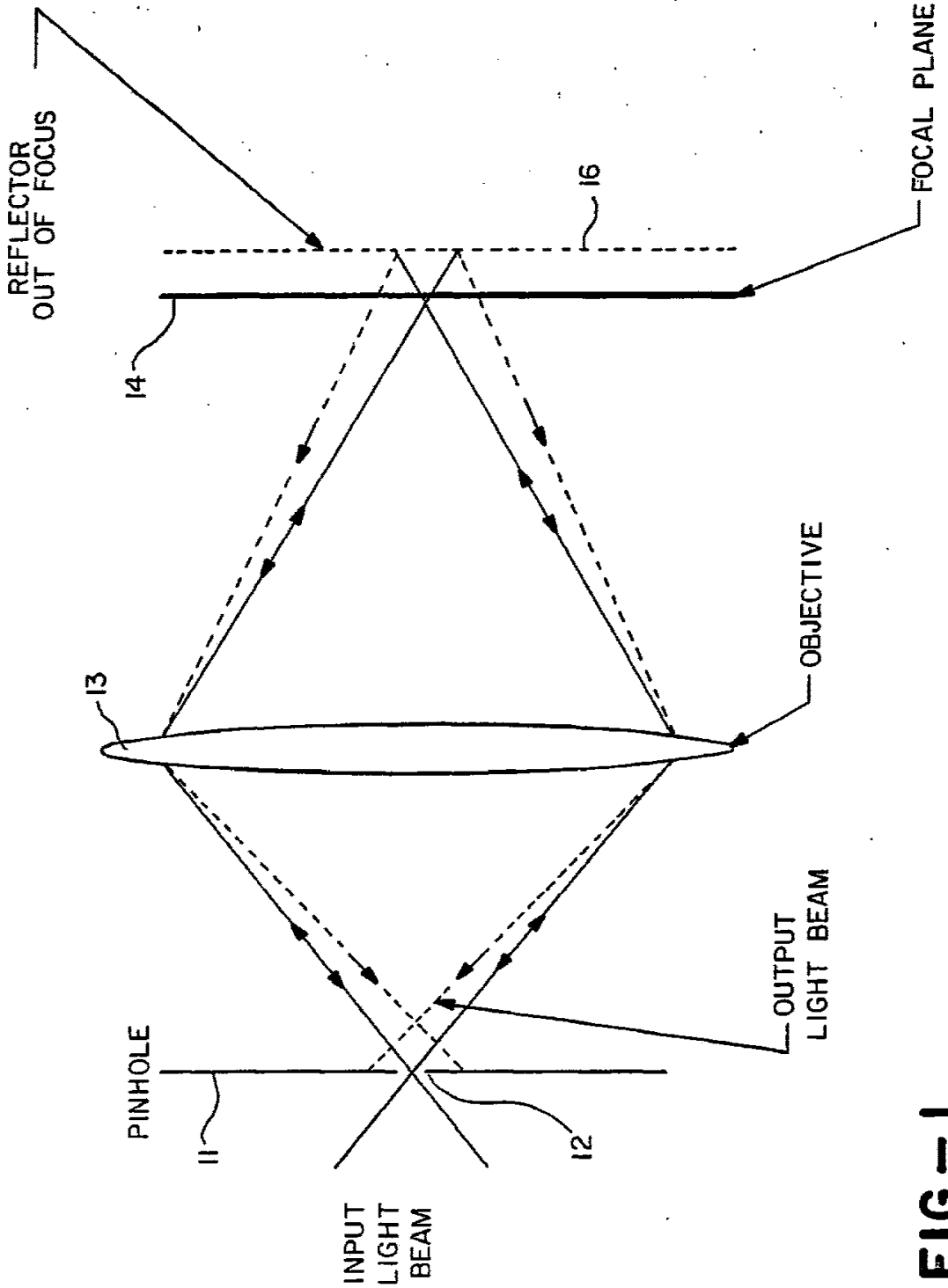

REFLECTOR
OUT OF FOCUS
16
FOCAL PLANE
14
13
OBJECTIVE
OUTPUT
LIGHT BEAM
PINHOLE
11
12
INPUT
LIGHT
BEAM

FIG. 1

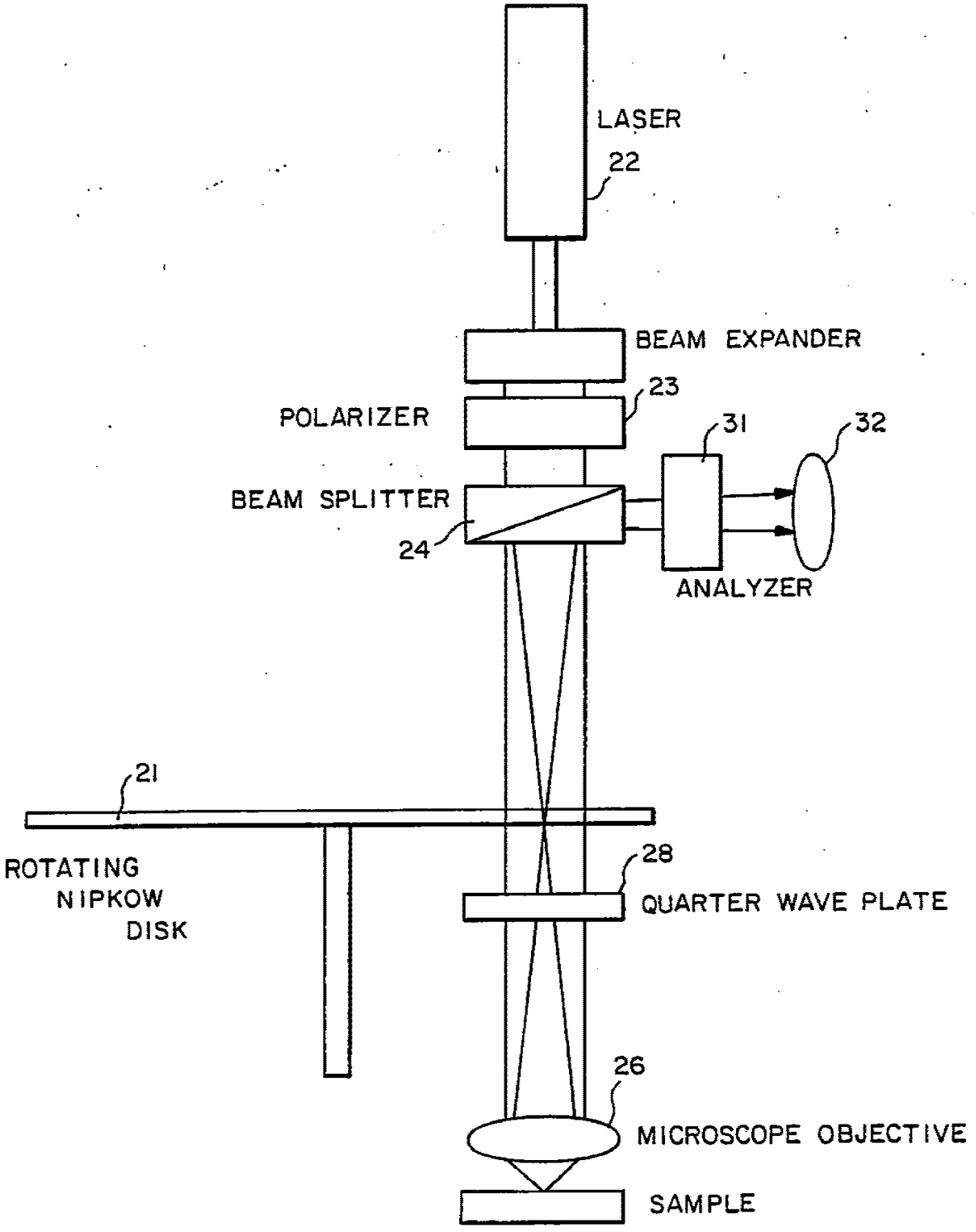

LASER
22
BEAM EXPANDER
23
POLARIZER
31
32
BEAM SPLITTER
24
ANALYZER
21
ROTATING
NIPKOW
DISK
28
QUARTER WAVE PLATE
26
MICROSCOPE OBJECTIVE
SAMPLE

FIG. —2

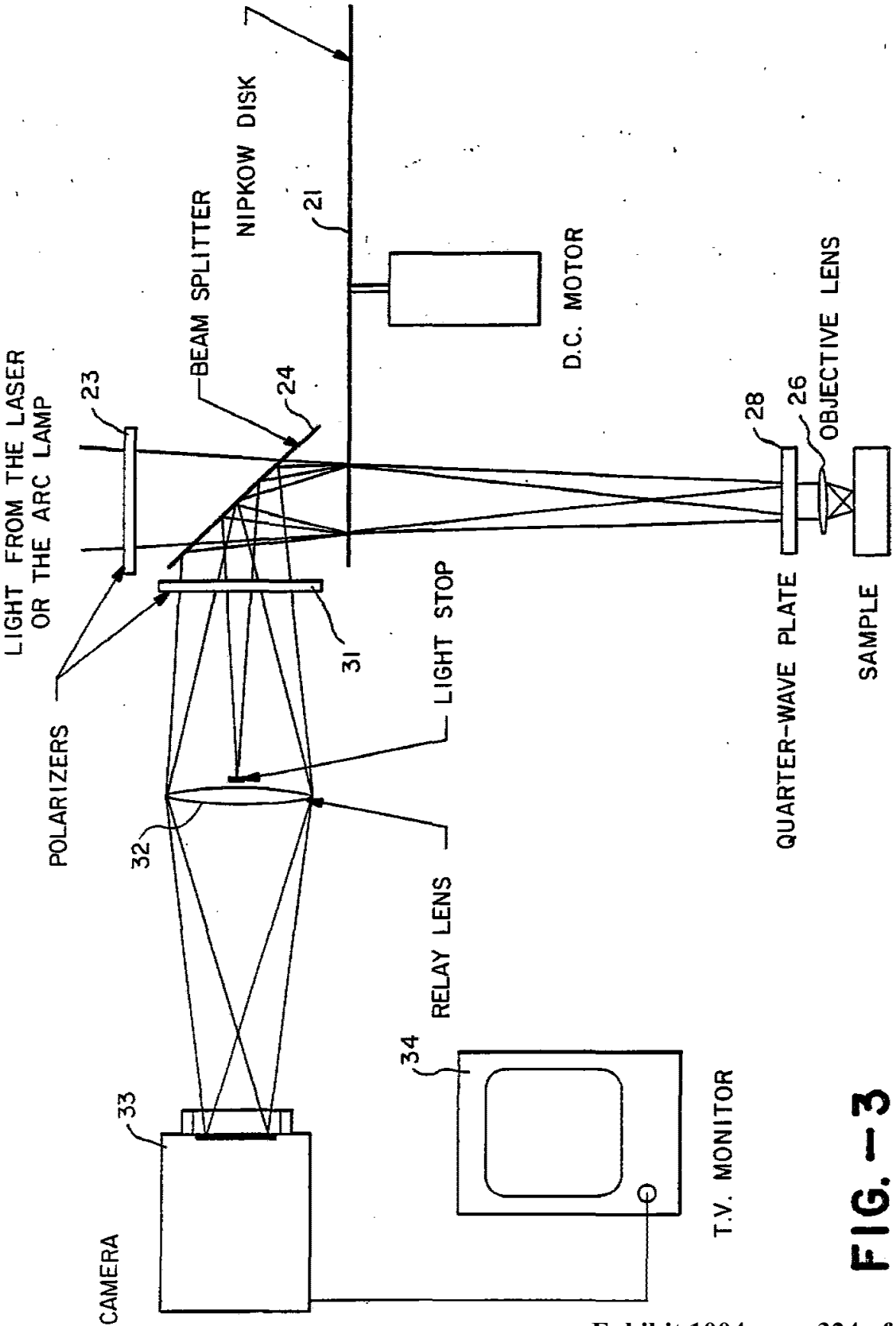

LIGHT FROM THE LASER OR THE ARC LAMP
23
BEAM SPLITTER
24
NIPKOW DISK
21
D.C. MOTOR
28
26
OBJECTIVE LENS
POLARIZERS
31
LIGHT STOP
QUARTER-WAVE PLATE
SAMPLE
32
RELAY LENS
34
33
CAMERA
T.V. MONITOR

FIG. - 3

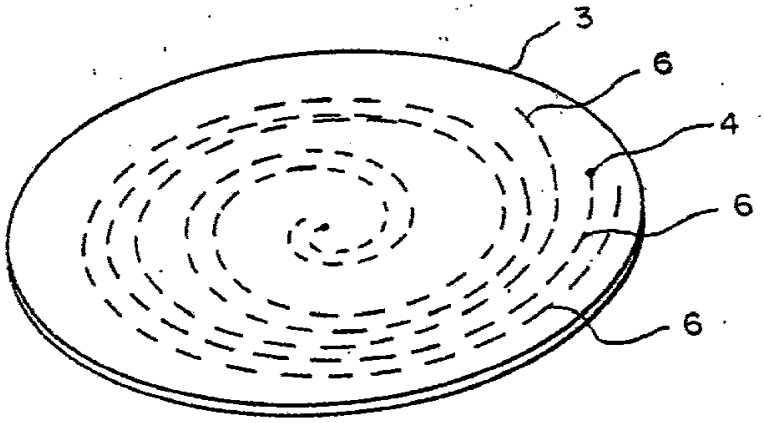


FIG. -4

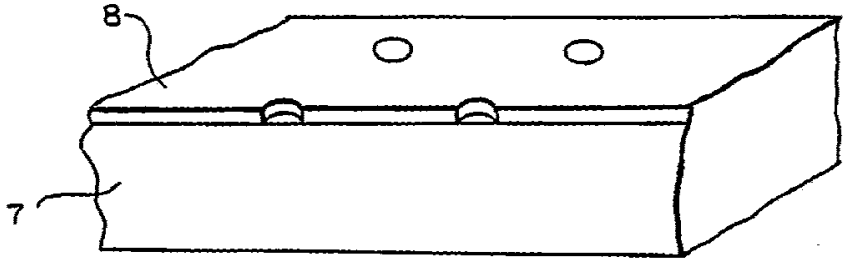


FIG. -5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 88/00904

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[4] G02B/21/00, 21/06, 26/10

U.S. CL 350/507, 510, 524, 274, 275, 527

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	350/507, 510, 524, 274, 275, 527

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X Y	U.S., A 3,926,500 Frosch et al, 16 December 1975 (16.12.75) (See entire document)	1, 3, 4 2
Y	U.S., A, 4,251,129 Suzuki et al, 17 February 1981 (17.02.81) (See entire document)	2
A	U.S., A, 4,062,623 Suzuki et al 13 December 1977 (13.12.77)	1-4
A	U.S., A, 3,517,980, Petran et al 30 June 1970 (30.6.70)	1-4

* Special categories of cited documents: [15]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [3]	Date of Mailing of this International Search Report [3]
17 May 1988	21 JUN 1988
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Jon W. Henry

Form PCT/ISA/210 (second sheet) (October 1981)

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **G01B 11/24**	**A1**	**(11) International Publication Number:** **WO 97/14932** **(43) International Publication Date:** 24 April 1997 (24.04.97)

(21) International Application Number: PCT/SE96/01329

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(30) Priority Data:
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(74) Agents: BERG, Sven, Anders et al.; H. Albihns Patentbyrå AB, P.O. Box 3137, S-103 62 Stockholm (SE).

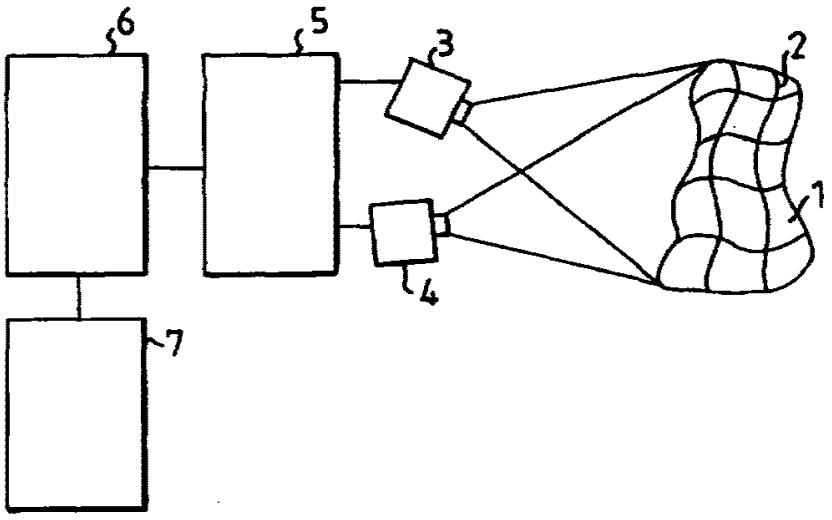
(81) Designated States: JP, NO, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: PROCESS AND DEVICE FOR THE MEASURING OF A THREE-DIMENSIONAL SHAPE

(57) Abstract

The invention relates to a method and a device for the measuring of the shape of an object (1) to be measured, where the object to be measured has its surface supplied with fluorescent substances in the shape of a pattern (2; 10). The pattern is read by optical reading units (3; 4; 14, 15-19) by reading the same parts of the pattern from mutually different directions. The positions in space of the read-off parts of the pattern are calculated based on the measuring data for the reading units.



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Process and device for the measuring of a three-dimensional shape

The present invention relates to a method for measuring of the type which is given in the preamble to claim 1, and a device for performing the method.

TECHNICAL BACKGROUND

With the possibilities to process, transfer and present information concerning measured objects, demands for an effective reading-in of information about the shape of a measured object for the purposes of data processing are increasing. Examples of industrial and medical applications, where such reading-in is advantageous, are the measuring of models for transferring to CAD-computers (CAD = Computer Aided Design), checking of the shapes of prototypes and finished products, measuring of the shapes of body parts for diagnostic purposes or for later fitting of prostheses, implants etc.

Today's technologies for contactless measuring of a three-dimensional shape are often based on some form of triangulation, where the object to be measured is illuminated with a structured light or by letting a laser point or a laser line scan the object. In these methods the optical characteristics of the measured surface influence the results of the measuring. It is, for example, difficult to measure on transparent, highly polished or "milky" surfaces.

Another relatively common way of performing measuring, described e.g. in US-A-5 305 151, is by means of interferometry, and consists of projecting a grid pattern on the surface of the object to be measured. The grid patterns appear different from different directions and distances. The grid pattern is registered simultaneously by two cameras from two directions. The fringe phases on the patterns registered by the two cameras are computed separately. The coordinates of the object are computed by a combination of the computed fringe phases.

According to another method for measuring, described in the Swedish Laid-open document 8902748-6, a pattern is projected onto the object to be measured. A picture of the pattern on the object to be measured is taken and the projected pattern and the pattern in the picture are compared in order to obtain the three-dimensional geometry of the measured objects, which in this case are teeth in the oral cavity.

The problem involved in projecting patterns is that all the measuring elements comprised in a measuring arrangement must be extremely stably arranged in relation to each another during the measuring, especially the pattern producer, both in relation to the measured object and to the recording means.

The measuring of measuring objects in order to get exact data concerning the shape of a measured object also often takes place by contact measuring in a coordinate measuring machine. SE-9000546 describes an optical method for contactless measuring of the shape of an object to be measured with the help of a coordinate machine. In this case an optical system is placed as a measuring probe in the coordinate measuring machine. The object to be measured is at least partially covered with a fluorescent substance, which is excited by a light beam emitted from the optical system. The optical system has detector means which are sensitive to the fluorescent light. This system gives the advantage that the surface layer of the object to be measured is well defined for the optical system but it requires an exact measuring with a coordinate measuring machine.

OBJECTS OF THE INVENTION

An object of the invention is to achieve the measuring of the three-dimensional shape of an object to be measured using stereo- and photogrammetric methods.

Another object of the invention is to achieve the measuring of polished and/or transparent objects to be measured.

Yet another object of the invention is to achieve the measuring of an object to be measured with simple subsequent processing of the measuring data.

Yet another object of the invention is to achieve the measuring of confined spaces, such as different types of cavities. For this purpose a very small reading unit is necessary.

Yet another object of the invention is to achieve the measuring of an object to be measured by a simple matching of measuring data taken from several observation angles.

Another object of the invention is to achieve the measuring of an object to be measured with a simple and cheap measuring head.

Yet another object of the invention is to achieve a device for measuring, where the measuring device can be placed in a random position in relation to the object to be measured and where measurements taken at different times will be equivalent without the position of the measuring device at the time of measuring influencing the measuring result.

The above mentioned objects are achieved by a method with the characteristics stated in claim 1. Further features and developments of the invention as well as a device for performing the method are mentioned in the rest of the claims.

The invention thus relates to a method for measuring the shape of an object to be measured, where the surface of the object to be measured is provided with a fluorescent substance, characterized by the fluorescent substances being applied to the surface of the object to be measured so that the surface receives a pattern; the pattern is read-off by optical reading units with reading-off of the same parts of the pattern from mutually different directions; and the positions in space for the read-off pattern parts are calculated with the aid of the measuring data from the reading units.

A pattern formed by fluorescent substances gives a high contrast between patterned and non-patterned surface parts. The measuring data for the reading units can include their respective reading positions in the reading unit or reading units, the respective positions and the respective reading angles of the reading unit or reading units during reading-in. The pattern is naturally adapted to the reading means so that it is clearly indicatable by it. The pattern can be regular, e.g. comprise a grid network, or irregular, e.g. comprising randomly placed dots, flakes or the like.

A device according to the invention for measuring of the shape of an object to be measured, where the surface of the object is equipped with a fluorescent substance, includes that the fluorescent substances are provided in the form of a pattern, at least one optical reading unit for the reading off of the same pattern parts of the object to be measured from mutually different directions, and a comparison means is connected to the reading unit or reading units for comparing the different readings with each other and individually calculate the position in space of the read-off pattern parts with the aid of differences between the readings for these pattern parts.

The invention is described in more detail below with reference to the appended drawings, where

Fig. 1 shows a schematic view of a first embodiment of a device according to the invention, and

Fig. 2 shows a schematic view of a second embodiment of a device according to the invention, and

Fig. 3 shows schematically an embodiment of an instrument for investigating a plurality of objects to be measured simultaneously.

Fig. 1 shows an object to be measured 1, which can be transparent or have a highly polished or milky surface, from which it is difficult to get an exact measuring result. It should, however, be noted that the invention is not limited to measurements made on objects to be measured with these characteristics but is also suitable for measurements of objects to be measured with any type of surface whatsoever. The

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surface of the object 1 to be measured in the embodiment shown is equipped with a pattern 2, which in the embodiment shown is checkered, but can have any shape whatsoever, e.g. dotted, dashed, wavy, etc.

Measuring against a surface with a fluorescent coating has proven to give good and exact results. The pattern on the surface can consequently be applied with fluorescent paint, which is the preferred embodiment. The pattern can, for example, be applied by spraying or coating the object to be measured with the fluorescent substances or by painting the object to be measured with the fluorescent substances with a painting means with a small contact surface, such as a pen or a thin paintbrush. The pattern can also be applied by taping the object to be measured with a fluorescent tape.

The pattern can also be applied by first coating the surface of the object to be measured with a layer to which fluorescent particles can easily adhere, e.g. a sticky surface, and subsequently applying fluorescent particles.

An example of another possibility is to provide the whole surface of the object to be measured with a film of fluorescent paint and applying the pattern over this film with a paint with different qualities, e.g. black and matt.

Another possibility for applying the pattern is to dip the object to be measured into a fluid containing nonfluorescent as well as fluorescent parts, for example to use a fluorescent paint with transparent microspheres which then form the pattern, or a paint with microspheres with fluorescent paint. The pretreatment of the object to be measured can in these cases simply comprise dipping into the paint.

The pattern can also be achieved by spraying fluorescent particles, e.g.microspheres, onto the surface of the object to be measured. The pattern can also occur as flakes in a paint. The flakes can be fluorescent in a nonfluorescent paint or vice versa.

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The pattern can also occur in the material of the object to be measured itself, which in that case is patterned all the way through. Measuring can, for example, take place on a positive or negative impression of e.g. teeth in order to get CAD-information (CAD = Computer Assisted Design) for subsequent data processing of the appearance of the teeth and subsequently following Computer Assisted Manufacturing (CAM). The impression can for this purpose be cast in a through-patterned material which gives a surface with a suitable fluorescent pattern.

It is also possible to use phototechnical methods. One such method involves applying a film of a light-sensitive or heat-sensitive material, which does not support fluorescent paint, exposing a pattern to light or heat with phototechnics and removing the exposed pattern parts, dipping the object to be measured in the fluorescent paint, which only fastens to the parts of the object to be measured with the uncovered pattern parts, and possibly exposing the remaining film to light or heat and removing it. The above mentioned ways for applying a fluorescent pattern are only given as examples and other ways of application are also conceivable for the man skilled in the art under the guidance of the above.

It is evident from that described above that both regular and irregular patterns can be used according to the invention.

The embodiment shown in Fig. 1 shows two cameras 3 and 4 directed towards the object 1 to be measured. Each camera is equipped with an electronically readable picture sensor in its picture plane. The cameras are preferably of a type with a sensor surface with discrete picture elements, so-called pixels. The picture sensor can be in that case, for example, of the CCD-type (CCD = Charge Coupled Device, i.e. it makes a charge-coupled transmission). It is obvious to the man skilled in the art that another type of picture sensor with discrete picture elements or individually readable sensors can also be used. Alternatively, the cameras can be of a type where a scanning optic transfers a small partial picture of an object to be measured to a surface-contact-sensing sensor, which gives a signal dependent on the coordinate position of

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the contact point on the sensor, for example a two-dimensional sensor known by the trademark SITEK®.

Instead of having two cameras, a single camera can be used. This can be moved between two different positions, or the object can also be moved between two exposures with a stationary camera.

Independently of the type of camera and carried out measuring operations, the signals from the cameras are transferred to a processing and comparison unit 5. If two cameras are used, this transfer can take place simultaneously. If one camera is used, these transfers take place in sequence one after the other with intermediate storage of the first transferred picture. The signals are treated such that only the parts of the exposed pictures which correspond to pattern parts on the object to be measured are isolated, and the rest of the picture parts are consequently discriminated away.

The use of fluorescence in connection with the pattern on the object gives a high contrast for the sensed pattern, which gives a secure measuring and a simple isolation of the corresponding pattern parts. Furthermore, the placing of the pattern directly on the object to be measured gives the advantage that it is stable on the object to be measured so that, without influencing the measuring results, the object to be measured can be freely moved, and also different measuring exposures can be made at different times. Furthermore, measuring of an object can be repeated at different times, between which the shape of the object may have changed, for example, it could have been deformed after having been exposed to temperature changes or other types of changes in the surroundings. The measuring device gives sufficient information from the object to be measured in order to give an over-determination of the measuring result. This can be used for extra exact positioning of the component measuring units in relation to the object to be measured and to each other. This makes the measuring device according to the invention robust and

relatively insensitive to how it and its units are placed in relation to the object to be measured during each measuring.

The pattern parts taken with the two cameras 3 and 4 are subsequently compared to each other, pixel for pixel, in the unit 5. For each compared pixel the difference in position on the picture sensor in the two cameras is transferred to a unit 6 for calculating the position in space for the point on the object to be measured which corresponds to the pixel in question. A calculation of the position in space takes place with the aid of knowledge of the respective angle of direction of the two cameras in relation to the actual pixel, the distance between the cameras and the respective positions of the pixels in the respective picture plane in the cameras, i.e. the position in space calculations take place with so-called triangulation pixel for pixel in the pattern on the object to be measured. It should be noted here that the direction of each camera for the different pixels in the picture sensor can be different but is completely individually known and written in a nonvolatile memory in the picture processing and comparison unit 5.

The current alignment of each camera 3, 4, with the object 1 to be measured, is measured. The alignment of each pixel with the object to be measured is then consequently a combination of the current alignment of the camera and the individual alignment of the pixel in relation to that of the camera. According to the invention a photogrammatic method is thus used.

The calculated positions in space are now determined in relation to a fixed point on the measuring arrangement. Subsequently, the calculating unit 6 can perform a transforming of the coordinates in order to place the three-dimensional shape of the object obtained by the measuring into a desired position in a suitable coordinate system. A suitable mathematical representation of the shape of the object to be measured is consequently made by the calculating unit 6. This can naturally also comprise other calculations than those given which are known to the man skilled in the art, especially in the art of the technical field for picture processing.

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The result of the calculations made by the position in space calculating unit 6 is transferred to a presentation unit 7, e.g. in the form of a list printed out on a printer, a three-dimensional presentation on a screen, an entry in a computer program of CAD-type with a presentation on a screen, possibly with the possibility to make changes in order to produce a shape which functions better in a particular connection or with adjustment of a mould or the like to the measured shape of the object 1 to be measured.

Fig. 2 shows the principle for a second embodiment. According to this, only one camera is used for taking the, at least two, requisite pictures of an object to be measured. In this embodiment the object 9 to be measured is shown, as an example, provided with a dotted irregular pattern 10, for example achieved through dipping the object to be measured in a paint which contains the pattern points as differing parts in the paint.

The embodiment shown in Fig. 2 is carried out in a way adapted for stereo-measuring especially in confined spaces, for example, measuring of a small hole in an inorganic or organic object in order to investigate a casting, or measuring in a person or animal of the auditory meatus in an ear, in the gullet, in the lungs or the like.

A bunch of fibers 11 are placed with one end 14 on the spot where the picture sensor is to be placed. A sensor plate (not shown) with a sensor element for each light-conducting fiber in the bunch of fibers 11 is placed at its other end. The bunch of fibers 11, which acts like a picture light-conductor, is surrounded by a tube-like, stiff casing 12, which has a part 13 which extends a suitable distance A in front of the surface 14. The outer end of part 13 is equipped with optics 15, which in principle can consist of a number of "camera eyes" placed beside each other along a surface, and controllable so that only one eye at a time is open. The surface can be flat or slightly curved such that each picture of the object to be measured through the different "camera eyes" is focussed onto the surface 14.

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Instead of forming the end of a bundle of optical fibers, a picture sensor can be placed in the same position as 14. The sensor has then a surface extension transverse to a line of symmetry for the camera and all its pixels can sense a partial picture, for example it can have a separate picture sensor element per partial picture or be a so-called CCD-sensor (CCD = Charged Coupled Device).

The reproducing optics 15 can comprise two or more fixed lenses 16,17,18, which from different positions reproduce the object to be measured (not shown) on the end surface 14 of the picture optical conductor. In order to ensure that just the picture from one lense at a time reaches the end surface, each lense is equipped with a shutter in the beam path (only schematically shown as a plate 19 in front of the lenses). The shutter can be mechanical or micromechanical, e.g. a rotating plate with one or more holes where only one hole at a time can be in front of one of the lenses 16-18, or it can be a unit with a non-movable shutter function and consist of a plate with controllable LCD-type elements, which can be controlled to optionally open and close the beam path from the object. Instead of lenses, small holes can be used so that the arrangement acts as a pinhole camera. This gives a worse resolution than with lenses but is considerably cheaper. In such a case the elements 15 and 19 can possibly be replaced by a plate with small controllable LCD-type elements, which each can be controlled to form an optical opening.

It is also possible to have a movable lense (not shown in Fig. 2), which is controllable to change position between the exposure of each picture of the clear pattern formed by applying the fluorescent pattern parts in or on the object to be measured.

Instead of opening just one camera eye at a time, the plate 19 can have differently coloured apertures. Each sensor element in the remote end (not shown) of the bunch of fibers 11 can comprise several partial elements, each of them individually sensitive only to one of the colours in the apertures or, alternatively, several CCD-sensors, each being sensitive to an individual colour, can be coupled to the end of

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the bunch of fibers. Alternatively, a CCD-sensor with possibility of individual sensitivity to different colours can be used. In this case the taking and the storage of the pictures for the comparisons can take place simultaneously instead of sequentially, as can also the comparisons themselves.

As the arrangement according to Fig. 2 functions as a pinhole-camera with optional openings, overlapping of the pictures from the object on different parts of the surface 14 occurs, depending on which of the lenses are used.

A shorter projecting part 13 gives a bigger overlapping surface per pair of lenses or holes, which means that fewer lenses or holes can be used and the position in space calculations can be carried out between a small number of overlapping pictures. However, this gives a wider sensing of the object, which is not always desirable during investigation of a small cavity such as a bore hole in a tooth or the like, where the investigating instrument is placed outside the cavity.

A longer projecting part 13 gives a smaller overlapping surface per pair of lenses or holes. The viewing angle per exposed picture will thus be smaller. Thus, the position in space calculations should in most cases be performed by comparison inside the overlapping regions for several pairs of pictures, which requires the storage of more pictures during a picture-taking procedure.

The same type of picture processing, comparison, calculating and presentation units 5-7 as those which are described in connection to Fig. 1, can be used also in the embodiments according to Figs. 2 and 3 and are therefore not shown. However, in most cases, data concerning the pictures taken is transferred in sequence one after the other instead of simultaneously to the picture processing and comparison unit 5, which therefore requires extra memory for intermediate storage of a picture (not shown).

As mentioned above, the measuring is performed against objects with patterns comprising fluorescent parts. An instrument comprising a camera of the type shown in Fig. 2 can thereby be equipped with a spray paint nozzle which possibly is extend-able during use (not shown in Fig. 2), either by the side of or concentric with it, or several spray painting nozzles can be fitted around its periphery. Before measuring of an object to be measured a spray painting function is activated so that the object to be measured is provided with its pattern. The measuring is performed subsequently using the camera.

The embodiment shown in Fig. 3 of a measuring instrument is especially usable for flexible positioning by an object to be measured, which can be relatively difficult to approach, for the measuring of it, such as a tooth inside a mouth of a patient and especially for the measuring of a bore hole in a tooth. Here a measuring head 20 with the camera equipment shown in Fig. 2 can be placed at the end of a control means 21. In Fig. 3 the control means 21 is shown as a handle, which is easily maneuver-able by an operator and of which the outer end 20 with the camera equipment is slightly curved in order to give approachability in confined spaces. The control means 21 can instead be controllably bendable and/or also a controllable arm can possibly be connected to the outer end 20 itself in order to control it, and in this case the optical fiber bundle 11 can come directly from the end 20. A controllable light source can also be placed by the measuring head 20 to illuminate the object to be measured during measuring.

The picture collecting end 14 in Fig. 2 is placed inside the outer end 20 in Fig. 3. The fiber bundle 11 is bendable outside the rod 32 and coherently arranged between the end 14 in the measuring head and an electronically readable picture sensor 22. as a second target point detector unit, placed at a distance from the measuring head 20.

The electronically readable picture sensor 22 is coupled to evaluation circuits 23 of the above described type.

In the case of investigating teeth, the teeth are coated before measuring with a coating of fluorescent particles, which can be brushed off. This coating can take place by activation of a spray-painting equipment connected to the measuring head 20 and comprising a controllable paint unit 24 coupled by a hose 25 to at least one nozzle (not shown) in the measuring head. It is appropriate that there are arrangements (not shown) on the measuring head in order to protect the optics during the spray-painting operation controlled from the unit 24, such as projecting out the nozzle or nozzles and/or temporarily closing of the opening to the optics. It is, however, obvious that the application of the pattern onto the object to be measured can instead be performed separately, and that an instrument without the parts 24, 25 can be used for the actual measuring.

The appropriate pictures are taken and are signal-processed, whereafter the coating is brushed and rinsed away.

Many modifications of the invention are possible within the scope given by the appended patent claims. For example, the measuring of two- as well as three-dimensional surfaces are equally possible. More than two recording units with different positions or alternatively mixers with more than two sequentially openable apertures can be used.

It should be noticed that the arrangements shown give more data concerning all the investigated points on the object than what is necessary in order to calculate the shape of the object, which means that the shape can be over-determined. In this way there is sufficient information in order to produce completely equivalent recordings for determining the shape at different opportunities with very different positionings of the measuring instrument in relation to the object to be measured, and also concerning the constituent components in the instrument, such as cameras 3 and 4 in the embodiment in Fig. 1, or using different types of viewing holes as in the embodiments in Figs. 2 and 3. The different types of calculations which are necessary are completely geometrical and are therefore not described. A man skilled in the art

should be completely intimate with how these are performed and how they can be programmed into a computer.

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Claims

1. Method for measuring of the shape of an object to be measured (1), where the object to be measured is equipped on its surface with fluorescent substances, **characterized** in
that the fluorescent substances are applied to the surface of the object to be measured
so that the surface receives a pattern (2;10);
that the pattern is read by optical reading units (3,4;14,15-19) with reading of the same parts of the pattern from mutually different directions; and
that the positions in space of the read-off parts of the pattern are calculated based on the measured data from the reading units.

2. Method according to Claim 1, **characterized** in that the measuring data for the reading units comprise their respective reading positions in the reading unit or reading units, the respective positions of the reading unit (14,15-19) or reading units (3, 4) and the respective reading directions during reading.

3. Method according to Calim 1 or 2, **characterized** in that the pattern is applied by spraying or painting the object to be measured with the fluorescent substances.

4. Method according to Claim 3, **characterized** in that the pattern is applied by painting the object to be measured with the fluorescent paint substances with a painting means with a small contact surface, such as a pen or thin paintbrush.

5. Method according to Claim 1 or 2, **characterized** in that the pattern is applied by dipping the object to be measured in a fluid which contains non-fluorescent as well as fluorescent parts.

6. Method according to Claim 1 or 2, **characterized** in that the pattern is applied by taping the object to be measured with a fluorescent tape.

7. Method according to Claim 1 or 2, **characterized** in that the pattern is applied by the surface of the object to be measured first being coated with a layer to which fluorescent particles easily stick, and subsequent application of fluorescent particles.

8. Method according to Claim 1 or 2, **characterized** in that the pattern is applied by phototechnical means.

9. Device for measuring of the shape of an object to be measured (1), where the object to be measured is provided with fluorescent substances, **characterized** by

a) the fluorescent substances applied in the form of a pattern (2;10);

b) at least one optical reading unit (3, 4; 14, 15-19) for reading of the same parts of the pattern on the object to be measured from mutually different directions;

c) calculating means (5, 6; 23) connected to the reading unit or reading units in order to compare the different readings with each other and individually calculate the position in space of the read-off parts of the pattern based on differences between the readings for these parts of the pattern.

10. Device according to Claim 9, **characterized** in that the reading units (3, 4) number at least two and are cameras, each with electronic target point detection of each part of the pattern in the picture plane of the camera.

11. Device according to Claim 9 or 10, **characterized** in that there is only one reading unit (15-19) but it is equipped with optics for reading of the target point detection, where the optics are equipped with a controllable unit (19) in order to provide each reading with mutually different optical paths.

12. Device according to Claim 11, **characterized** in that a picture formed by the reading unit via an optical fiber bundle (11) is connected to a target point detector unit (22), whereby the target point values are electronically readable; and that the input of the comparison unit (23) is connected to the target point detector unit.

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13. Device according to Claim 12, **characterized** in that the reading unit is fitted into a reading head arrangement (20) adapted for flexible positioning by the object to be measured, and that the target point detector unit (22) is placed stationary.

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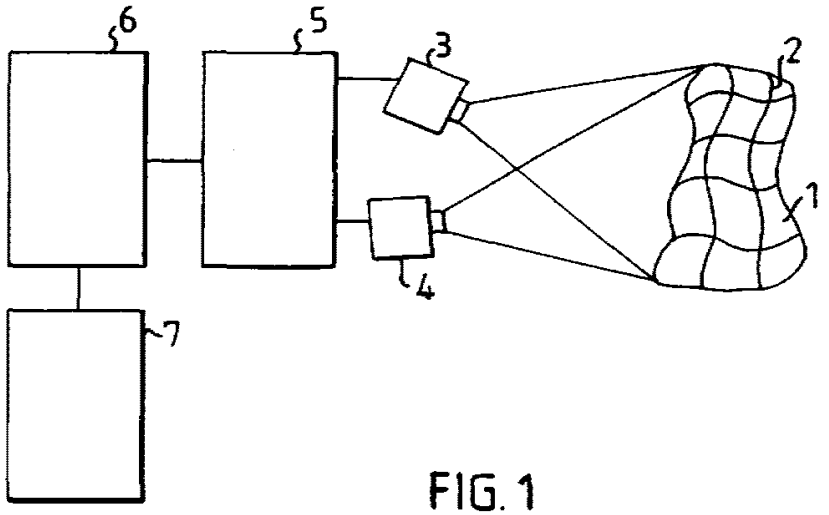


FIG. 1

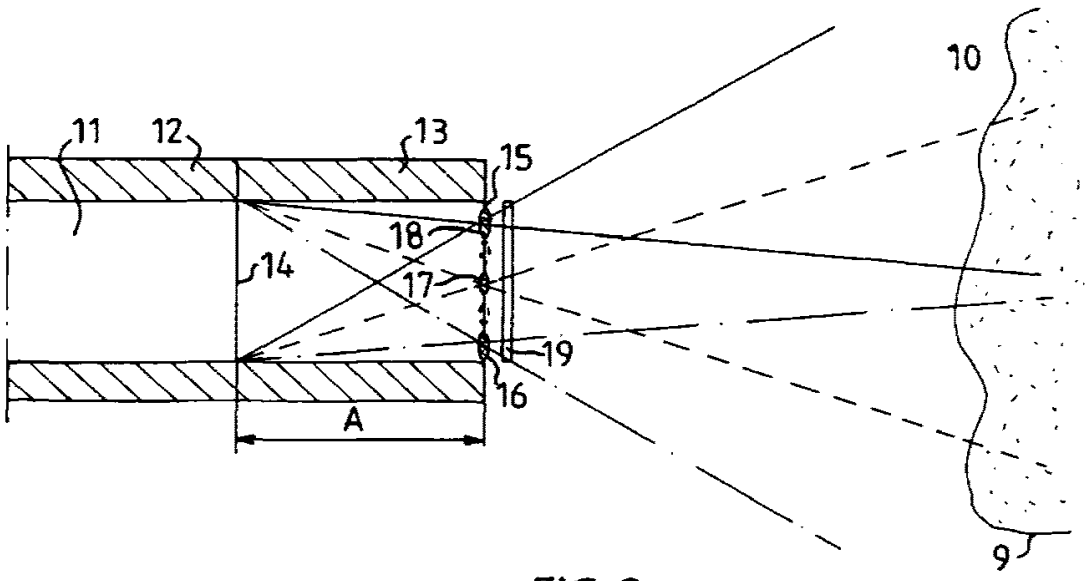


FIG. 2

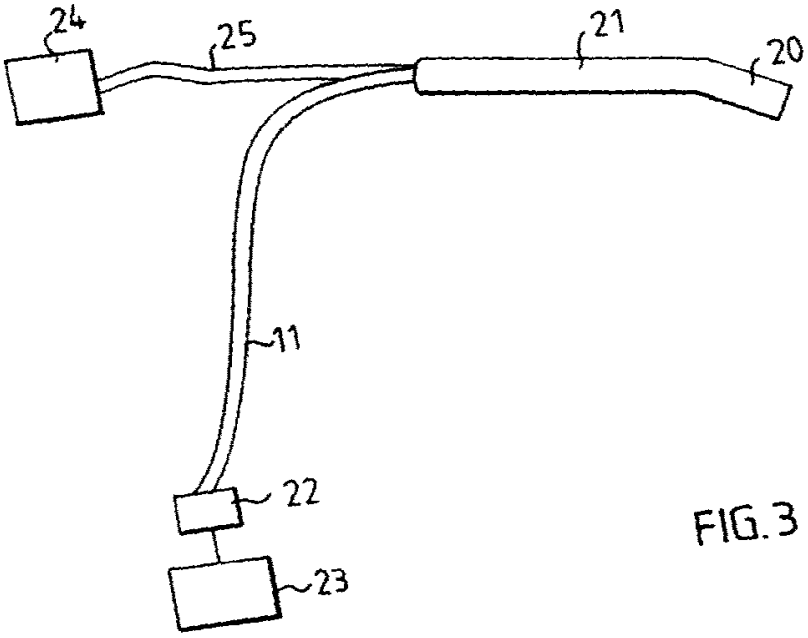


FIG. 3

INTERNATIONAL SEARCH REPORT

Int. ational application No.
PCT/SE 96/01329

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01B 11/24
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 4034007 A1 (SIEMENS AG), 30 April 1992 (30.04.92), figure 1, abstract --	1,9
A	DE 3721247 A1 (JENOPTIK JENA GMBH), 3 March 1988 (03.03.88), figures 1,2, abstract --	1,9
A	DE 4206499 A1 (HÄUSER,GERD), 16 Sept 1993 (16.09.93), column 4, line 17 - column 8, line 49, figures 4,5 --	1,9
A	SE 464048 B (C.E.JOHANSSON AB), 25 February 1991 (25.02.91), figures 1,2 --	1,9

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 January 1997	06 -02- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

Int ational application No.
PCT/SE 96/01329

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4802759 A (G.MATSUMOTO ET AL.), 7 February 1989 (07.02.89), figures 1,2, abstract --	1,9
A	US 5175601 A (J.M.FITTS), 29 December 1992 (29.12.92), figure 1, abstract --	1,9
A	US 5307151 A (A.HOF ET AL), 26 April 1994 (26.04.94) -- --------	1,9

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/10/96

national application No.
PCT/SE 96/01329

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DE-A1- 3721247	03/03/88	NONE	
DE-A1- 4206499	16/09/93	DE-D- 59302962	00/00/00
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		JP-A- 5209728	20/08/93

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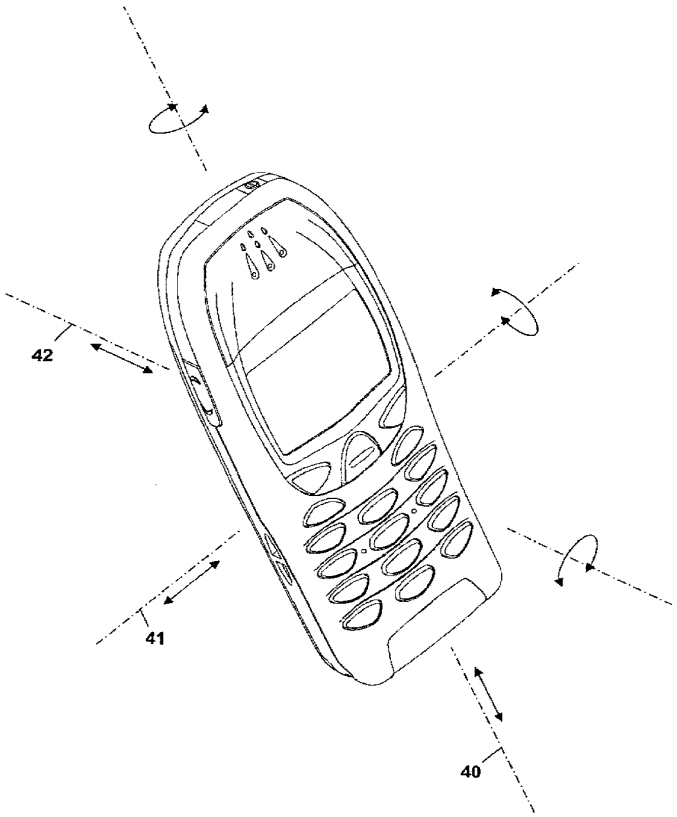
(74) Agent: **VAN WALSTIJN, B., Gerard, G.**; Walstijn Intellectual Property ApS, Parkovsvej 3, DK-2820 Gentofte (DK).

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(54) Title: IMAGE CONTROL



(57) Abstract: The present invention relates to the field of hand-held devices that are equipped wit a processor and a digital camera for capturing motion video or still images. Images captured by the camera are used to determine motion of the hand-held device. A resulting motion signal is used as input to a user interface. Displayed images can be scrolled, zoomed or rotated by moving the hand-held device. The motion signal can also be used as input for a graphical user interface to move a cursor or other object of the graphical user interface over the display. The invention relates further to a hand-held device provided with means for sensing motion, a display, a keypad with at least a first- and a second key, and a graphical user interface with objects and a cursor. The hand-held device also comprises means for transforming the sensed motion of the handheld device into a signal suitable for moving the cursor over the display.

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IMAGE CONTROL

The present invention relates to the field of hand-held devices that are equipped with a processor and a digital camera for capturing motion video or still images, in particular such devices that further comprise a display for displaying images or a graphical or character based user interface.

BACKGROUND ART

Hand-held devices provided with digital image capturing equipment, digital processing power and high resolution displays are becoming increasingly more common in a wide variety of uses.

For example, small mobile phones are recently being equipped with digital cameras and relatively small high resolution LCD screens. Hand-held computers commonly called "personal digital assistants" (PDA) are also available and are typically equipped with small high resolution display screens and have slots for receiving e.g. a digital camera. Similarly, communicators having both cellular communication and computer capabilities are available, typically having small display screens and an inbuilt or detachable digital camera. These small, hand-held devices do not, and cannot, conveniently have conventional input devices, such as a computer mouse and other control keys. Therefore, conventional personal computer interfaces, which also have their own drawbacks, are not suited for these small hand-held devices.

As a result, there are significant limitations on using such small hand-held devices in both obtaining output, e.g. viewing data on the display screen, and in inputting

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commands, e.g. changing the area viewed on the display screen or controlling the performance of a particular parameter associated with the device. Further, given the limited area available, not only on the display screen but also on the entire device, adding additional control keys, etc., is both difficult and burdensome to a user requiring two hand operation of the device.

US 6466198 discloses a system and method for view navigation and magnification of the display of hand-held devices in response to the orientation changes along only two axes of rotation as measured by sensors inside the devices. The view navigation system can be engaged and controlled by simultaneously pressing switches on both sides of the hand-held device. Miniature sensors like accelerometers, tilt sensors, or magneto-resistive direction sensors sense the orientation changes. These miniature sensors are presently not typically standard equipment for hand-held devices. Thus, such sensors add cost, use precious space and add weight.

The present invention is directed toward overcoming one or more of the above-identified problems.

DISCLOSURE OF THE INVENTION

On this background, it is an object of the present invention to provide a hand-held device of the kind referred to initially, which allows user input with the same hand that holds the device, without requiring the dedicated sensatory equipment used by prior art hand-held devices.

This object is achieved in accordance with claim 1, by providing a hand-held device comprising a processor, a digital camera for capturing motion video or still images,

and means for transforming a signal from the camera into a motion signal indicative of the motion of the hand-held device.

Thus, by using a sensor that is available to start with in many hand-held devices -- namely a digital camera -- for a secondary use, namely creating a motion signal indicative of the motion of the hand-held device, a hand-held device with motion sensing is provided in a economical and reliable manner.

The hand-held device may further comprise a user interface in which motion of the hand-held device is - through the motion signal derived thereof - used as a user input.

The hand-held may further comprise a display, preferably a display suitable for displaying captured images.

Motion of a given type of the hand-held device can be used to manipulate images shown at least in part on the display, preferably by moving the images in a manner substantially corresponding to the movement of the hand-held device.

Different types of motion the hand-held device can e.g. be used to move, and/or zoom, and/or expand/collapse and/or rotate images displayed on the display.

Motion substantially parallel to the plane of the display of the hand-held device can be used to scroll an image displayed on the display. Motion substantially perpendicular to the plane of the display can be used to zoom an image displayed on the display. Rotational motion of the hand-held device can be used to rotate an image displayed on the display.

The images that are manipulated can e.g. be images that were previously captured by the camera.

The movement of image can be inverted with respect to motion of the hand-held device, since some users may prefer this.

The user interface may comprise a graphical user interface and motion of the hand-held device can be used as an input to the graphical user interface.

Motion of the hand-held device can be used to manipulate an object displayed by the graphical user interface, preferably by moving the object in a manner substantially corresponding to the motion or to the inverted motion of the hand-held device, whereby the object displayed by the graphical user interface can be an icon, a dialogue box, a window, a menu or a pointer.

Motion of a given type of the hand-held device can be used to move, and/or zoom, and/or expand/collapse and/or rotate objects displayed by the graphical user interface.

Motion substantially parallel to the plane of the display of the hand-held device can be used to scroll an object displayed by the graphical user interface. Motion substantially perpendicular to the plane of the display can be used to zoom an object displayed by the graphical user interface. Rotational motion of the hand-held device can be used to rotate an object displayed by the graphical user interface.

The digital camera can be an inbuilt camera or can be a detachable camera. The camera may be movable relative to the hand-held device.

The means for transforming a signal from the camera into a motion signal preferably derives the motion signal from changes between succeeding images captured by the camera.

The camera can be equipped with an autofocus system, whereby the focusing setting of the autofocus system can be used for detecting movement in the camera direction.

The hand-held device may further comprise at least one key. The functionality of a motion type can be dependent on the state of the at least one key.

Rotational motion of the hand-held device about an axis substantially perpendicular to the display may be used to cause an inverse rotational movement of the image or graphical user interface object relative to the display, preferably in a manner such that the image or object is static with respect to the fixed coordinate system in which the hand-held device is situated.

The motion signal can be used to adjust device settings, such as sound settings, keypad settings and display settings.

The hand-held device may further comprise a keypad with at least a first and a second key and the graphical user interface comprising a cursor, whereby motion of the hand-held device can be used to position the cursor over an object of the graphical user interface and primary functions associated with the object concerned can be activated by pressing the first key and secondary functions associated with the object of the concerned can be activated by pressing the second key.

The functionality of the first key can be associated with selection and activation of objects of the graphical user

interface, and the functionality of the second key can be associated with calling up a context-sensitive menu.

The selection of the object concerned can be performed by pressing and releasing the first key. Activation of the object concerned can be performed by pressing and releasing the first key twice in rapid succession. Moving or resizing of the object concerned can be performed by holding down the first key while moving the hand-held device to move the cursor.

The first key and the second key can be softkeys, whereby the current functionality of the softkeys is shown in the display, preferably in dedicated fields of the display.

The first key can be placed below the display on the left side of the latter, preferably proximate to lower edge of the display, and the second key can be placed below the display on the right side of the latter, preferably proximate to lower edge of the display.

It is another object of the present invention to provide an improved method for proving user input to hand-held devices. This object is achieved by providing a method for creating user input for a hand-held device that has a processor, a user interface and a digital camera for capturing motion video or still images comprising the steps of:

determining motion of the hand-held device from the camera signal;

using the determined motion of the hand-held device as an input for the user interface.

It is yet another object of the present invention to provide a use of a digital camera of a hand-held device

that has a processor to produce a motion signal indicative of motion of the hand-held device.

A further object of the invention is to provide a hand-held device with an improved graphical user interface. This object is achieved by providing a hand-held device comprising a processor, means for sensing motion of the hand-held device, a display, a keypad with at least a first- and a second key, a graphical user interface with objects and a cursor, and means for transforming the sensed motion of the handheld device into a signal suitable for moving the cursor over the display.

By controlling the position of a cursor through motion of the handheld device it becomes possible to provide a user-friendly cursor controlled graphical user interface for hand-held devices.

Preferably, motion of the hand-held device is used to position the cursor over objects of the graphical user interface and primary functions associated with the object concerned are activated by pressing the first key and secondary functions associated with the object concerned are activated by pressing the second key.

The functionality of the first key can be associated with selection and activation of objects of the graphical user interface, and the functionality of the second key can be preferably associated with calling up a context-sensitive menu.

Selection of the object concerned is preferably performed by pressing and releasing the first key, and activation of the object concerned is preferably performed by pressing and releasing the first key twice in rapid succession.

Moving or resizing of the object concerned can be performed by holding down the first key while moving the hand-held device to move the cursor and the object concerned in unison therewith.

The first key and the second key can be softkeys, whereby the current functionality of the softkeys is shown in the display, preferably in dedicated fields of the display.

The first key can be placed below the display on the left side of the latter, preferably proximate to lower edge of the display, and the second key can be placed below the display on the right side of the latter, preferably proximate to lower edge of the display.

The means for transforming motion of the handheld device into a signal suitable for moving the cursor over the display may further comprise a tilt sensor and/or an image capturing device and/or an accelerometer.

The hand-held device according may further comprise means to transform a signal from the image capturing device, i.e. camera and/or tilt sensor and/or accelerometer into a position signal for the cursor.

The means for transforming a signal from the camera into a motion signal preferably derives the motion signal from changes between succeeding images, or parts of succeeding images captured by the camera.

The camera may have an autofocus system, whereby the focusing setting of the autofocus system is used for detecting movement in the camera direction.

The graphical user interface may include one or more of the following object types: icons, dialogue boxes, windows, menus, pointers.

Further objects, features, advantages and properties of the hand-held device, method for proving user input and use of a digital camera in a hand-held device according to the invention will become apparent from the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present description, the invention will be explained in more detail with reference to the exemplary embodiments shown in the drawings, in which:

Fig. 1 illustrates a preferred embodiment of a hand-held device according to the invention,
Fig. 2 shows a block diagram of the hand-held device of the embodiment of Fig. 1,
Fig. 3 indicates the axes of movement and rotation along which the hand-held device is moved and rotated in order to create user input in accordance with the present invention,
Figs. 3.1 to 3.7 illustrate the use of the present invention for zooming, scrolling and rotating images shown on the display,
Figs. 3.8 to 3.10 illustrate the use of the present invention for user input to a graphical user interface to scroll a table in a window and to resize a window,
Figs. 3.11 to 3.13 illustrate the use of the present invention for scrolling a magnifying window over the display,

Figs. 3.14 and 3.15 illustrate the use of the present invention for moving a part of an image by cutting an pasting,

Fig. 3.16 illustrates the use of the present invention with a text editing application,

Fig. 3.17 illustrates the use of the present invention with an application for entering musical notes in a stave,

Fig. 3.18 illustrates the use of the present invention with a labyrinth game

Fig. 3.19 illustrates the use of the present invention for controlling a video game,

Fig. 3.20 illustrates the use of the present invention with an application for controlling the sound settings of a music player funtion,

Fig. 4 outlines a software flow diagram for zooming, scrolling and rotating images shown on the display, and

Figs. 5 and 6 show an alternative preferred embodiment of a hand-held device according to the invention.

DETAILED DESCRIPTION

This invention allows hand-held communication or computing devices with a relatively small display to receive user input by moving or rotating the device. In particular with devices having a display, the invention allows convenient navigation of a large stored virtual display or of objects in a graphical user interface. Such devices may include PDA devices, camcorders, digital photo cameras, digital binoculars (solid-state stereoscopic imaging system incorporated for viewing and digitally recording magnified stereo images), mobile hand-held terminals, advanced pagers, mobile telephones, and communicators.

According to a preferred embodiment, the hand-held device is a hand portable phone, preferably a cellular/mobile phone.

Fig. 1 shows a mobile phone according to the invention, and it will be seen that the phone, which is generally designated by 1, comprises a user interface having a keypad 2, a display 3, an on/off button 4 , a speaker 5 (only the openings are shown), and a microphone 6 (only the opening is shown). The phone 1 according to the preferred embodiment is adapted for communication via a cellular network, such as the GSM 900/1800 MHz network.

The keypad 7 has a first group of keys 8 as alphanumeric keys, by means of which the user can enter a telephone number, write a text message (SMS), write a name (associated with the phone number), etc. Each of the twelve alphanumeric keys 8 is provided with a figure "0-9" or a sign "#" or "*", respectively. In alpha mode each key is associated with a number of letters and special signs used in the text editing.

The keypad 7 additionally comprises two softkeys 9, two call handling keys 12, and an arrow key 10. The function of the softkeys depends on the state of the phone and the navigation in the menu can be performed by using the navigation-key. The present function of the softkeys 9 is shown in separate fields in the display 3, just above keys 9. The two call handling keys 12 are used for establishing a call or a conference call, terminating a call or rejecting an incoming call. This key layout is characteristic for e.g. the Nokia 6210™ phone.

The arrow key 10 is an up/down key which can be used for cursor movement and scrolling and is placed centrally on the front surface of the phone between the display 3 and the group of alphanumeric keys 7. A battery pack 14 is mounted on the back of the phone and supplies electrical power for the electronic components of the mobile phone.

The phone has a flat display 3 that is typically made of a LCD with optional back lighting, such as a TFT matrix capable of displaying color images.

The phone is equipped with a digital camera 35 of which only the lens 36 is visible in Fig. 1. The camera is arranged at the rear of the phone above the battery pack 14. The camera direction is therefore substantially perpendicular to the rear surface of the phone 1. Just under the camera an infrared port 38 for IrDA communication is provided (only window of the port is shown). The camera may alternatively have a rotatable connection to the phone (not shown), to allow adjustment of the camera direction relative to the housing of the phone.

Fig. 2 schematically shows the most important parts of a preferred embodiment of the phone, in the form of a block diagram. A processor 18 controls the communication with the network via the transmitter/receiver circuit 19 and an internal antenna 20. A microphone 6 transforms the user's speech into analogue signals, the analogue signals formed thereby are A/D converted in an A/D converter (not shown) before the speech is encoded in a digital signal processing unit 14 (DSP). The encoded speech signal is transferred to the processor 18, which i.e. supports the GSM terminal software. The processor 18 also forms the interface to the peripheral units of the apparatus, including a RAM memory 17a and a Flash ROM memory 17b, a SIM card 16, and the keypad 2 (as well as data, power supply, etc.). The digital signal-processing unit 14 speech-decodes the signal, which is transferred from the processor 18 to the earpiece 5 via a D/A converter (not shown). The processor communicates in two directions with the IrDA port 38 (infrared port) that allows data

communication with other devices that are equipped with such a port, such a PC's, laptops, personal digital assistants (PDA) and other mobile phones. The phone may further be equipped with a short range RF transmitter receiver (not shown), e.g. according to the Bluetooth standard, for data transmission with other devices as mentioned for IR data communication.

The processor 18 also forms the interface for the display controller 31. The image controller 31 receives the image files from the processor 18 and renders images for showing on the display 3.

A camera controller 37 is also connected to the processor 18 and controls the digital camera 35. The camera controller 37 sets the resolution, the refresh rate, the focus, and zoom factor of the camera 35. The camera controller 37 sets the focus automatically through any of the well-known auto focus techniques available. The output signal of the camera 35 is connected to the processor 18.

When the camera is used to detect motion of the hand-held device, the camera controller 37 automatically selects the appropriate resolution and refresh rate, so that the refresh rate is high enough to derive a smooth motion signal from the changes in the succeeding images. For motion detection it is not usually necessary to use the complete image captured by the digital camera. The software can pick out a particular section of the image for the motion detection so that the amount of data that has to be processed is reduced. These two measures (low resolution and using a section of the image) allow higher sampling rates and reduced power consumption because of lower data processing power demands.

Some surfaces in the camera view may not be particularly suited for detecting motion, e.g. because of a uniform surface, or because the distance to the objects in the camera view is too large to determine changes in distance accurately. Such problems may be solved (in the embodiment with the adjustable camera direction) by directing the camera to another available object with sufficient texture, such as the user. The camera direction is thus reversed compared to the "normal" direction. The motion signal derived from the camera signal is therefore automatically inversed when the camera is directed to the user.

The camera 35 is a conventional digital camera and therefore not all the features of the camera 35 are shown. The image sensor of the digital camera can be any of the known configurations for solid-state image sensors, such as frame transfer, interline transfer CCDs, or diode arrays.

Standard CCD devices are sensitive to both visual light and near infrared light. Conventional digital cameras for capturing images with visual light are therefore provided with an infrared filter for preventing influences of infrared light on the captured image. The mobile phone 1 is also provided with an infrared filter (not shown). The infrared filter can be moved out of the path of the light into the camera for capturing infrared images. The IrDA port 38 can be set to irradiate continuously to function as a light source for the camera 35 when it is in the infrared mode. Thus, the camera 35 can be used when there is little or no ambient light. The use of an IrDA port as a light source for a digital camera and the details of a device to move the infrared filter in and out of the camera path as well adjustments to the auto focus system

are disclosed in US patent application with serial nr. 10/029,968, hereby incorporated by reference.

The lens 36 is preferably a fixed focal length lens with movable lens group to allow auto focus, however, lens 36 could be any type of lens providing for adjustment to focus on different parts of the image received, as will be understood to those skilled in the art.

The characteristics of visible light and near infrared light with respect to focusing are slightly different. Therefore, the auto focus system has two settings; a first setting for capturing images with visual light and a second setting for infrared light.

Standard software for processing, storing and recalling pictures captured with visual light and captured with infrared light is installed on the phone 1. This software may as such be conventional and commercially available. The software is also able to control the refresh rate of the images shown on the display.

Optionally, the phone 1 may also comprise one or two tilt sensors 39 which determine the direction and magnitude of the displacement relative to vertical using the planetary gravitational field. Such sensors could be any of well known types such as those operating with an encoding disk on a freely rotatable shaft connected to a weight, or of the type that uses sphere provided with an asymmetrical weight that floats in a liquid. Alternatively the tilt sensor could by of the gyroscopic type. The signals of the camera the tilt sensors can be combined for generating the motion signal.

The phone 1 in accordance with e preferred embodiment employs two operational modes associated with the use of

motion of the phone to generate user input, which throughout this document are referred to as navigation mode and fixed mode. When set to the navigation mode, motion of the phone 1 is used as input, and when displaying an image, the display view is automatically scrolled, zoomed and rotated to follow movements of the holding hand. The navigation mode is activated by pressing the left softkey 9 "Navigate". Thus, the navigation mode is activated and the functionality of the left softkey 9 changes to "Fixed". When set back to the fixed mode by pressing the left softkey "Fixed" again, the display view becomes stationary and no longer follows the movements of the hand.

Fig. 3 indicates the relative axes of orientation along which the phone 1 is rotated or translated in order to navigate an image on the display 3. Throughout this document, axis 40 will be referred to as the Y-axis, and motion of the phone in the direction of the Y-axis is in a preferred embodiment used to scroll images in the Y-direction. Similarly, axis 41 will be referred to as the X-axis and motion of the phone in the direction of the X-axis is in a preferred embodiment used to scroll images in the X-direction. Motion in the camera direction measured along the Z-axis 42 is in a preferred embodiment used to control the zoom factor of the images shown on the display 3. Rotation about the Z-axis is used to rotate images shown on the display 3. Though these are the preferred functions assigned with movements along the X- ,Y- and Z-axes, any other functionality can be assigned to movement in the direction of these axes or to rotational movement about these axes.

While the scrolling, zooming, and rotation of the display follows the movements of the device, the rate of scrolling/zooming/rotation as well as the amount of

scrolling/zooming/rotation need not follow the exact amount of change in position, and can be inverted. As will be discussed below, the control software of the present invention can smooth the movements of the phone to provide a convenient effect on the display.

Figs. 3.1 to 3.13 show an overview of the operation of the phone 1 to scroll, zoom and rotate images.

With reference to Fig. 3.1, a high resolution image of a holiday snapshot comprising a lake, a bridge and a mountain peak stored in the RAM 17a is shown for viewing on the display 3. The display 3 is too small to show the entire image with sufficient size to appreciate all the details in the image conveniently. The user presses the left softkey 9 "Navigate" to enter the navigation mode. The phone activates the navigation mode and changes the label above the left softkey 9 to "Fixed". In Fig. 3.2, the navigation process is started when the operator's hand moves the phone 1 along the Z- axis 42 in the direction of arrow 42' for magnifying the view so that the display 3 shows the central portion of the image with the bridge in an enlarged manner (Fig. 3.3). By moving the phone along the Y-axis 40 in the direction of arrow 40' the display 3 scrolls the images upwards and the mountain peak above the bridge can be viewed (Fig. 3.5).

In Fig. 3.6 the holiday snapshot is shown in a portrait orientation and can only be properly viewed with the phone in a horizontal position. The user wishes to view the image with the phone in an upright position so that the image will be displayed in a landscape position with respect to the display 3. The user presses the left softkey 9 "Navigate" to activate the navigation mode and rotates the phone a half turn anticlockwise (Fig. 3.7). The movement of the phone 1 creates a series of changing

images captured by the camera 35 from which the software on the phone derives a motion signal. Upon detection the rotational movement about the Z-axis the software on the phone rotates the displayed image in the opposite direction, and when the user has completed a half anticlockwise turn the software has rotated the image a half turn clockwise, and the user can conveniently view the image with the phone in an upright position. The image is thus static with respect to the fixed coordinate system in which the phone 1 device is situated.

The settings for the responses to motion of the phone 1 can thus be set in way in which the user perceives the view as that of a static image over which a magnifying window (the display 3) is moved.

Fig. 3.8 shows a display 3 of the phone in a mode in which a graphical user interface is used to command the device. A window 70 containing a scrollable table is displayed on the display 3. Scroll bars 71 and 72 are shown to the right and at the bottom of the table, respectively. A cursor 73 can be moved over the display by moving the phone in the direction of the X- and Y-axes. The left softkey 9 "Left-click" has the same functionality as the left mouse button as known from many windows based graphical user interfaces, namely to select a primary function associated with an object marked by the cursor 73. By clicking, double clicking or holding the left softkey 9 down. The right softkey 9 "Right-click" also has the same functionality as the right mouse button as known from many windows based graphical user interfaces, namely to select secondary functions associated with an object marked by the cursor 73. It is possible to assign the "Left click" and "Right click" to other keys of the phone, but using a similar layout as for the keys of a computer mouse may facilitate user acceptance.

Example 1: The user wishes to scroll the table to the right to view column E. By holding the left softkey 9 "Left-click" pressed and moving the phone to the right along the X-axis the table is scrolled by dragging it with the cursor to the right as shown in Fig. 3.9.

Example 2: The user wishes to resize the window 70. After placing the cursor 73 on the upper bar of the window 70 and while holding the left softkey 9 "Left-click" movement of the phone 1 in the direction of the Z-axis resizes the window 70. Moving the phone towards the user enlarges the window as shown in Fig. 3.10 and moving away from the user reduces the size of the window (not shown).

Example 3: The user wishes to move a part of an image in an image editing program. The part of the image to be moved is marked with a sizable box 65. Holding the left softkey 9 "Left-click" down and moving the mouse by rotating the phone about the X- and Y-axis resizes the box (Fig. 3.14). After sizing the box 65 the left softkey 9 is released and the cursor 73 can be moved freely. The box can be dragged and dropped to the desired position by placing the cursor 71 in the box 65 and holding the left softkey 9 "Left-click" down whilst rotating the phone about the Y- and/or X-axis until the box has moved to the desired position. By releasing the left softkey 9 the boxed is dropped and the cursor 73 can move freely again. Thus, the part of the image in the box is cut from the original position and pasted to the new position.

In the same or manner any object e.g. text in a text editor program, or numbers/text in a spreadsheet can be marked, resized, dragged and dropped "click and drag" with the left softkey.

The most common "gestures" performed by moving the phone and pressing the softkeys are:

- point (to place the cursor over an object of the graphical user interface),
- left-click (to press and release the left softkey) to select the object which the cursor is placed,
- double-click (to press and release a softkey twice in rapid succession) to activate the object that the cursor is placed over,
- right-click (to press and release the right softkey) to call up a context-sensitive menu, and
- drag (to hold down the left softkey while moving the phone to move the cursor) to move or resize objects.

Figs. 3.11 to 3.13 show another method of manipulation magnified portion of an image. Fig. 3.11 shows the display 3 with an image of a several advanced type mobile phones. A magnifying window 103 enlarges a portion of the image to allow the user a view with both a good overview and the possibility to view detail in a selected portion of the image. The magnifying window 103 can be moved over the display 3 by holding down the left softkey 9 "Navigate" whilst moving the phone in the direction of arrow 41' and/or arrow 40' (Fig. 3.12) to place the magnifying window at the desired position (Fig 3.13). The magnifying factor of the magnifying window can be changed by moving the phone 1 in the direction of the Z-axis (not shown).

Fig 3.16 shows another example of the use of the present intention in the form of an application for entering text. In the upper part of the display shows a string of characters already entered. A set of characters that can be entered, in this example the alphabet, is displayed below the upper part of the display. Other character sets could comprise a number set or special signs set, etc.

The functionality of the left softkey 9 "Type" and the right softkey 9 "Options" is shown in the lower part of the display. One of the characters of the character set is marked by bold print. By rotating the phone about the Y-axis 40 the marking moves left or right. By rotating the phone about the X-axis 41 the marking moves up and down. The marked character is added to the string of characters by pressing the left softkey 9 "Type".

By pressing the right softkey "Options" a scrollable list of selectable menu items is displayed (not shown) comprising: "Clear last character", "Clear screen", "Number character set", "Symbol character set", and "Exit", one of the menu items being marked by inverse print. The list can be scrolled by rotating the phone about the Z-axis 41, and the marked menu item is selected by pressing the left softkey 9 "Select".

Fig 3.17 shows another example of the use of the present invention in the form of an application for entering musical notes in a stave 69. A cursor 73 (shape changed to a cross for this application) is used to indicate the position where a note is to be entered. By rotating the phone about the Y-axis 40 the cursor can be moved left an right. By rotating the phone about the X-axis 41 the cursor can move up and down.

The cursor is placed above the position in the stave at which a note is to be entered, higher tones are placed higher up in the stave and lower tones are placed lower in the stave. A tone is entered by pressing the left softkey 9 "Type". After typing a note the application prompts for entering the length of the note by displaying the text "Length? 1=1 2=½ 4=¼ 8=1/8" between the stave and the labels for the softkeys. The note length is entered by

pressing the alphanumeric key with the value associated with the desired note length.

By pressing the right softkey "Options" a scrollable list of selectable menu items is displayed (not shown) comprising: "Clear last note", "Clear stave", "Enter special notes", and "Exit", one of the menu items being marked by inverse print. The list can be scrolled by rotating the phone about the X-axis 41, and the marked menu item is selected by pressing the left softkey 9 "Select".

Fig. 3.18 shows another example of the use of the present invention in the form of an application simulating a labyrinth game. The player (user of the hand-held device) endeavors to guide a virtual ball 59 through a virtual labyrinth formed by virtual walls 57 on a virtual playing surface past a plurality of virtual openings 58 though which the virtual ball 59 may drop.

The application simulates the effect caused by gravity that tilting a real playing surface out of the horizontal plane has on a real ball, e.g. the virtual ball starts rolling to the lower side of the display 3 when the latter is tilted out of the horizontal plane. Also the effect of gravity on a real ball passing over a real opening is simulated by the application, e.g. the virtual ball drops through the virtual opening when it passes over a virtual opening.

At the start of the game, the display is held horizontally, or any other orientation that the user deems suitable as reference orientation to calibrate the virtual "horizontal" position of the display. The movement of the virtual ball over the virtual playing surface is controlled by moving the phone out of- and back into the

horizontal plane by rotating it rotating about the Y-axis 40 and/or the X-axis. The rotational movements are detected from the changes between the succeeding images captured by the camera and translated into changes in speed and rolling direction of the virtual ball.

Fig 3.19 shows another example of the use of the present invention in the form of an application for controlling another computer game, in this example a car racing simulation. The player (user of the hand-held device) endeavors to "drive" a car around a racing circuit as fast as possible. The application allows the player to control the steering breaking and giving gas functions. The imaginary view on the racing circuit is the main content of the display, but is not shown on Fig. 3.19. The display further shows a steering wheel and rearview mirrors. A race is started by double clicking the left softkey 9 "Action". The control settings for speed and directions are calibrated and set to zero for the present position and orientation of the phone 1. After an audible start signal the driver is supposed to attempt to follow the displayed racing circuit. The "car" is steered by rotating the phone about the z-axis 42. Rotating the phone clockwise out of the calibrated position about the Z-axis makes the "car" turn right. Rotating the phone further out of the calibrated orientation, make the "car" turn sharper and vice versa. Similarly, rotating the phone anti-clockwise about the Z-axis out of the calibrated position makes the "car" turn left. The speed of the "car" is controlled by tilting the phone 1 about the X-axis 41. Rotating the phone 1 out of the calibrated position in one direction is used to give "gas". Rotating the phone 1 further out of the calibrated orientation increases the amount of "gas", and vice versa. The amount of breaking applied to the car is similarly controlled by rotating the phone 1 out of the calibrated position in the opposite

direction. The user may select which direction of rotation about the X-axis is used to give "gas", whereby the breaking direction is always the opposite. Other computer games that can be controlled in a similar manner but using more axes of motion/control include motor bike racing, and helicopter flying. For motorbike racing the factor balance can be included in relation to motion about one of the axes, to produce a very realistic experience, with e.g. steering bar rotation connected to rotation about the Z-axis, giving gas and breaking connected to rotation about the X-axis and balance connected to translative motion along the X-axis. For enhancing the games the capacity of the mobile phone to generate sound via the loudspeaker, in particular a hands-free loudspeaker is used to simulate e.g. motor, and/or propeller sound. The vibrator function (not shown) of the mobile phone can be used to give feedback in connection with shocks and crashes.

Fig 3.20 shows another example of the use of the present invention in the form of an application for controlling the sound setting of a music player function of the phone. The application allows a user to control volume, bass and treble. The application shows a volume button, a bass button and a treble button on the display 3. The button that is to be manipulated is be marked by a higher line thickness (as shown for the "Volume" button in Fig. 3.20). The marking can be moved to other buttons by rotating the phone about the Y-axis 40. The marked button is manipulated by holding the left softkey 9 "Control" down while rotating the phone about the Z-axis 42. Clockwise rotation of the phone results in an increased setting of the parameter concerned, anticlockwise rotation of the phone results in a decreased setting of the parameter concerned. The application ends by pressing the right softkey 9 "Exit". Alternatively, the display shows slide control knobs for each of the parameters to be controlled

(not shown). The knob that is to be manipulated is be marked by a higher line thickness. The marking can be moved to other knobs by rotating the phone about the Y-axis 40. The marked knob is manipulated by holding the left softkey 9 "Control" down while moving the phone in the direction of the Z-axis 42. Moving the phone in the direction in which the display 3 is facing increases the parameter setting concerned, moving the phone in the opposite direction results in a decreased setting of the parameter concerned.

Another example of the use of the present invention is in connection with another terminal such as a PC (not shown). The motion signal of the phone is transmitted to the PC to control the movement of an object. The object could be a 3-D object displayed on a screen connected to the PC, whereby orientation changes of the phone are used to change the orientation of the displayed object. The orientation of the object on the screen can be completely synchronized with the orientation of the phone. After an initial calibration of the relative positions, e.g. when the phone is upright, the displayed object is also upright. For e.g. presenting a product, the product can be shown as an object on a large screen. To change the orientation of the object the user changes the orientation of the phone by rotating it, and the PC rotates the displayed object in the same way in response to the signal that it receives from the phone.

Another example of using the phone with another terminal, i.e. a workstation or a PC is for moving through an imaginary 3-D space displayed on a screen by e.g. a CAD program. The movements of the phone in the real 3-D world are incorporated in the signal that is sent to the workstation and the PC or workstation translates the signal to movements of the viewing position in the "3-D

space" displayed on the screen. Changes in the orientation of the phone are also incorporated in the signal that is sent to the workstation and translated to changes of the viewing direction in the "3-D space" displayed on the screen. Thus the user can "walk" through an imaginary room by walking around in the real world whilst holding or carrying the phone, and change the viewing direction by pointing the phone in the desired viewing direction. To facilitate this manner of use, the invention could be incorporated in a smaller device that is integrated in a helmet or mounted to another kind of headgear, so that viewing direction can be changed by the user turning his/her head in the desired direction of view.

This manner of controlling the viewing position and the viewing direction can equally well be used for computer games and any other software applications that display a virtual 3-D space on a screen, i.e. to move through and observe a room, or any other place created in a virtual world. Another example of a use of this manner of controlling is game application that guides, i.e. instructs a user to follow a virtual path and checks through the motion signal if the user really travels this path. Such games could be used by a group of users with interactive mobile phones in a suitable open space such as a sports ground.

Fig. 4 outlines the software flow diagram for the manipulation of an image as described with reference to Figs. 3.1 to 3.7. The flow from start 80 to end 98 is performed several times a second in a standard polling process of the processor 18. At the initialization step at block 82, the current view settings are marked. The label above the left softkey 9 is set to "Navigation" in block 84. The status of the left softkey 9 is checked in block 86. If the left softkey 9 is pressed, the system is set to

the navigation mode in block 88 and the label above the left softkey is changed to "Fixed".

At block 90 the camera image and auto focus settings are acquired, stored and compared to the previous readings. If a change in image or in auto focus setting is detected at block 92, the program derives the movement of the phone 1 from the changes in block 94 and computes the new view settings i.e. zoom factor, rotation angle and portion of the image to be displayed. It also instructs the display controller 31 to refresh the display 3 to show the new view and it saves the present camera image as the basis for comparison in the next iteration of the process.

In block 96 the status of the left softkey 9 is checked and if it is pressed the process ends at block 98 until the program is polled again. If the check for the left softkey 9 is negative, the program goes to step 90 and the above process repeats itself.

The program can be set with different response curves for computing the new view setting in response to changes in camera image and/or auto focus setting at block 94. Fine or coarse modes of response can be set by the operator or can be changed dynamically during the time the system is in the navigation mode. With fine response, the display view changes at a relatively slow rate in response to the movements of the phone. With coarse response, the display view changes rapidly in response to the movements of the phone. The response can also be inverted to adapt to user preferences.

The functionality associated with a given type of motion of the phone 1 can be set. Thus, the user can e.g. set the program such that the cursor 73 can be moved up and down by rotation about the X- axis and can be moved left and

right by rotation about the Z-axis. Given types of motion of the phone 1 can be associated with functionality that does not relate to the display 3, such as sound settings (e.g. volume and balance) and display settings (e.g. brightness, color balance and contrast).

Figs. 5 and 6 show an alternative preferred embodiment of a hand-held device according to the invention in the form of a communicator 101. The communicator 101 is basically built up in the same way as the mobile phone 1 though with a larger display 103 and a larger keyboard 107. A camera 135 (only lens 136 is shown) is mounted in the back/bottom of the communicator and has the same functionality as the camera in the phone 1. The internal hardware is also build up in the same way as the phone 1, but with increased processing power and a larger memory. Movements of the communicator 101 in the direction of or about the X-axis 141, the Y-axis 140 and Z-axis 142 have the same functionality as in the phone 1.

Although the present invention has been described in detail for purpose of illustration, it is understood that such detail is solely for that purpose, and variations can be made therein by those skilled in the art without departing from the scope of the invention.

Thus, while the preferred embodiments of the devices and methods have been described in reference to the environment in which they were developed, they are merely illustrative of the principles of the inventions. Other embodiments and configurations may be devised without departing from the scope of the appended claims.

CLAIMS:

1. A hand-held device comprising a processor, a digital camera for capturing motion video or still images, and means for transforming a signal from the camera into a motion signal indicative of the motion of the hand-held device.

2. A hand-held device according to claim 1, further comprising a user interface in which motion of the hand-held device is - through the motion signal derived thereof - used as a user input.

3. A hand-held device according to claim 1 or 2, further comprising a display suitable for displaying captured images.

4. A hand-held device according to claim 3, in which motion of a given type of the hand-held device is used to manipulate images shown at least in part on the display, preferably by moving the images in a manner substantially corresponding to the movement of the hand-held device.

5. A hand-held device according to claim 4, in which a given type of motion the hand-held device is used to move, and/or zoom, and/or expand/collapse and/or rotate images displayed on the display.

6. A hand-held device according to claim 5, in which motion substantially parallel to the plane of the display of the hand-held device is used to scroll an image displayed on the display, and/or motion substantially perpendicular to the plane of the display is used to zoom an image displayed on the display and/or rotational motion of the hand-held device is used to rotate an image displayed on the display.

7. A hand-held device according to any of claims 4 to 6, in which the images are images previously captured by the camera.

8. A hand-held device according to any of claims 4 to 7, in which movement of image is inverted with respect to motion of the hand-held device.

9. A hand-held device according to any of claims 2 to 8, in which the user interface comprises a graphical user interface, and wherein motion of the hand-held device is used as an input to the graphical user interface.

10. A hand-held device according to claim 9, in which motion of the hand-held device is used to manipulate an object displayed by the graphical user interface, preferably by moving the object in a manner substantially corresponding to the motion or to the inverted motion of the hand-held device, whereby the object displayed by the graphical user interface can be, an icon, a dialogue box, a window, a menu or a pointer.

11. A hand-held device according to claim 9, in which motion of a given type of the hand-held device is used to move, and/or zoom, and/or expand/collapse and/or rotate objects displayed by the graphical user interface.

12. A hand-held device according to claim 11, in which motion substantially parallel to the plane of the display of the hand-held device is used to scroll an object displayed by the graphical user interface, and/or motion substantially perpendicular to the plane of the display is used to zoom an object displayed by the graphical user interface and/or rotational motion of the hand-held device

is used to rotate an object displayed by the graphical user interface.

13. A hand-held device according to any of claims 2 to 12, in which the digital camera is detachable.

14. A hand-held device according to any of claims 2 to 13, in which the digital camera is movable relative to the hand-held device.

15. A hand-held device according to any of claims 2 to 14, in which the means for transforming a signal from the camera into a motion signal derives the motion signal from changes between succeeding images, or parts of succeeding images captured by the camera.

16. A hand-held device according to any of claims 2 to 15, in which the camera has an autofocus system, whereby the focusing setting of the autofocus system is used for detecting movement in the camera direction.

17. A hand-held device according to any of claims 2 to 16, further comprising at least one key, wherein the functionality of a motion type is dependent on the state of the at least one key.

18. A hand-held device according to any of claims 2 to 17, in which rotational motion of the hand-held device about an axis substantially perpendicular to the display results in an inverse rotational movement of the image or graphical user interface object relative to the display, preferably in a manner such that the image or object is static with respect to the fixed coordinate system in which the hand-held device is situated.

19. A hand-held device according to any of claims 2 to 18, in which the motion signal is used to adjust device settings, the device settings preferably comprising sound settings and display settings.

20. A hand-held device according to any of claims 9 to 19, further comprising a keypad with at least a first- and a second key and the graphical user interface comprises a cursor, whereby motion of the hand-held device is used to position the cursor over an object of the graphical user interface and primary functions associated with the object concerned are activated by pressing the first key and secondary functions associated with the object of the concerned are activated by pressing the second key.

21. A hand-held device according to claim 20, in which the functionality of the first key is associated with selection and activation of objects of the graphical user interface, and in which the functionality of the second key is preferably associated with calling up a context-sensitive menu.

22. A hand-held device according to claim 21, in which selection of the object concerned is performed by pressing and releasing the first key, and activation of the object concerned is preferably performed by pressing and releasing the first key twice in rapid succession.

23. A hand-held device according to claim 21 or 22, in which moving or resizing of the object concerned is performed by holding down the first key while moving the hand-held device to move the cursor.

24. A hand-held device according to any of claims 20 to 23, in which the first key and the second key are softkeys whereby the current functionality of the softkeys is

shown in the display, preferably in dedicated fields of the display.

25. A hand-held device according to claim 24, in which the first key is placed below the display on the left side of the latter, preferably proximate to lower edge of the display, and the second key is placed below the display on the right side of the latter, preferably proximate to lower edge of the display.

26. A hand-held device according to any of claims 1 to 25, further comprising at least one gravity based tilt sensor, and whereby the signal from the at least one tilt sensor is used in combination with the signal from the camera for creating the motion signal.

27. A hand-held device according to claim 26, wherein a tilt sensor is associated with the X-axis and/or a tilt sensor is associated with the Z-axis.

28. A hand-held device according to claim 27, wherein the signal form the at least one tilt sensor is used to determine the absolute orientation of the handheld device relative to the direction of the gravitational pull.

29. A hand-held device according to any of claims 1 to 28, further comprising means for sending the motion signal to another terminal via cable, infrared waves or radio frequency waves.

30. A system comprising a hand-held device according to claim 29 and a terminal capable of displaying imaginary three-dimensional objects on a two-dimensional screen, said terminal comprising means to change the orientation of the displayed object in response to signals received from the handheld device, whereby orientation changes of

the hand-held device are translated to corresponding orientation changes of the displayed object.

31. A system according to claim 30, in which position changes of the handheld device are translated to position changes of the displayed object.

32. A system comprising a hand-held device according to claim 29 and a terminal capable of displaying an imaginary three-dimensional space on a two-dimensional screen, said terminal comprising means to change the viewing position in the imaginary three-dimensional space in response to signals received from the handheld device, whereby positional changes of the hand-held device are translated to corresponding changes in the viewing position.

33. A system according to claim 30, in which orientation changes of the handheld device are translated into corresponding changes in the viewing direction in the imaginary three-dimensional space.

34. A method for creating user input for a hand-held device that has a processor, a user interface and a digital camera for capturing motion video or still images comprising the steps of:

determining motion of the hand-held device from the camera signal;

using the determined motion of the hand-held device as an input for the user interface.

35. Use of a digital camera for capturing motion video or still images of a hand-held device that has a processor to produce a motion signal indicative of motion of the hand-held device.

36. A hand-held device comprising a processor, means for sensing motion of the hand-held device, a display, a keypad with at least a first- and a second key, a graphical user interface with objects and a cursor, and means for transforming the sensed motion of the handheld device into a signal suitable for moving the cursor over the display.

37. A hand-held device according to claim 36, in which motion of the hand-held device is used to position the cursor over an object of the graphical user interface and primary functions associated with the object concerned are activated by pressing the first key and secondary functions associated with the object concerned are activated by pressing the second key.

38. A hand-held device according to claim 37, in which the functionality of the first key is associated with selection and activation of objects of the graphical user interface, and in which the functionality of the second key is preferably associated with calling up a context-sensitive menu.

39. A hand-held device according to claim 38, in which selection of the object concerned is performed by pressing and releasing the first key, and activation of the object concerned is preferably performed by pressing and releasing the first key twice in rapid succession.

40. A hand-held device according to claim 38 or 39, in which moving or resizing of the object concerned is performed by holding down the first key while moving the hand-held device to move the cursor and the object concerned in unison therewith.

41. A hand-held device according to any of claims 36 to 40, in which the first key and the second key are softkeys whereby the current functionality of the softkeys is shown in the display, preferably in dedicated fields of the display.

42. A hand-held device according to claim 41, in which the first key is placed below the display on the left side of the latter, preferably proximate to lower edge of the display, and the second key is placed below the display on the right side of the latter, preferably proximate to lower edge of the display.

43. A hand-held device according to any of claims 36 to 42, in which said means for transforming motion of the handheld device into a signal suitable for moving the cursor over the display comprises a tilt sensor and/or an image capturing device and/or an accelerometer.

44. A hand-held device according to claim 43, in which said image capturing device is a motion video or still image digital camera.

45. A hand-held device according to any of claims 36 to 44, further comprising means to transform a signal from the camera and/or tilt sensor and/or accelerometer into a position signal for the cursor.

46. A hand-held device according to claim 45, in which said means for transforming a signal from the camera into a motion signal derives the motion signal from changes between succeeding images, or parts of succeeding images captured by the camera.

47. A hand-held device according to any of claims 44 to 46, in which the camera has an autofocus system, whereby

the focusing setting of the autofocus system is used for detecting movement in the camera direction.

48. A hand-held device according to any of claims 36 to 47, in which the graphical user interface includes one or more of the following object types: icons, dialogue boxes, windows, menus, pointers.

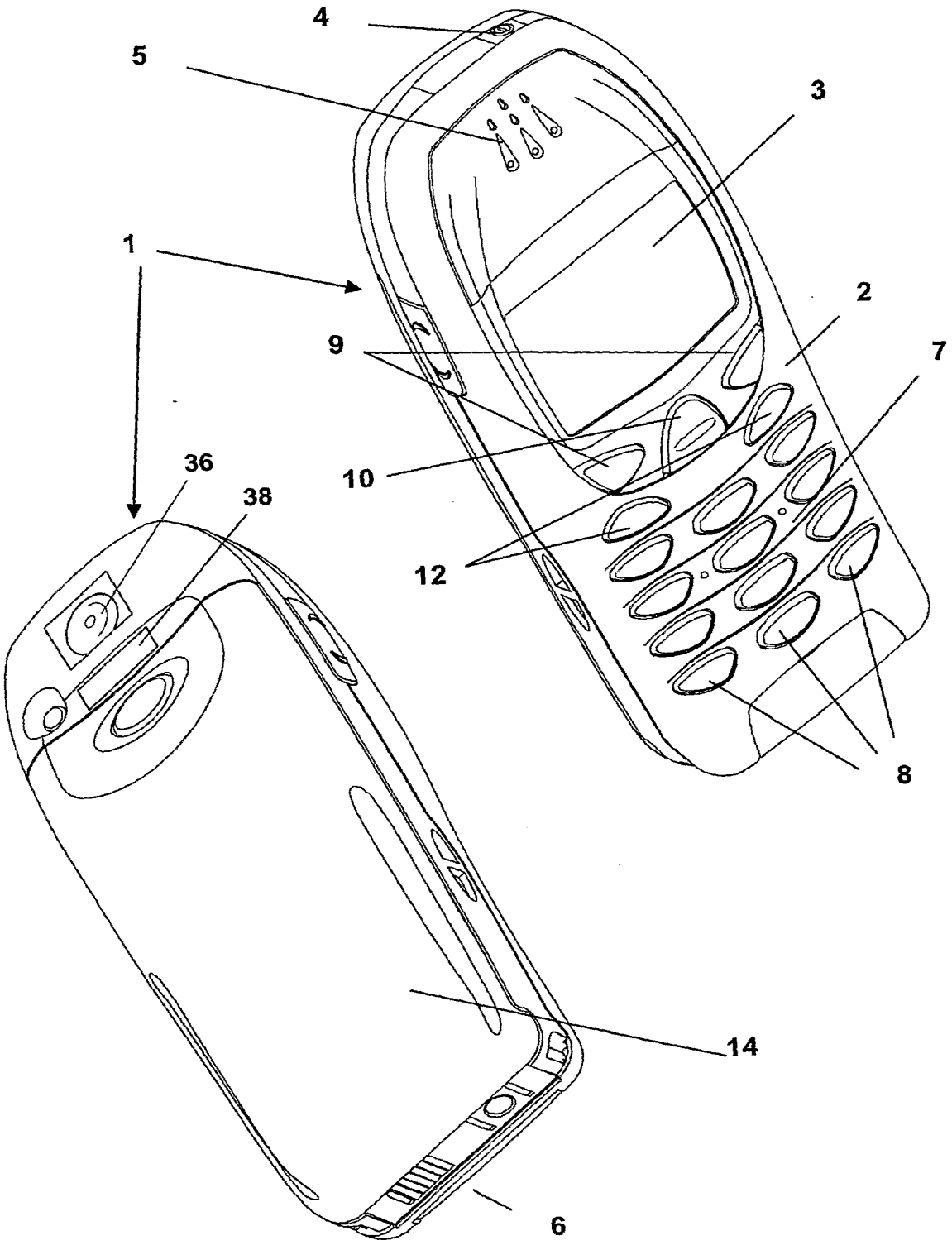


Fig. 1

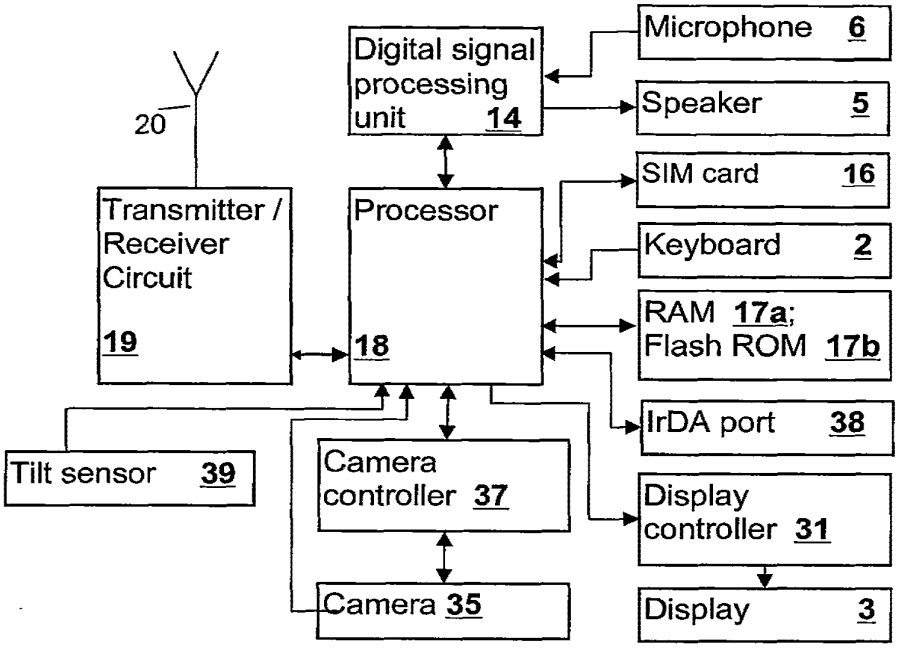

Microphone 6
Digital signal processing unit 14
Speaker 5
20
SIM card 16
Transmitter / Receiver Circuit 19
Processor 18
Keyboard 2
RAM 17a; Flash ROM 17b
IrDA port 38
Tilt sensor 39
Camera controller 37
Display controller 31
Camera 35
Display 3

Fig. 2

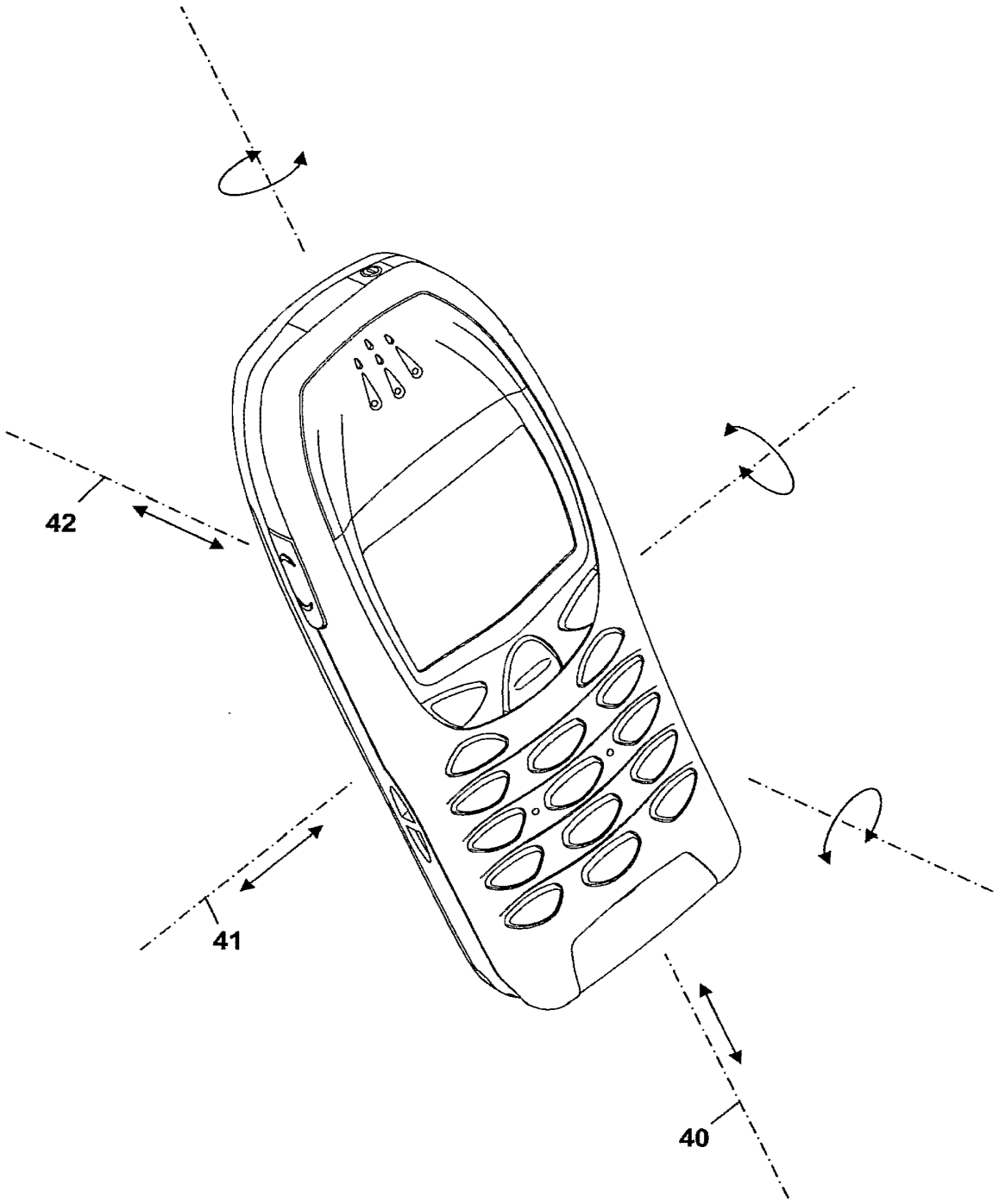


Fig. 3

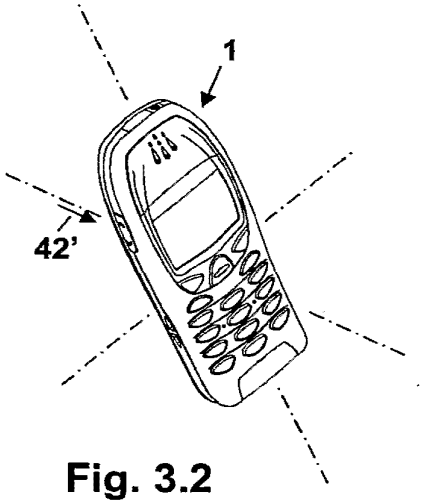


Fig. 3.2

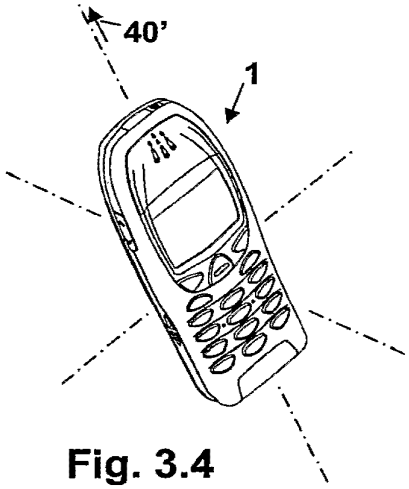


Fig. 3.4

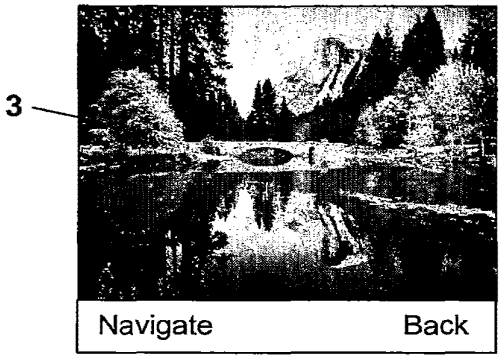


Fig. 3.1

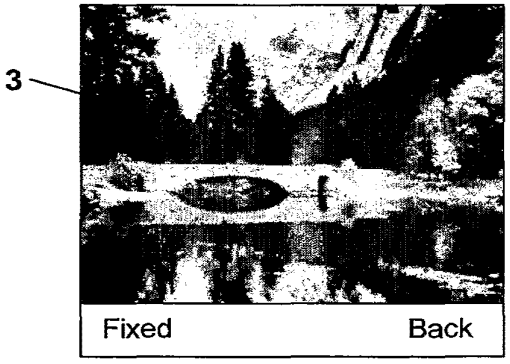


Fig. 3.3

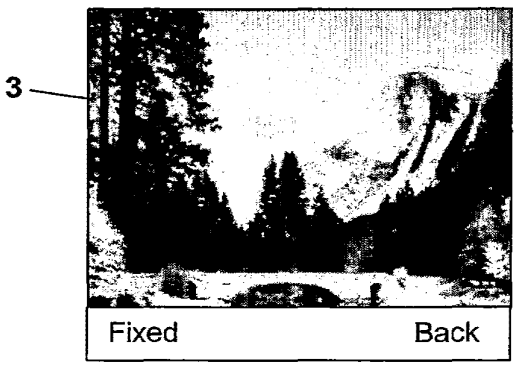


Fig. 3.5

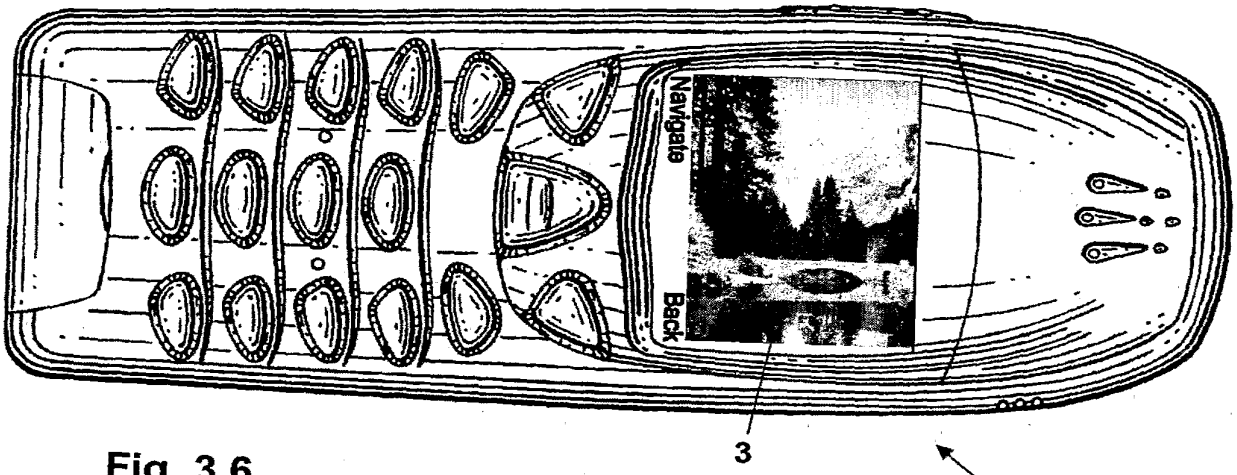


Fig. 3.6

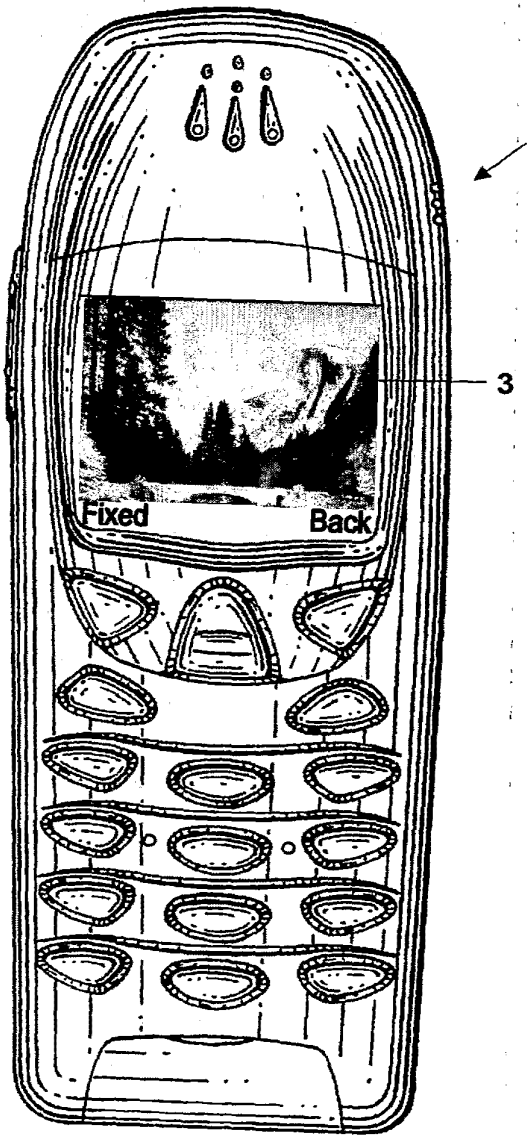


Fig. 3.7

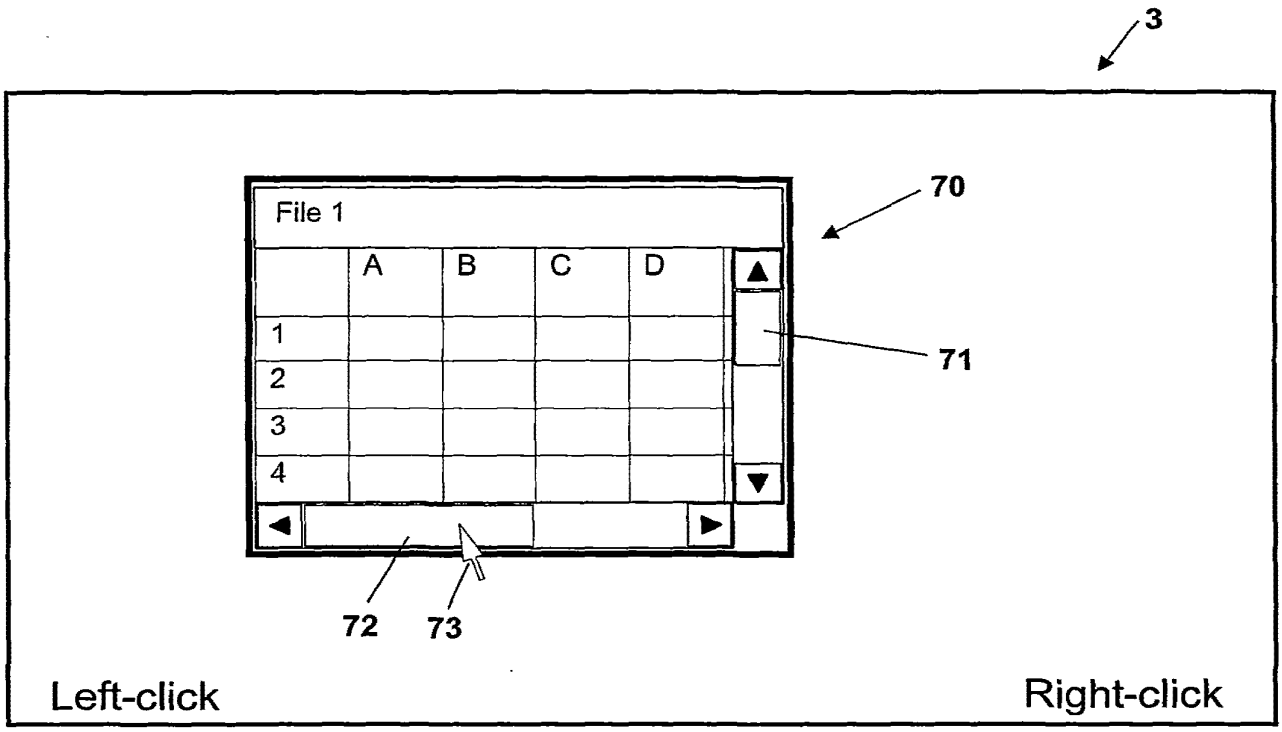

3
File 1
A
B
C
D
1
2
3
4
70
71
72
73
Left-click
Right-click

Fig. 3.8

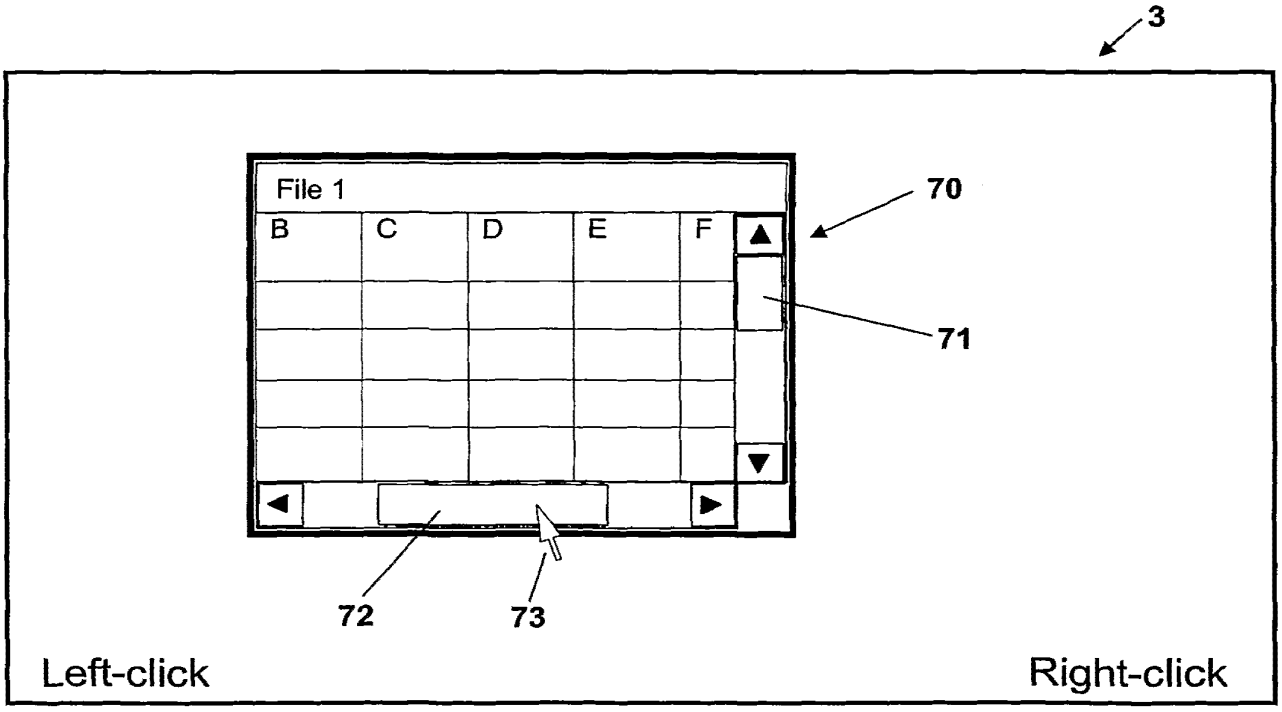

3
File 1
B
C
D
E
F
70
71
72
73
Left-click
Right-click

Fig. 3.9

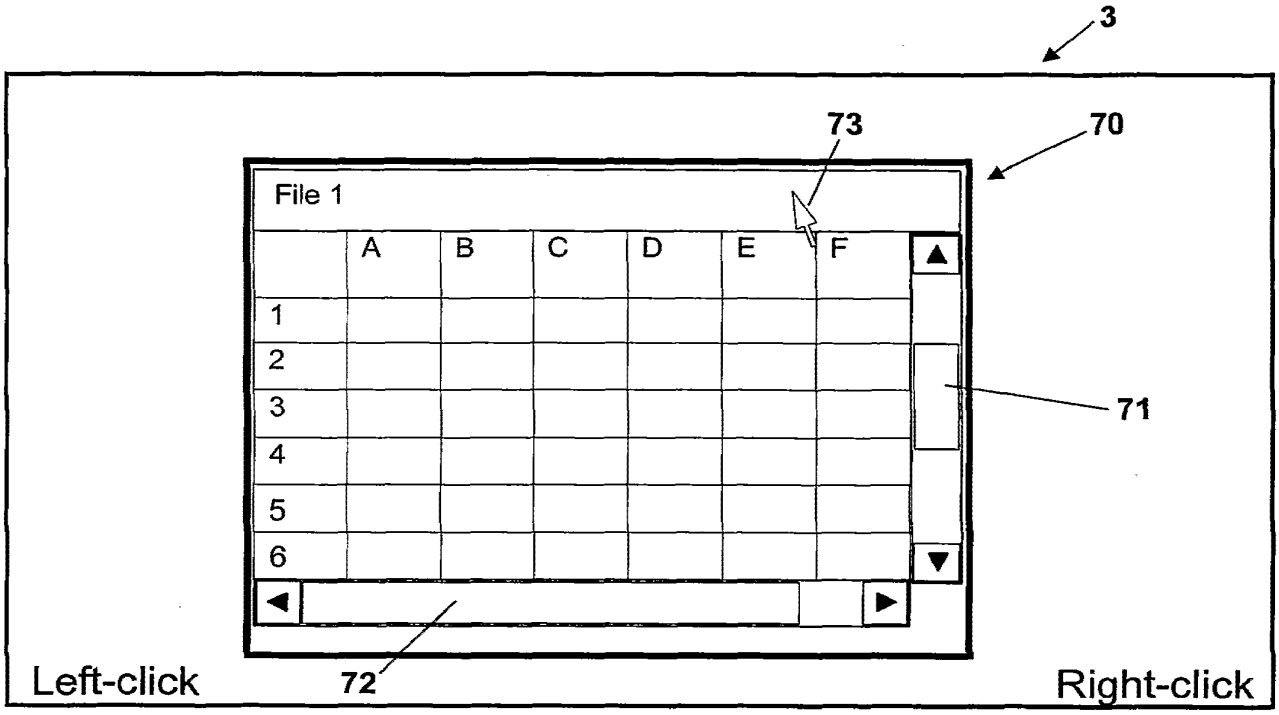


Fig. 3.10

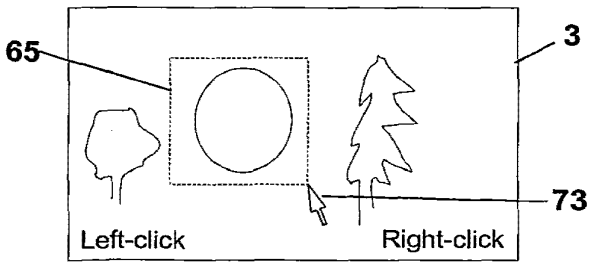


Fig. 3.14

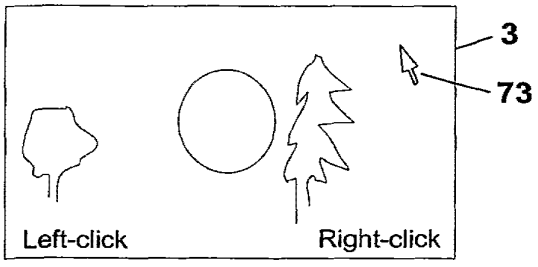


Fig. 3.15

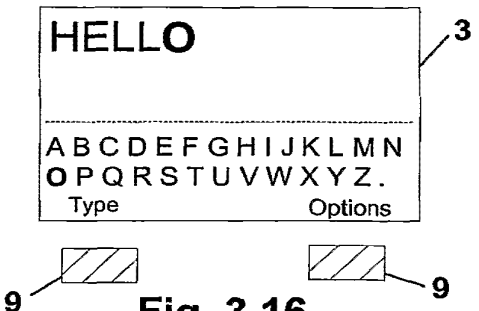


Fig. 3.16

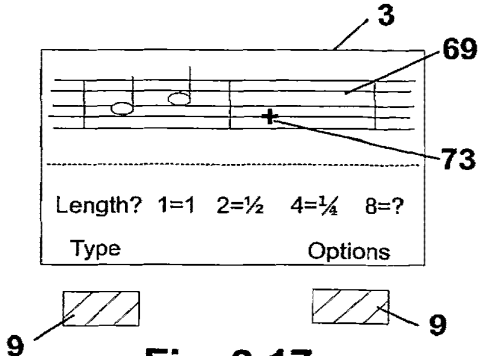


Fig. 3.17

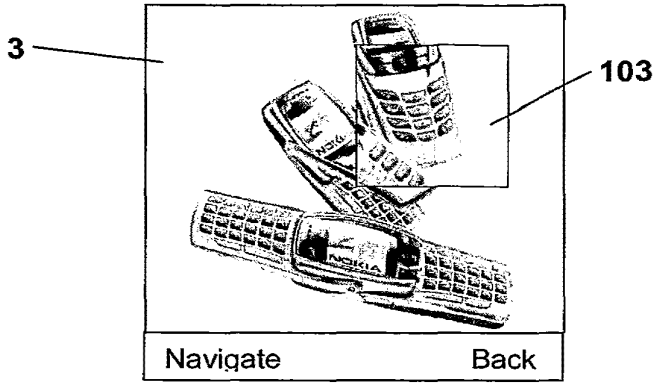


Fig. 3.11

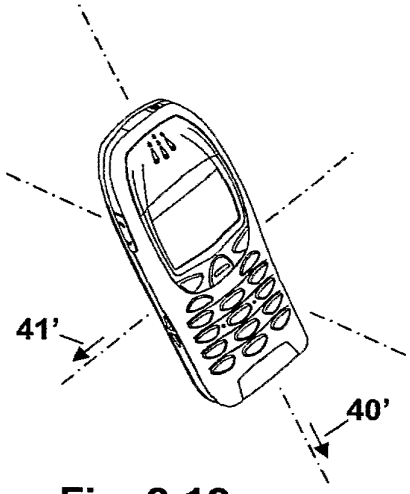


Fig. 3.12

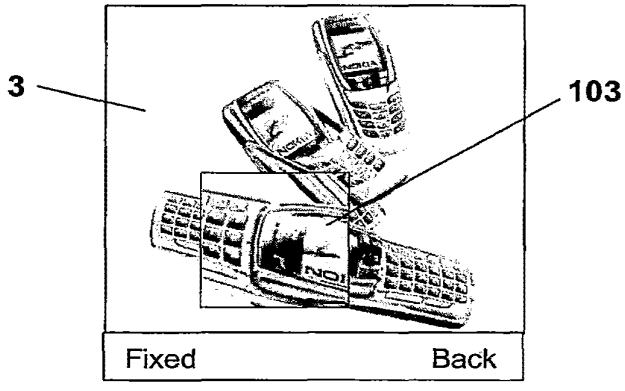


Fig. 3.13

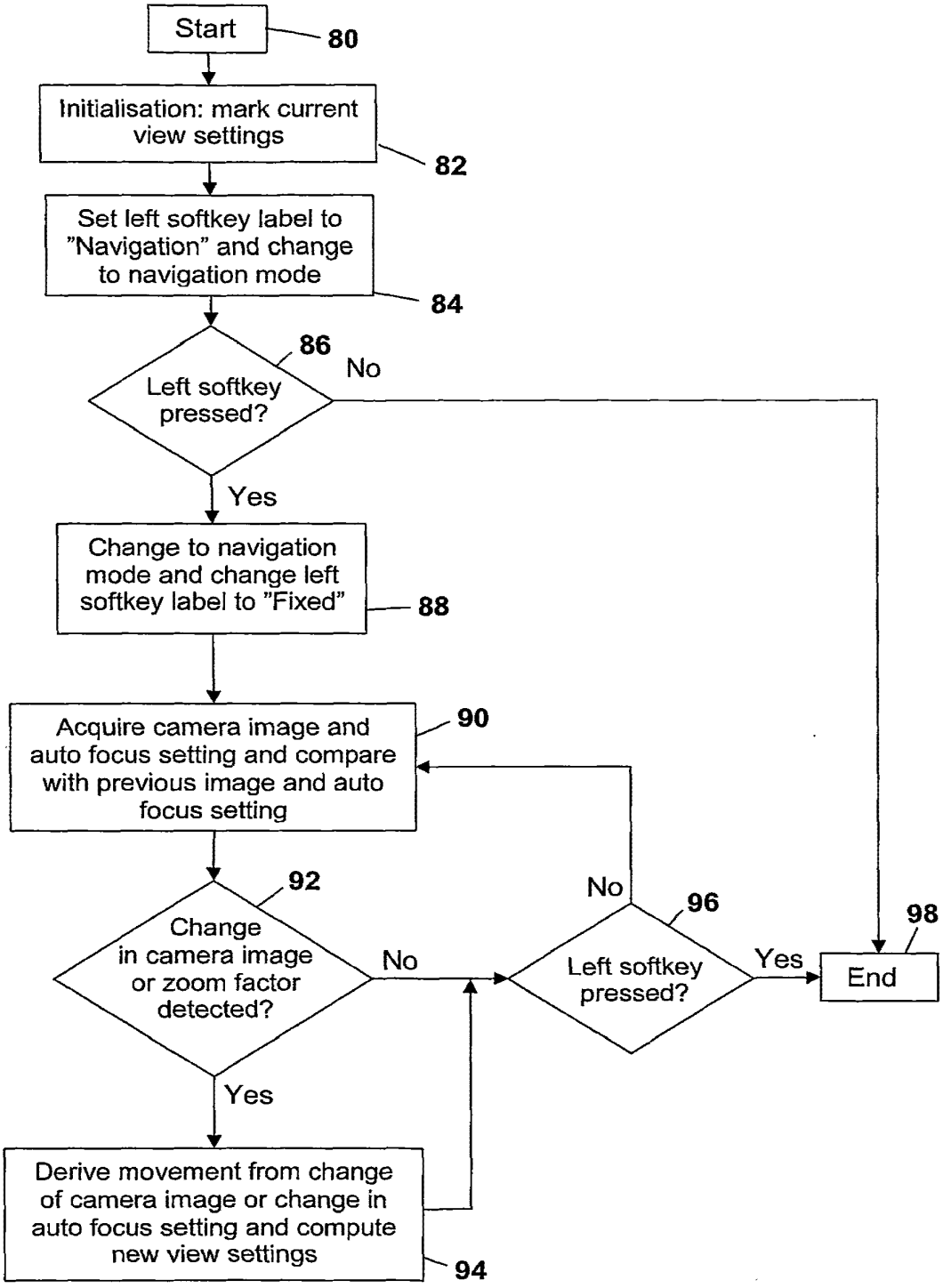

Start
80
Initialisation: mark current view settings
82
Set left softkey label to "Navigation" and change to navigation mode
84
86
Left softkey pressed?
No
Yes
Change to navigation mode and change left softkey label to "Fixed"
88
Acquire camera image and auto focus setting and compare with previous image and auto focus setting
90
92
Change in camera image or zoom factor detected?
No
Yes
96
Left softkey pressed?
No
Yes
98
End
Derive movement from change of camera image or change in auto focus setting and compute new view settings
94

Fig. 4

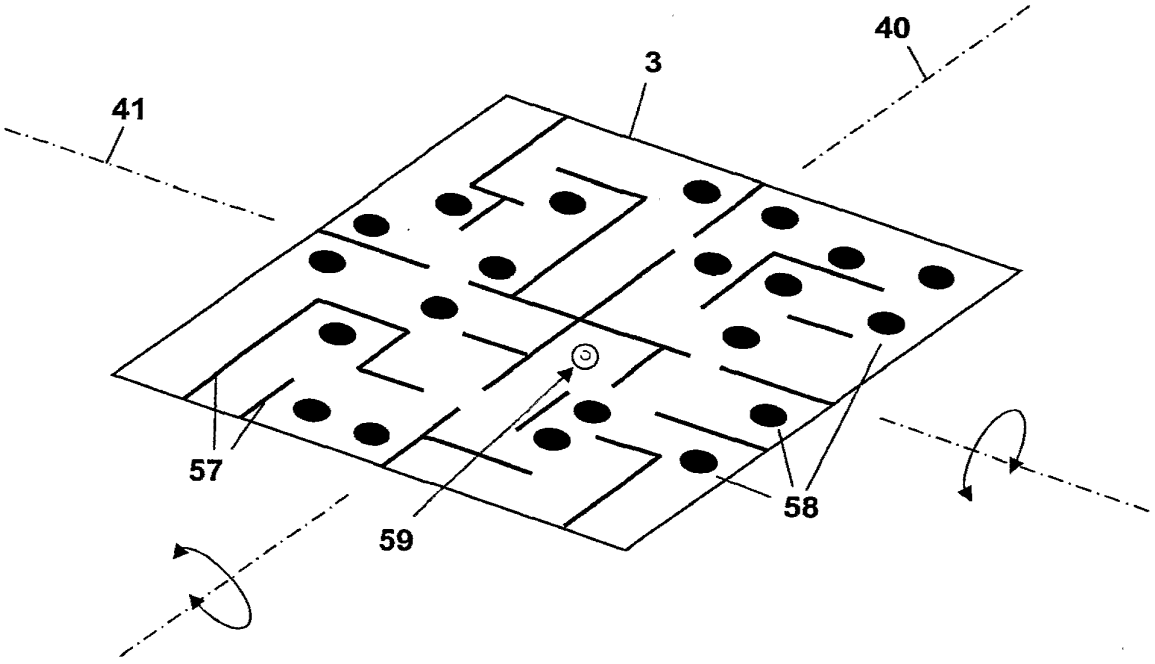


Fig. 3.18

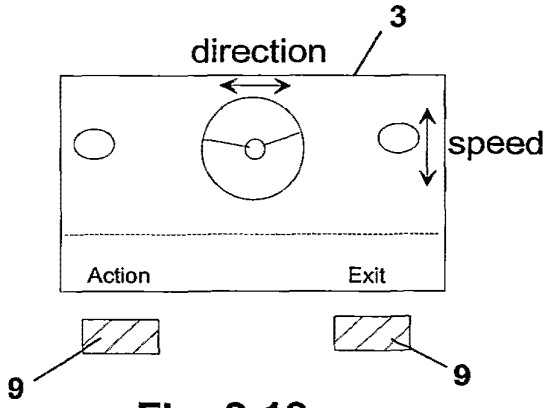


Fig. 3.19

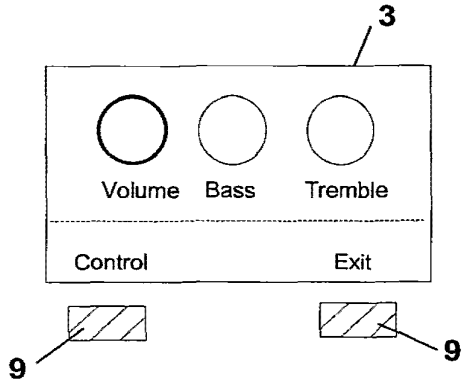


Fig. 3.20

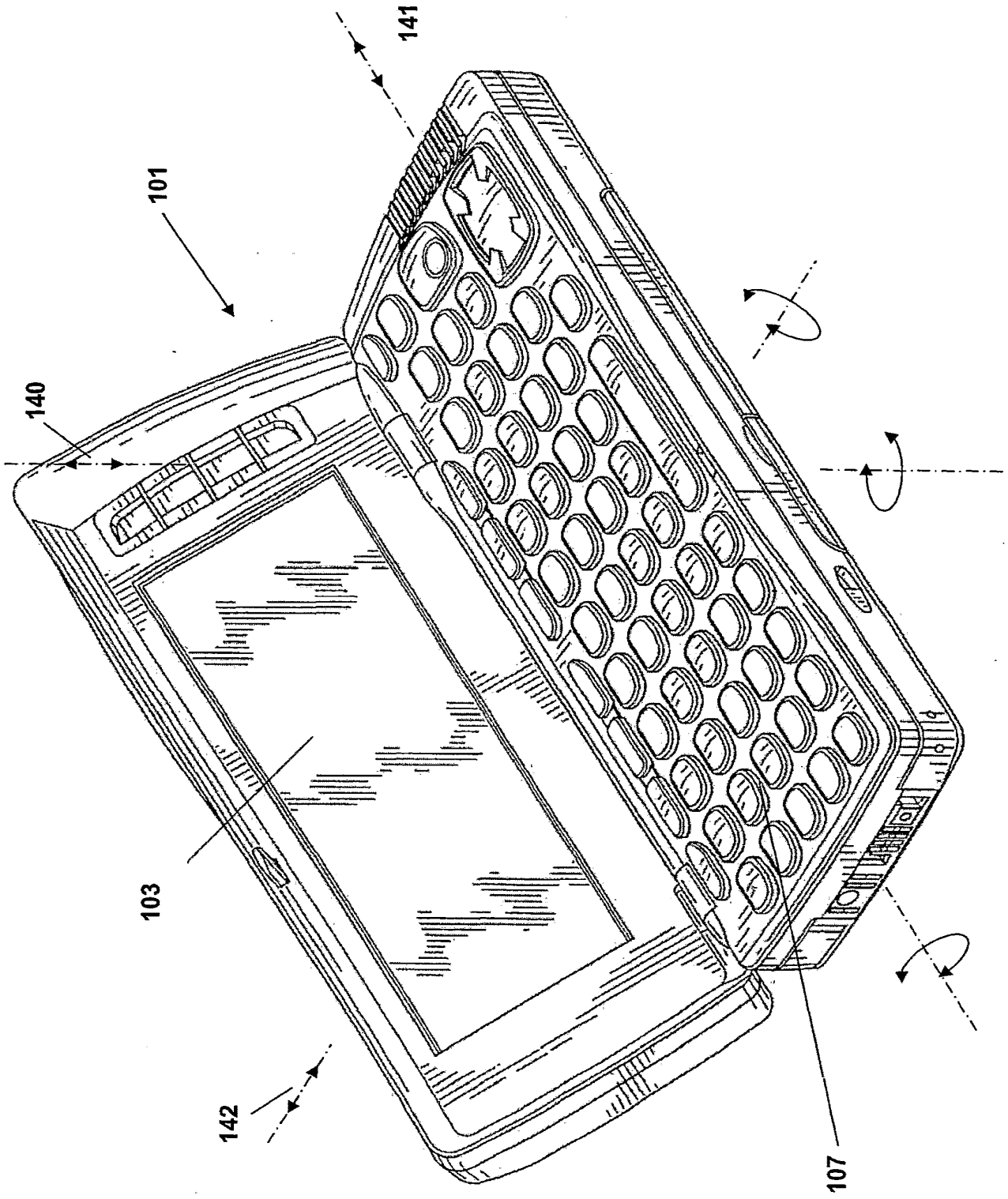


Fig. 5

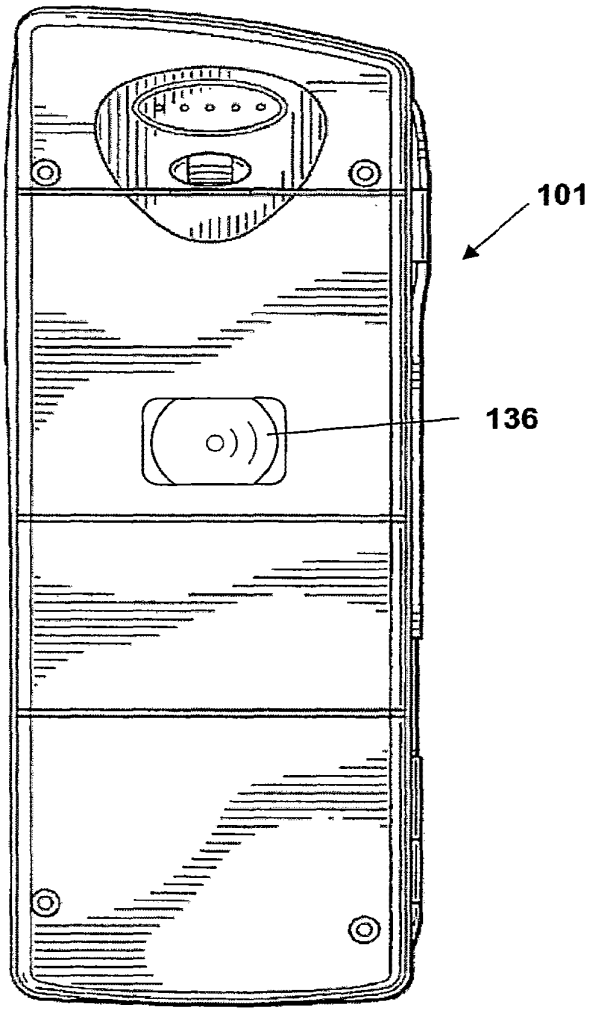


Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/00607

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N5/225 H04N7/14 H04M1/725 H04N5/232 H04M1/247

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	page 5, line 15 -page 11	16, 26-29,47
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Y	EP 1 246 464 A (MITSUBISHI ELECTRIC CORP) 2 October 2002 (2002-10-02) paragraph '0041! - paragraph '0066!	26-28

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 June 2003	26/06/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Materne, A

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INTERNATIONAL SEARCH REPORT

Internat[redacted] Application No
PCT/EP 03/00607

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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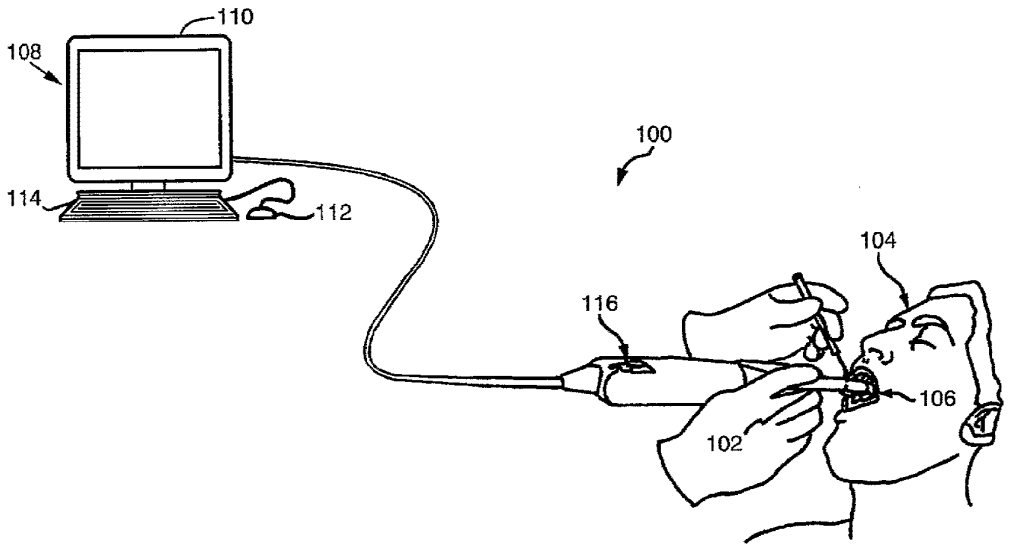
(74) Agents: **EDMAN, Sean J.,** et al.; 3m Center, Office Of Intellectual Property Counsel, P.o. Box 33427, Saint Paul, Minnesota 55133-3427 (US).

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[Continued on next page]

(54) Title: DIGITAL DENTISTRY



(57) Abstract: The systems and methods disclosed herein employ a scanning system for capturing highly detailed digital dental models. These models may be used within a dentist's office for a wide array of dental functions including quality control, restoration design, and fitting. These models may also, or instead, be transmitted to dental laboratories that may, alone or in collaboration with the originating dentist or other dental professionals, transform the digital model into a physical realization of a dental hardware item.

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Published:

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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DIGITAL DENTISTRY

RELATED APPLICATIONS

[0001] This application claims priority to U.S. App. No. 60/761,078, filed on January 20, 2006.

BACKGROUND

1. Field of the Invention.

[0002] The invention relates to dentistry, and more particularly for dental applications of digital, three-dimensional representations of dentition.

2. Description of the Related Art.

[0003] Dentistry today largely continues in the mold of the past, using techniques pioneered by ancient Egyptians. One basic technique for manufacturing a dental restoration, the so-called lost wax method, employs a wax pattern from which a metal casting is made. A mold of the wax pattern is made using a high-heat investment material. The mold is then heated in a furnace, the pattern is then burned out, and the investment ring is cast or filled with some type of alloy or some other substance to provide a final version of a dental restoration. A dentist bonds this prosthetic to a site in a patient's mouth that has been hand-prepared to match the prosthetic. As a significant disadvantage, a substantial burden is placed on practicing dentists to physically match restorations and tooth surfaces. Further complicating this process, the wax model itself is typically created from a physical cast of the patient's mouth. The casting process can introduce errors into a final restoration, as can material handling in the multiple steps carried out by a dental laboratory to go from the original dental impression to the final restoration.

[0004] In theory, digital dentistry offers manifest advantages of quality, portability, and durability as compared to cast models of physical impressions. However, advances in dentistry have been muted, at least in part due to the inability to easily capture adequate three-dimensional data for teeth and surrounding soft tissue. In addition, dentistry has achieved only limited gains from general improvements in manufacturing technologies because each dental patient and restoration presents a unique, one-off product.

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DENTAL IMAGING

[0005] There remains a need for dentistry tools that capture high-quality digital dental models, as well as tools that permit the design and manufacture of dental hardware from such models.

SUMMARY

[0006] The systems and methods disclosed herein employ a scanning system for capturing highly detailed digital dental models. These models may be used within a dentist's office for a wide array of dental functions including quality control, restoration design, and fitting. These models may also, or instead, be transmitted to dental laboratories that may, alone or in collaboration with the originating dentist or other dental professionals, transform the digital model into a physical realization of a dental hardware item.

[0007] A method disclosed herein includes acquiring a three-dimensional representation of one or more intraoral structures of a dental patient using an intraoral scanner; and providing the three-dimensional representation to a dental fabrication facility.

[0008] The method may further include fabricating a dental restoration at the dental fabrication facility using the three-dimensional representation. The dental fabrication facility may include a dental laboratory. The one or more intraoral structures may include at least one dental implant, at least one tooth, at least one tooth surface prepared for a dental restoration, at least one previously restored tooth, and/or at least one area of soft tissue. The method may further include fabricating a dental prosthesis at the dental fabrication facility using the three-dimensional representation.

[0009] The method may further include transmitting the three-dimensional representation to a dental laboratory and, in response, receiving an assessment of quality for the three-dimensional representation from the dental laboratory. The assessment of quality may be received before the dental patient leaves a dentist's office. The assessment of quality may include an assessment of acceptability of the three-dimensional representation. The method may further include transmitting the three-dimensional representation to a dental laboratory and, in response, receiving an assessment of quality of the at least one prepared tooth surface. Transmitting the three-dimensional representation to a dental fabrication facility may include transmitting to a remote dental laboratory for fabrication of a dental restoration for the one or more intraoral structures. The method may further include transmitting the

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three-dimensional representation to a dental data hub. The method may further include transmitting a prescription for the dental restoration with the three-dimensional representation. The method may further include transmitting the three-dimensional representation to a model production laboratory. The model production laboratory may be a milling facility, a manufacturing facility, or a three-dimensional rapid prototyping facility. Transmitting the three-dimensional representation to a dental fabrication facility may include providing the three-dimensional representation to an in-office dental laboratory for fabrication of a dental restoration for the one or more intraoral structures.

[0010] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, may perform the steps of: acquiring one or more images of one or more intraoral structures of a dental patient from an intraoral scanner; converting the one or more images into a three-dimensional representation of the one or more intraoral structures; and transmitting the three-dimensional representation to a dental fabrication facility.

[0011] The computer program may further include computer code that performs the step of comparing quality of the three-dimensional representation to predefined quality criteria. The predefined quality criteria may include acceptability of the three-dimensional representation for fabrication. The computer program may further include computer code that performs the steps of: retrieving a prescription for at least one of a prosthesis or an appliance by a dentist; and combining the prescription with the three-dimensional representation prior to transmitting the three-dimensional representation. The one or more intraoral structures may include at least one dental implant, one tooth, or one tooth surface prepared for a dental restoration. The computer program may further include computer code that performs the step of comparing quality of the at least one prepared tooth surface to predefined quality criteria. The one or more intraoral structures may include at least one area of soft tissue.

[0012] A system disclosed herein includes an intraoral scanner for acquiring a three-dimensional representation of one or more intraoral structures of a dental patient; and a transmission means for transmitting the three-dimensional representation to a dental fabrication facility.

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[0013] The system may further include a first fabrication means for fabricating a dental restoration at the dental fabrication facility using the three-dimensional representation. The one or more intraoral structures may include at least one dental implant, one tooth, least one tooth surface prepared for a dental restoration, or one area of soft tissue. The system may further include a second fabrication means for fabricating a dental prosthesis at the dental fabrication facility using the three-dimensional representation. The system may further include a quality assessment means for assessing quality of the three-dimensional representation. The quality assessment means may include a means for determining acceptability of the three-dimensional representation for use with the first fabrication means. The quality assessment means may include a means for determining acceptability of the three-dimensional representation for use with the second fabrication means. The one or more intraoral structures may include at least one tooth surface prepared for a dental restoration, wherein the quality assessment means includes a means for determining quality of the at least one prepared tooth surface.

[0014] In another aspect, a method disclosed herein includes receiving a three-dimensional representation of a tooth, the tooth prepared for a dental restoration; specifying a cementation void between the tooth surface and the dental restoration; and fabricating the dental restoration such that the dental restoration, when mated to the tooth surface, defines an empty space corresponding to the cementation void.

[0015] The method may include adjusting the cementation void, such as according to a dentist's preferences or according to the type of cement to be used in the cementation void. The cementation void may be specified by a dentist. The dentist may send the specification to a dental laboratory. The cementation void may be specified by a dental laboratory. The method may include three-dimensionally printing a die including the cementation void. The method may include fabricating a die including the cementation void with a stereo lithography apparatus. The method may include three-dimensionally printing a wax-up including the cementation void. The method may include milling a die including the cementation void. The method may include integrating the cementation void into a digital surface representation of the tooth. The method may include integrating the cementation void into a dental model. The three-dimensional representation may include a digital surface representation of the tooth. Fabricating the dental restoration may include fabricating the dental restoration in an in-house laboratory in a dentist's office. The method may

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further include fabricating an opposing arch for an arch including the tooth, the opposing arch including a die spacer having a predetermined thickness.

[0016] In another aspect, a computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring one or more images of a tooth of a dental patient from an intraoral scanner, the tooth including a tooth surface prepared for a dental restoration; converting the one or more images into a three-dimensional representation of the tooth; specifying a cementation void between the tooth surface and the dental restoration; combining the specification for the cementation void with the three-dimensional representation into a fabrication specification; and transmitting the fabrication specification to a dental fabrication facility.

[0017] A dentist may specify the cementation void. The computer program product may include code that performs the step of receiving a specification of the cementation void from the dental fabrication facility. The computer program product may include code for three-dimensionally printing the cementation void to a die. The computer program product may include code for three-dimensionally printing the cementation void to a wax up. The computer program product may include code that performs the step of integrating the cementation void into a digital surface representation of the tooth.

[0018] In another aspect, a system disclosed herein includes a first means for three-dimensionally representing a tooth, the tooth prepared for a dental restoration; a second means for specifying a cementation void, the cementation void representing an empty space between the tooth surface and the dental restoration; and a fabrication means for fabricating the dental restoration such that the dental restoration, when mated to the tooth surface, defines an empty space corresponding to the cementation void.

[0019] The system may include an adjustment means for adjusting the cementation void. The adjustment means may include means for incorporating a dentist's preferences. The adjustment means may include means for adjusting the cementation void according to a type of cement. The system may include a first printing means for three-dimensionally printing a die including the cementation void. The system may include a second printing means for three-dimensionally printing a wax-up including the cementation void. The system may include a milling means for

milling a die including the cementation void. The system may include a milling means for milling an investment chamber for casting including the cementation void. The system may include a model means for integrating the cementation void into a model of a dental impression. The three-dimensional representation of a tooth may include a digital surface representation of the tooth.

[0020] In another aspect, a method disclosed herein includes fabricating a dental object; acquiring a first three-dimensional representation of the object; and measuring a dimensional accuracy of the first three-dimensional representation. The first three-dimensional representation may include a digital surface representation. The dental object may include a dental prosthesis, a dental implant, a dental appliance, a dental restoration, a restorative component, or an abutment. The method may include acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy may include evaluating a fit between the item of the first three-dimensional representation and the at least one tooth surface of the second three-dimensional representation. The method may further include acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy may include evaluating one or more contact points between the item of the first three-dimensional representation and the one or more teeth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface. The method may further include acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object and at least one opposing tooth, wherein measuring a dimensional accuracy may include evaluating one or more contact points between the item of the first three-dimensional representation and the at least one opposing tooth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface. The second three-dimensional representation may be acquired as a plurality of separate scans. The second three-dimensional representation may be acquired as a continuous scan of the at least one tooth surface and the at least one opposing tooth in occlusion. A dentist may specify tightness of fit of the dental object. Measuring a dimensional accuracy may include quantifying tightness of fit of the dental object. Measuring a dimensional accuracy includes measuring quality of a margin.

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[0021] A computer program product may include computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring one or more images of a dental object; converting the one or more images of the dental object into a first three-dimensional representation of the item; and measuring a dimensional accuracy of the first three-dimensional representation. The first three-dimensional representation may include a digital surface representation.

[0022] The dental object may include a dental prosthesis, a dental implant, a dental appliance, a dental restoration, a restorative component, or an abutment. The computer program product may include code that performs the steps of: acquiring one or more images of one or more teeth including at least one tooth surface prepared for the dental object; and converting the one or more images of the one or more teeth into a second three-dimensional representation of the one or more teeth, wherein measuring a dimensional accuracy includes evaluating a fit between the item of the first three-dimensional representation and the at least one tooth surface of the second three-dimensional representation. The computer program product may include code that performs the steps of: acquiring one or more images of one or more teeth including at least one tooth surface prepared for the dental object; converting the one or more images of the one or more teeth into a second three-dimensional representation of the one or more teeth; and generating one or more contact points between the item of the first three-dimensional representation and the one or more teeth of the second three-dimensional representation by virtually affixing the item to the at least one tooth surface, wherein measuring includes evaluating one or more contact points.

[0023] The computer program product may further include computer code that performs the steps of: acquiring one or more images of one or more teeth including at least one tooth surface prepared for the dental object and at least one opposing tooth; converting the one or more images of the one or more teeth and the at least one opposing tooth into a second three-dimensional representation of the one or more teeth and the at least one opposing tooth; and generating one or more contact points between the item of the first three-dimensional representation and the at least one opposing tooth of the second three-dimensional representation by virtually affixing the item to the at least one tooth surface, wherein measuring includes evaluating one or more contact points. Measuring a dimensional accuracy may

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include quantifying tightness of fit of the dental object. Measuring a dimensional accuracy may include measuring quality of a margin.

[0024] A system disclosed herein includes a fabrication means for fabricating a dental object; a first means for acquiring a first three-dimensional representation of the item; and a measurement means for measuring a dimensional accuracy of the first three-dimensional representation. The first three-dimensional representation may include a digital surface representation.

[0025] The dental object may include a dental prosthesis, a dental implant, a dental appliance, a dental restoration, a restorative component, or an abutment. The system may further include a second means for acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy may include evaluating a fit between the item of the first three-dimensional representation and the at least one tooth surface of the second three-dimensional representation. The system may further include a second means for acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy may include evaluating one or more contact points between the item of the first three-dimensional representation and the one or more teeth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface. The system may further include a second means for acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object and at least one opposing tooth, wherein measuring a dimensional accuracy may include evaluating one or more contact points between the item of the first three-dimensional representation and the at least one opposing tooth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface. A dentist may specify tightness of fit of the dental object. Measuring a dimensional accuracy may include quantifying tightness of fit of the dental object. Measuring a dimensional accuracy includes measuring quality of a margin.

[0026] A method disclosed herein includes acquiring a three-dimensional representation including three-dimensional surface data for at least two independent dental structures; and acquiring motion data characterizing a relative motion of the at least two independent dental structures with respect to one another within a mouth.

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[0027] The method may include deriving TMJ condyle paths of rotation and translation from the motion data and the three-dimensional surface data. The method may include providing input to a virtual dental articulator. The method may include providing specifications for a physical dental articulator. The method may include providing specifications for a disposable dental articulator. Acquiring the three-dimensional representation may include acquiring the three-dimensional representation using an intraoral scanner. Acquiring motion data may include acquiring motion data from a video source.

[0028] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, may perform the steps of: acquiring one or more images of at least two independent dental structures of a dental patient from an intraoral scanner; converting the one or more images into a three-dimensional representation of the at least two independent dental structures; acquiring motion data characterizing a relative motion of the at least two independent dental structures with respect to one another; and combining the three-dimensional representation with the motion data to derive TMJ condyle paths of rotation and translation.

[0029] The computer program may include code that performs the steps of: generating an image sequence of the combined three-dimensional representation and the motion data; generating a display signal of the image sequence. Acquiring motion data may include acquiring motion data from a video source.

[0030] A system disclosed herein includes a first means for acquiring one or more images of at least two independent dental structures of a dental patient; a conversion means for converting the one or more images into a three-dimensional representation of the at least two independent dental structures; and a second means for acquiring motion data characterizing a relative motion of the at least two independent dental structures with respect to one another. The system may include an analysis means for deriving TMJ condyle paths of rotation and translation using the three-dimensional representation and the motion data.

[0031] The system may include an action means for combining the three-dimensional representation and the motion data to generate an articulation input. The system may include a first model means for virtually articulating the articulation input. The system may include a second model means for physically articulating the articulation input. The system may include a disposable model means for physically

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articulating the articulation input. The first means may include a means for acquiring the one or more images using an intraoral scanner. The second means may include a means for acquiring the motion data from a video source.

[0032] In another aspect, a method disclosed herein includes receiving an electronic dental prescription including prescription data, a first three-dimensional representation of one or more intraoral structures including at least one tooth surface prepared for an artificial dental object, and a second three-dimensional representation of the at least one tooth surface prior to preparation for the artificial dental object; and fabricating the artificial dental object for the one or more intraoral structures using the electronic dental prescription.

[0033] Receiving an electronic dental prescription may include receiving a three-dimensional representation from a dental data hub or from a dentist. Receiving a three-dimensional representation may include receiving a prescription for a dental restoration for the tooth surface. At least one of the first and second three-dimensional representations may include a digital surface representation of a full arch. The electronic dental prescription may include a prescription for an appliance, a prosthesis, or an item of dental hardware. Fabricating an artificial dental object may include fabricating a dental restoration in an in-house laboratory in a dentist's office.

[0034] A system disclosed herein includes a communication means for receiving a prescription data, a first three-dimensional representation of one or more intraoral structures including at least one tooth surface prepared for an artificial dental object, and a second three-dimensional representation of the at least one tooth surface prior to preparation for the artificial dental object; and a fabrication means for fabricating a dental restoration for the one or more intraoral structures using the three-dimensional representation.

[0035] The communication means may include a means for receiving the electronic dental prescription from a dental data hub or a dentist. The electronic dental prescription may include a prescription for a dental restoration. At least one of the first and second three-dimensional representations may include a digital surface representation of a full arch. The electronic dental prescription may include a prescription for one or more of an appliance, a prosthesis, and an item of dental hardware. The fabrication means may include in an in-house laboratory in a dentist's office.

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[0036] In another aspect, a method disclosed herein includes a single dental visit, the steps of: acquiring a three-dimensional representation of one or more intraoral structures from a dental patient, the intraoral structures may include at least one tooth surface prepared for an artificial dental object; and processing the three-dimensional representation to provide feedback to a dentist concerning the at least one tooth surface.

[0037] The feedback may identify corrective action. The corrective action may include acquiring an additional three-dimensional representation of the one or more intraoral structures. The corrective action may include additional surface preparation of the at least one tooth. The feedback may identify a margin for fitting the dental restoration to the at least one tooth surface. The margin for fitting may be edited. The feedback may include a visual display of one or more regions of inadequate margin for fitting the dental restoration to the at least one tooth surface. The feedback may include a visual display recommending additional preparatory work required for the at least one tooth surface. The feedback may include a visual display recommending acquiring additional three-dimensional representations of one or more regions of the one or more intraoral structures. The feedback may include identifying an incomplete three-dimensional representation. The feedback may include identifying errors in the three-dimensional representation. The feedback may include visual highlighting of a margin line on a display of the three-dimensional representation.

[0038] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring one or more images of one or more intraoral structures of a dental patient, the intraoral structures including at least one tooth surface prepared for an artificial dental object; converting the one or more images into a three-dimensional representation of the one or more intraoral structures; analyzing the at least one tooth surface within the three-dimensional representation; generating a feedback signal, the feedback signal representative of the result of analyzing the at least one tooth surface; and outputting the feedback signal to provide feedback to a dentist.

[0039] The feedback signal may identify corrective action. The corrective action may include acquiring an additional one or more images of the one or more intraoral dental structures. The corrective action may include additional surface

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preparation of the at least one tooth. The feedback signal may identify a margin for fitting the dental restoration to the at least one tooth surface. The margin for fitting may be edited.

[0040] In another aspect, a system disclosed herein includes a scanning device configured to intraorally capture surface image data from a surface within a mouth of a dental patient; a computer coupled to the scanning device and receiving the surface image data therefrom, the computer configured to resolve the surface image data into a digital surface reconstruction, the computer further configured to generate a visualization of the digital surface reconstruction and provide the visualization as a display signal; and a display coupled to the computer and receiving the display signal therefrom, the display converting the display signal into a viewable image of the visualization. The surface may include dentition.

[0041] The scanning device may capture surface image data at a video frame rate. The system may include a user interface controlled by the computer and rendered on the display. The user interface may provide at least one tool for analyzing the surface. The user interface may include a tool that may provide real time feedback to the user. The real time feedback may include visual cues within the rendered image. The at least one tool may include a distance measurement tool, a tool that may evaluate adequacy of tooth structure removal from a dental restoration surface preparation, a tool that may evaluate adequacy of margin preparations, a tool that evaluates taper, a tool that evaluates undercut, or a tool that identifies scan deficiencies. The scan deficiencies may include holes in the surface. The at least one tool may include a tool that evaluates adequacy of removal path in multiple unit preparation. The at least one tool may include a tool that identifies irregularities in one or more occlusal surfaces requiring further preparation. Analyzing the surface may include an evaluation of suitability for three-dimensional printing, of suitability for milling, or of suitability for manual fabrication.

[0042] The computer may be further configured to automatically annotate the visualization with a visual indication of an evaluation. The visual indication includes an evaluation of contour of a surface preparation. The surface image data may include at least two tooth surfaces in occlusion. The visual indication may include an evaluation of margin of a surface preparation. The visual indication includes an evaluation of occlusal clearance of a surface preparation. The surface may include at least one surface prepared for a dental restoration, the evaluation

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including an evaluation of an adequacy of the at least one surface for receiving the dental restoration. The visual indication may include display of a contour of an actual tooth and a computer-generated surface preparation. The computer-generated surface preparation may be based upon intact configuration of the actual tooth prior to preparation.

[0043] In another aspect, a method disclosed herein includes receiving a three-dimensional representation that may include three-dimensional surface data from an intraoral structure including at least one tooth having a tooth surface prepared for a dental restoration; and presenting the three-dimensional representation in a user interface, the user interface may include a first tool for identifying a margin line for the dental restoration on the at least one tooth and a second tool for recessing a region of the three-dimensional representation below the margin line.

[0044] The first tool may provide automated identification of the margin line. The method may include removing a portion of the three-dimensional representation below the margin line with the second tool. The method may include removing a portion of the three-dimensional representation below the margin line with the second tool to provide a virtual ditched die, and three-dimensionally printing the ditched die.

[0045] A system disclosed herein includes a means for receiving a three-dimensional representation including three-dimensional surface data from an intraoral structure that may include at least one tooth having a tooth surface prepared for a dental restoration; and a user interface means for presenting the three-dimensional representation to a user, the user interface means may include a first tool means for identifying a margin line for the dental restoration on the at least one tooth and a second tool means for recessing a region of the three-dimensional representation below the margin line.

[0046] The first tool means may include a means for providing automated identification of the margin line. The system may include a means for removing a portion of the three-dimensional representation below the margin line. The system may include a means for removing a portion of the three-dimensional representation below the margin line to provide a virtual ditched die, and a means for three-dimensionally printing the ditched die.

[0047] In another aspect, a method disclosed herein includes acquiring a digital dental impression that may include three-dimensional surface data for at least

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two independent dental structures; and acquiring orientation data that may define a relative position of at least a portion of each of the at least two independent dental structures while in occlusion.

[0048] The orientation data may include three-dimensional surface data that spans the at least two independent dental structures while in occlusion. The orientation data may include three-dimensional surface data from each of the at least two independent dental structures while in occlusion. The occlusion may include a centric occlusion. The method may include applying the orientation data to position a virtual model of the at least two independent dental structures in a virtual articulator. The method may include fabricating models of each of the at least two independent dental structures and may apply the orientation data to position the models within a dental articulator. Acquiring orientation data may include acquiring three-dimensional data of a buccal side of dentition. Acquiring orientation data may include acquiring three-dimensional data of a labial side of dentition.

[0049] A system disclosed herein includes a first acquisition means for acquiring a digital dental impression including three-dimensional surface data for at least two independent dental structures; and a second acquisition means for that may acquire orientation data defining a relative position of at least a portion of each of the at least two independent dental structures while in occlusion.

[0050] The orientation data may include three-dimensional surface data that spans the at least two independent dental structures while in occlusion. The orientation data may include three-dimensional surface data from each of the at least two independent dental structures while in occlusion. The occlusion may include a centric occlusion. The system may include a model means for virtually articulating the at least two independent dental structures. The system may include a fabrication means for fabricating models of each of the at least two independent dental structures; and a model means for physically articulating the fabricated models. The orientation data may include three-dimensional data of a buccal side of dentition. The orientation data may include three-dimensional data of a labial side of dentition.

[0051] In another aspect, a method disclosed herein includes providing an intraoral three-dimensional scanning device; and scanning a plurality of teeth in an arch with the device in a scan path that may include a motion that begins at a first lingual point, traverses laterally over a first occlusal point and a first buccal point, translates to a second buccal point adjacent to the first buccal point, and then traverses

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laterally over a second occlusal point adjacent to the first occlusal point and a second lingual point adjacent to the first lingual point.

[0052] The method may include scanning the plurality of teeth in the arch with the device using a motion that translates to a third lingual point, and then may traverse laterally over a third occlusal point adjacent to the second occlusal point and a third buccal point adjacent to the second buccal point. The first lingual point and the second lingual point may be spaced apart such that a field of view of the scanning device includes at least one overlapping portion of the plurality of teeth when the scanning device is positioned to image the first and second lingual points respectively. The scan path may begin at a third buccal point, a third palatal point, or a third labial point.

[0053] In another aspect, a method disclosed herein includes within a single dental visit, the steps of: acquiring a three-dimensional representation of one or more intraoral structures including at least one tooth prepared for a dental restoration; and processing the three-dimensional representation that may provide feedback to a dentist concerning the at least one tooth.

[0054] The feedback may include a physical dimension, a dimension of the at least one tooth prior to preparation for the dental restoration, a contour of the at least one tooth, a clearance relative to one or more adjacent teeth for a dental restoration associated with the at least one tooth, or a position of the at least one tooth. The feedback may include a clearance relative to one or more teeth in an opposing occluded arch.

[0055] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring a three-dimensional representation of one or more intraoral structures that may include at least one tooth prepared for a dental restoration; analyzing the three-dimensional representation; generating a feedback signal, the feedback signal may represent the analysis of the three-dimensional representation; and outputting the feedback signal to a dentist.

[0056] The feedback signal may include a physical dimension, a dimension of the at least one tooth prior to preparation for the dental restoration, a contour of the at least one tooth, a clearance relative to one or more adjacent teeth for a dental restoration associated with the at least one tooth, or a position of the at least one tooth.

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The feedback may include a clearance relative to one or more teeth in an opposing occluded arch.

[0057] A system disclosed herein includes an acquisition means for acquiring a three-dimensional representation of one or more intraoral structures including at least one tooth prepared for a dental restoration; an analysis means for analyzing the three-dimensional representation; a means for generating a feedback signal, the feedback signal representing the analysis of the three-dimensional representation; and a signal means for providing the feedback signal to a dentist.

[0058] The feedback signal may include a physical dimension, a dimension of the at least one tooth prior to preparation for the dental restoration, a contour of the at least one tooth, a clearance relative to one or more adjacent teeth for a dental restoration associated with the at least one tooth, or a position of the at least one tooth. The feedback may include a clearance relative to one or more teeth in an opposing occluded arch.

[0059] In another aspect, a method disclosed herein includes acquiring a three-dimensional representation from a dental patient including a digital surface representation of one or more intraoral structures; and providing a visual display of the three-dimensional representation in real time. The visual display of the three-dimensional representation may be superimposed on a real time two-dimensional video image of the one or more intraoral structures.

[0060] The one or more intraoral structures may include at least one tooth, at least one tooth surface prepared for a dental restoration, at least one restored tooth, at least one implant, or at least one area of soft tissue. The method may include processing the three-dimensional representation to generate user feedback concerning the one or more intraoral structures, and may provide a visual display of the user feedback. The feedback may include highlighting areas in the three-dimensional representation requiring additional attention.

[0061] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring one or more images of one or more intraoral structures; processing the one or more images into a three-dimensional representation including a digital surface representation of the one or more intraoral structures; and generating a first visual display signal of the three-dimensional representation in real time.

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[0062] The computer program product may include computer code that performs the step of generating a second visual display signal wherein the three-dimensional representation is superimposed on a real time two-dimensional video image of the one or more intraoral structures. The one or more intraoral structures may include at least one tooth, at least one tooth surface prepared for a dental restoration, at least one restored tooth, at least one implant, or at least one area of soft tissue. The computer program product may include computer code that performs the steps of: analyzing the three-dimensional representation; may generate a feedback signal representative of the analysis of the three-dimensional representation; generate a third visual display signal including the feedback signal. The third visual display signal may include highlighted areas of the three-dimensional representation requiring additional attention.

[0063] A system disclosed herein includes: an acquisition means for acquiring a three-dimensional representation from a dental patient, the three-dimensional representation may include a digital surface representation of one or more intraoral structures; and a display means for visually displaying the three-dimensional representation in real time.

[0064] The display means may include a means for superimposing the three-dimensional representation on a real time two-dimensional video image of the one or more intraoral structures. The one or more intraoral structures may include at least one tooth, at least one tooth surface prepared for a dental restoration, at least one restored tooth, at least one implant, or at least one area of soft tissue. The system may include: an analysis means for analyzing the three-dimensional representation; a feedback means for generating a feedback signal representative of the analysis of the three-dimensional representation, wherein the display means includes a means for visually displaying the feedback signal. The feedback means may include a means for highlighting areas in the three-dimensional representation requiring additional attention.

[0065] In another aspect, a handheld imaging device for a three-dimensional imaging system disclosed herein includes: an elongated body including a first end, a second end, and a central axis; a video rate three-dimensional scanning device within the elongated body, the video rate three-dimensional scanning device may have an optical axis for receiving images, the optical axis substantially perpendicular to the central axis at a position near the first end of the elongated body; and the second end

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adapted for gripping by a human hand, and the second end may include a user input responsive to user manipulation to generate control signals for transmission to a processor associated with the imaging system. The user input may include a mouse, track ball, button, switch, mini joystick, touchpad, keypad, or thumb wheel. The control signals may be transmitted to the processor through a wireless communication medium. The user input may control a user interface associated with the imaging system.

[0066] A handheld imaging device for a three-dimensional imaging system disclosed herein includes: an elongated body including a central axis, a first end, and a second end, the second end adapted for gripping by a human hand and a central axis; a video rate three-dimensional scanning device within the elongated body, the video rate three-dimensional scanning device having an optical axis for receiving images, the optical axis substantially perpendicular to the central axis at a position near the first end of the elongated body; and a physical offset shaped and sized to maintain a desired distance of the first end from an imaging subject along the optical axis. The physical offset may include one or more wheels for slidably engaging a surface of the imaging subject.

[0067] In another aspect, a method disclosed herein includes: acquiring a three-dimensional representation from a dental patient including a digital surface representation of one or more intraoral structures, the intraoral structures may include a dental arch; processing the three-dimensional representation that may provide a digital dental model including one or more alignment guides to aid in positioning an orthodontic fixture; and fabricating a physical model from the digital dental model.

[0068] The method may include constructing the orthodontic fixture on the physical model using the alignment guides. The method may include constructing a support for the orthodontic fixture on the digital dental model. The alignment guides may include visual markings. The alignment guides may include at least one substantially horizontal shelf for the orthodontic fixture. Processing may include virtually placing a plurality of orthodontic brackets onto the three-dimensional representation, and adding a plurality of bracket supports to the digital dental model to support a physical realization of the plurality of orthodontic brackets on the physical model. The method may include fabricating the physical realization of the plurality of orthodontic brackets, positioning each one of the plurality of orthodontic brackets onto the physical model, and vacuum forming an appliance over the plurality of

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orthodontic brackets, the appliance maintaining the plurality of orthodontic brackets in fixed relation to one another. The method may include applying the appliance with the plurality of orthodontic brackets to the dental arch. The appliance may be formed of a soft, clear material. The method may include transmitting the digital dental model to a remote dental laboratory. Processing may include virtually placing a plurality of orthodontic brackets onto the three-dimensional representation in a bracket arrangement, and generating a digital model of a bracket guide adapted to position a physical realization of the plurality of orthodontic brackets in the bracket arrangement on the dental arch. The method may include three-dimensionally printing the bracket guide. The physical model may include fabricating the physical model in an in-house dental laboratory in a dentist's office.

[0069] In another aspect, a method disclosed herein includes: acquiring a three-dimensional representation from a dental patient including a digital surface representation of one or more intraoral structures, the intraoral structures may include a dental arch; adding a plurality of virtual brackets to the three-dimensional representation to provide a bracket model; processing the bracket model to generate a bracket guide model, the bracket guide model adapted to maintain a physical realization of the plurality of virtual brackets in a fixed orientation with respect to one another, the fixed orientation corresponding to a desired orientation of the physical realization on the dental arch; fabricating a bracket guide from the bracket guide model; and attaching the physical realization of the plurality of virtual brackets to the bracket guide model.

[0070] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring one or more images of one or more intraoral structures, the intraoral structures may include a dental arch; processing the one or more images into a three-dimensional representation of the one or more intraoral structures; transforming the three-dimensional representation into a digital dental model, the digital dental model including one or more orthodontic fixture alignment guides; and generating a virtual orthodontic fixture using the alignment guides.

[0071] The computer program product may include code that performs the step of constructing a support for the virtual orthodontic fixture on the digital dental model. The alignment guides may include visual markings. The alignment guides

may include at least one substantially horizontal shelf for the virtual orthodontic fixture. Transforming may include virtually placing a plurality of orthodontic brackets onto the dental arch of the three-dimensional representation, and adding a plurality of bracket supports to the digital dental model. The computer program product may include code that performs the step of transmitting the digital dental model to a remote dental laboratory.

[0072] A system disclosed herein includes: an acquisition means for acquiring a three-dimensional representation from a dental patient including a digital surface representation of one or more intraoral structures, the intraoral structures may include a dental arch; a processing means for processing the three-dimensional representation that may provide a digital dental model including one or more alignment guides to aid in positioning an orthodontic fixture; and a first fabrication means for fabricating a physical model from the digital dental model.

[0073] The system may include a means for constructing the orthodontic fixture on the physical model using the alignment guides. The processing means may include a means for constructing a support for the orthodontic fixture on the digital dental model. The alignment guides may include visual markings. The alignment guides may include at least one substantially horizontal shelf for the orthodontic fixture. The processing means may include a means for virtually placing a plurality of orthodontic brackets onto the three-dimensional representation, and adding a plurality of bracket supports to the digital dental model to support a physical realization of the plurality of orthodontic brackets on the physical model. The system may include a second fabrication means for fabricating the physical realization of the plurality of orthodontic brackets, a positioning means for positioning each one of the plurality of orthodontic brackets onto the physical model, and a forming means for vacuum forming an appliance over the plurality of orthodontic brackets, the appliance maintaining the plurality of orthodontic brackets in fixed relation to one another. The system may include a means for applying the appliance with the plurality of orthodontic brackets to the dental arch. The appliance may be formed of a soft, clear material. The system may include a communication means for transmitting the digital dental model to a remote dental laboratory. The processing means may include a means for virtually placing a plurality of orthodontic brackets onto the three-dimensional representation in a bracket arrangement, and a model means for generating a digital model of a bracket guide adapted to position a physical realization

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of the plurality of orthodontic brackets in the bracket arrangement on the dental arch. The system may include a printing means for three-dimensionally printing the bracket guide. The fabrication means may include a means for fabricating the physical model in an in-house dental laboratory in a dentist's office.

[0074] A three-dimensional data acquisition system adapted for intraoral acquisition of dental data from one or more intraoral structures, as disclosed herein, may include a first operating mode for capturing scan data and rendering a low-quality three-dimensional image from the scan data in real time, and a second operating mode for generating a high-quality three dimensional image from the scan data after exiting the first operating mode, the high-quality three-dimensional image may have greater spatial resolution than the low-quality three-dimensional image.

[0075] The system may further including a display that renders the low-quality three-dimensional image superimposed on a video image of the one or more intraoral structures. Rendering a low-quality three-dimensional image may include rendering the low-quality three-dimensional image at a frame rate of the video image. The system may include a communications interface for transmitting the high-quality three-dimensional image to a dental laboratory.

[0076] In another aspect, a system disclosed herein includes: a scanning device configured to intraorally capture surface image data from a surface within a mouth of a dental patient; a computer coupled to the scanning device and receiving the surface image data therefrom, the computer configured to resolve the surface image data into a three-dimensional representation, the computer may be further configured to generate a visualization of the three-dimensional representation and to provide the visualization as a display signal; and a display coupled to the computer and receiving the display signal therefrom, the display adapted to convert the display signal into a viewable image, the display being a touch-screen display adapted to receive a user input through direct contact with a surface of the display, wherein the user input is interpreted by the computer to affect manipulation of the three-dimensional representation. The user input may affect rotational orientation of the visualization on the display.

[0077] The display may include areas for one or more user controls accessible through the touch-screen display. The user controls may include a zoom control, a pan control, or case management controls. The case management controls may include a control to transmit the three-dimensional representation to a dental lab,

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a control to evaluate quality of the three-dimensional representation, a tool to edit the three-dimensional representation, or a control to create a dental prescription.

[0078] The user controls may include a control to define a cementation void, a control to define a margin line, a control to infer a margin line from the three-dimensional representation, a control to recess a region of the three-dimensional representation below a margin line, a control to virtually fit a dental restoration to a prepared tooth surface, include a virtual dental articulator, or include a tool to design a dental restoration fitted to the surface within the mouth of the dental patient.

[0079] The three-dimensional model may include two arches; the display may include an area for one or more user controls accessible through the touch-screen display to permit positioning the two arches within a virtual articulator. The system may include a user interface displayed on the display and controlled by the computer. The user interface may be accessible through the touch-screen.

[0080] A system disclosed herein includes: a digital dental impression that may include three-dimensional digital surface data for one or more intraoral structures, the digital dental impression may be captured using a three-dimensional intraoral scanning device and stored in a computer readable medium; a first computer may be configured to render the digital dental impression from a point of view; and a second computer at a remote location may be configure to simultaneously render the digital dental impression from the point of view.

[0081] The system may include a control for passing control of the point of view between the first computer and the second computer. The system may include the first computer and the second computer including a collaborative tool for manipulating the model, for sectioning the model, or for rearranging one or more sections of the model. The system may include the first computer and the second computer including a collaborative cursor control tool. The system may include the first computer and the second computer connected by a communication channel. The communication channel may include one or more of VoIP, IRC, video conferencing, or instant messaging. The second computer may be operated by a consulting dentist, a dental technician, in a dental laboratory, or by an oral surgeon. The second computer may be operated by a dental specialist including one or more of a periodontist, a prosthodontist, a pedodontist, an orthodontic specialist, an oral and maxillofacial surgery specialist, an oral and maxillofacial radiology specialist, an endodontist, and an oral and maxillofacial pathologist.

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[0082] A method disclosed herein includes: seating a dental patient in a clinical office; acquiring a digital dental impression that may include three-dimensional digital surface data for one or more intraoral structures from an intraoral scan of the dental patient; transmitting the digital dental impression to a dental laboratory before the patient leaves the office; receiving an evaluation of the digital dental impression from the dental laboratory before the patient leaves the office; and if the evaluation is unfavorable, repeating the step of acquiring the digital dental impression.

[0083] If the evaluation includes an identification of at least one region of the one or more intraoral structures requiring additional preparation, the method may include preparing the one or more intraoral structures according to the evaluation. The evaluation may include an evaluation of surface continuity, an evaluation of data density, or an evaluation of feature detail. The one or more intraoral structures may include a tooth surface prepared for a dental restoration. The digital dental impression may include a case plan for the restoration. The case plan may include a type of restoration, a design of restoration, or a list of restoration components. The list of restoration components may include a full ceramic component. The list of restoration components may include a PFM component. The case plan may include a specification of one or more restoration materials.

[0084] A system disclosed herein includes: a means for acquiring a digital dental impression, the digital dental impression may include three-dimensional digital surface data for one or more intraoral structures from an intraoral scan of a dental patient seated in a clinical office; a request means for transmitting the digital dental impression to a dental laboratory before the patient leaves the office; an evaluation means for determining if the digital dental impression must be reacquired before the patient leaves the office; and a response means for transmitting the determination to the clinical office.

[0085] The evaluation means may include a means for evaluating surface continuity, a means for evaluating data density, or a means for evaluating feature detail. The one or more intraoral structures may include a tooth surface prepared for a dental restoration. The digital dental impression may include a case plan for the restoration, a type of restoration, a design of restoration, or a list of restoration components. The list of restoration components may include a full ceramic

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component. The list of restoration components may include a PFM component. The case plan may include a specification of one or more restoration materials.

[0086] A system disclosed herein includes: a scanning device for real time capture of three-dimensional surface data; a monitor that may render the three-dimensional surface data in real time; a processor that may be configure to evaluate quality of the three-dimensional surface data, and may generate a signal representative of a data quality during a scan; and a feedback device that may be responsive to the signal to produce a user alert concerning the data quality when the data quality degrades below a predetermined threshold.

[0087] The scanning device may resolve the three-dimensional surface data from a plurality of two-dimensional image sets, and wherein the evaluation of quality may include evaluation of ability to determine spatial relationships from the plurality of two-dimensional image sets. The evaluation of quality may include evaluation of point cloud density. The evaluation of quality may include evaluation of scanning device motion. The feedback device may include an LED, a speaker, a buzzer, a vibrator, or a wand. The feedback device may be positioned on the wand. The feedback device may be further responsive to the signal to produce a second user alert when the data quality is within an acceptable range.

[0088] In another aspect, a method disclosed in herein may include: scheduling a preparation visit for a dental restoration for a patient; obtaining a digital surface representation of one or more intraoral structures of the patient, this may include at least one tooth associated with the dental restoration; and fabricating a temporary restoration based upon the digital surface representation.

[0089] Fabricating a temporary restoration may include transmitting the digital surface representation to a dental laboratory. Fabricating a temporary restoration may include applying the digital surface representation to prepare a design for the temporary restoration and transmitting the design to a dental laboratory. The method may include three-dimensionally printing the temporary restoration. The method may include three-dimensionally printing the temporary restoration at a dentist's office where the preparation visit is scheduled. The method may include milling the temporary restoration. The method may include milling the temporary restoration at a dental office where the preparation visit is scheduled. Obtaining a digital surface representation may include three-dimensionally scanning the one or more intraoral structures on a day of the preparation visit. Obtaining a digital surface

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representation may include retrieving the digital surface representation from prior dental data for the patient. Fabricating the temporary restoration may include fabricating the temporary restoration prior to the preparation visit, the temporary restoration may include one or more characteristics of the at least one tooth. The method may include, on the day of the preparation visit, adapting a surface of the at least one tooth to receive the temporary restoration. The method may include, on the day of the preparation visit, adapting the temporary restoration to fit a prepared surface of the at least one tooth. The step of fabricating may be performed at an in-house dental laboratory at a dentist's office.

[0090] A method disclosed herein includes: acquiring a digital dental impression including three-dimensional digital surface data for one or more intraoral structures, the intraoral structures may include at least one tooth surface prepared for a dental restoration; and acquiring additional three-dimensional data with greater spatial resolution around the at least one tooth surface prepared for the dental restoration.

[0091] The acquiring additional three-dimensional data may include acquiring additional data from the at least one tooth surface, post-processing source data for the digital dental impression, or post-processing the three-dimensional digital surface data.

[0092] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, may perform the steps of: acquiring one or more images of one or more intraoral structures, the intraoral structures may include at least one tooth surface prepared for a dental restoration; and generating a digital dental impression that may include three-dimensional digital surface data from the one or more images.

[0093] The computer program product may include code that performs the step of post-processing source data for the digital dental impression to generate additional three-dimensional data with greater spatial resolution. The computer program product may include code that performs the step of post-processing the three-dimensional digital surface data to generate additional three-dimensional data with greater spatial resolution.

[0094] A system disclosed herein includes: a first means for acquiring a digital dental impression that may include three-dimensional digital surface data for one or more intraoral structures, the intraoral structures may include at least one tooth

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surface prepared for a dental restoration; and a second means for acquiring additional three-dimensional data with greater spatial resolution around the at least one tooth surface prepared for the dental restoration.

[0095] The second means may include a means for acquiring additional data from the at least one tooth surface, a means for post-processing source data for the digital dental impression, or a means for post-processing the three-dimensional digital surface data.

[0096] A method disclosed herein includes: acquiring a digital surface representation for one or more intraoral structures, the intraoral structures may include at least one tooth surface prepared for a dental restoration; fabricating a kit from the digital surface representation, the kit may include two or more components suitable for use in fabrication of the dental restoration; and sending the kit to a dental laboratory for fabrication of the dental restoration. The kit may include one or more of a die, a quad model, an opposing quad model, an opposing model, a base, a pre-articulated base, and a waxup.

[0097] The method may include transmitting the digital surface representation to a production facility. The step of fabricating may be performed at the production facility. The kit may include one or more components selected from the group of pre-cut components, pre-indexed components, and pre-articulated components. The step of fabricating may be performed at a dentist's office.

[0098] An artificial dental object disclosed herein includes an exposed surface, the exposed surface finished with a texture to enhance acquisition of three dimensional image data from the exposed surface with a multi-aperture three-dimensional scanning device. The texture may include pseudo-random three-dimensional noise.

[0099] The artificial dental object may include an impression coping, a fixture, a healing abutment, or a temporary impression coping. The artificial dental object may include a dental prosthesis, a dental restoration, a dental appliance, or an item of dental hardware.

[00100] In another aspect, a method disclosed herein includes acquiring a three-dimensional representation of one or more intraoral structures, the intraoral structures including at least one intraoral surface suitable for an artificial dental object; transmitting the three-dimensional representation to a dental insurer; and

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receiving authorization from the dental insurer to perform a dental procedure including the artificial dental object.

[00101] The artificial dental object may include one or more of an implant, a crown, an impression coping, a bridge, a fixture, and an abutment. The intraoral surface may include at least one edentulous space. The intraoral surface may include at least one tooth surface.

[00102] A computer program product disclosed herein may include code that, when executed on one or more computer devices, performs the steps of: acquiring a three-dimensional representation of one or more intraoral structures, the intraoral structures including at least one intraoral surface suitable for an artificial dental object; transmitting the three-dimensional representation to a dental insurer; and receiving authorization from the dental insurer to perform a dental procedure including the artificial dental object.

[00103] The artificial dental object may include one or more of an implant, a crown, an impression coping, a fixture, a bridge, and an abutment. The intraoral surface may include at least one edentulous space. The intraoral surface may include at least one tooth surface.

[00104] A system disclosed herein includes a means for acquiring a three-dimensional representation of one or more intraoral structures, the intraoral structures including at least one intraoral surface suitable for an artificial dental object; a first communication means for transmitting the three-dimensional representation to a dental insurer; and a second communication means for receiving authorization from the dental insurer to perform a dental procedure including the artificial dental object.

[00105] The artificial dental object may include one or more of an implant, a crown, an impression coping, a fixture, a bridge and an abutment. The at least one intraoral surface may include an edentulous space. The at least one intraoral surface includes a tooth surface.

[00106] In another aspect, a method disclosed herein includes acquiring a three-dimensional representation of one or more intraoral structures, the intraoral structures including at least one intraoral surface related to a dental procedure; and transmitting the three-dimensional representation to a dental insurer as a record of the dental procedure.

[00107] The dental procedure may relate to one or more of an implant, a crown, an impression coping, a fixture, a bridge, and an abutment. The method may

include receiving a payment from the insurer for a procedure involving the artificial dental object. The intraoral surface may include an edentulous space. The intraoral surface may include a tooth surface prepared for an artificial dental object. The intraoral surface may include a restored tooth.

[00108] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of: acquiring a three-dimensional representation of one or more intraoral structures, the intraoral structures including at one intraoral surface related to a dental procedure; and transmitting the three-dimensional representation to a dental insurer as a record of the dental procedure.

[00109] The dental procedure may relate to one or more of an implant, a crown, an impression coping, a bridge, and an abutment. The code may further include code that performs the step of receiving a record of payment from the insurer for the dental procedure. The intraoral surface may include an edentulous space. The intraoral surface may include a tooth surface prepared for an artificial dental object. The intraoral surface may include a restored tooth.

[00110] A system disclosed herein may include a means for acquiring a three-dimensional representation of one or more intraoral structures, the intraoral structures including at least one intraoral surface related to a dental procedure; and a communication means for transmitting the three-dimensional representation to a dental insurer as a record of the dental procedure.

[00111] The dental procedure may to one or more of an implant, a crown, an impression coping, a bridge, and an abutment. The communication means may include a means for receiving a payment from the insurer for the dental procedure.

[00112] In another aspect, a method disclosed herein includes receiving a three-dimensional representation of one or more intraoral structures from a dentist; receiving a proposed dental procedure from the dentist; determining whether the proposed dental procedure is appropriate for the one or more intraoral structures; and transmitting a reply to the dentist. The reply may include an approval to perform the dental procedure. The reply may include a denial to perform the dental procedure. The method may include authorizing payment for the dental procedure.

[00113] A computer program product disclosed herein includes computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, may perform the steps of: receiving a three-

dimensional representation of one or more intraoral structures from a dentist; receiving a proposed dental procedure from the dentist; comparing the proposed dental procedure to a predetermined list of appropriate procedures for the one or more intraoral structures; and transmitting a reply to the dentist. The reply may include an approval to perform the dental procedure. The reply may include a denial to perform the dental procedure. The computer program product may include computer code that performs the step of authorizing payment for the dental procedure.

[00114] A system disclosed herein includes: a first means for receiving a three-dimensional representation of one or more intraoral structures from a dentist; a second means for receiving a proposed dental procedure from the dentist; an evaluation means for determining whether the proposed dental procedure is appropriate for the one or more intraoral structures; and a reply means for transmitting a reply to the dentist. The reply may include an approval to perform the dental procedure. The reply may include a denial to perform the dental procedure. The system may include a means for authorizing payment for the dental procedure.

[00115] A system disclosed herein includes: a dental data repository coupled to a communications network, the dental data repository may be adapted to receive dental data including three-dimensional representations of intraoral structures and prescriptions for dental procedures from a plurality of dentists.

[00116] The dental data repository may be adapted to transmit prescriptions and three-dimensional representations to a plurality of dental laboratories. The at least one of the prescriptions may identify a specific one of the plurality of dental laboratories. The dental data repository may be further adapted to communicate with one or more dental insurers for authorization of dental procedures. The dental data repository may be further adapted to communicate with one or more dental insurers to coordinate payment for dental procedures. The system may include a dental laboratory interface for the plurality of dental laboratories to provide status on work in progress. The system may include a dental laboratory interface for the plurality of dental laboratories to receive work assignments. The system may include a dentist interface for the plurality of dentists to monitor work in progress. The system may include a dentist interface for the plurality of dentists to submit prescriptions and three-dimensional representations. The system may include a transaction engine for transmitting payments among two or more of one of the plurality of dentists, one of the plurality of dental laboratories, and one of the one or more dental insurers. The

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system may include a collaboration interface for two or more of the plurality of dentists to collaborate on a dental matter.

BRIEF DESCRIPTION OF THE FIGURES

[00117] The invention and the following detailed description of certain embodiments thereof may be understood by reference to the following figures.

[00118] Fig. 1 shows a dental image capture system.

[00119] Fig. 2 shows entities participating in a digital dentistry network.

[00120] Fig. 3 shows a user interface that may be used in a digital dental system.

[00121] Fig. 4 depicts a quality control procedure for use in a digital dental system.

[00122] Fig. 5 shows a dental laboratory procedure using a digital dental model.

[00123] Fig. 6 illustrates a scan path that may be used with a three-dimensional image capture system.

[00124] Figs. 7A and 7B show a modeling environment for creating alignment guides for orthodontic hardware.

DETAILED DESCRIPTION

[00125] Described are a wide array of systems and methods for digital dentistry. However, it will be appreciated that the inventive concepts disclosed herein are not limited to the specific embodiments disclosed. For example, the general techniques disclosed herein may be usefully employed in any environment where precise, three-dimensional data might be usefully captured and processed, including orthopedics, digital animation, and customized manufacturing. In addition, while numerous variations and implementations of digital dentistry techniques are described, it will be appreciated that other combinations of the specific scanning, processing, and manufacturing techniques described herein may be used, and that such variations are intended to fall within the scope of this disclosure.

[00126] In the following description, the term "image" generally refers to a two-dimensional set of pixels forming a two-dimensional view of a subject within an image plane. The term "image set" generally refers to a set of related two dimensional images that might be resolved into three-dimensional data. The term

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"point cloud" generally refers to a three-dimensional set of points forming a three-dimensional view of the subject reconstructed from a number of two-dimensional views. In a three-dimensional image capture system, a number of such point clouds may also be registered and combined into an aggregate point cloud constructed from images captured by a moving camera. Thus it will be understood that pixels generally refer to two-dimensional data and points generally refer to three-dimensional data, unless another meaning is specifically indicated or clear from the context.

[00127] The terms "three-dimensional surface representation", "digital surface representation", "three-dimensional surface map", and the like, as used herein, are intended to refer to any three-dimensional surface map of an object, such as a point cloud of surface data, a set of two-dimensional polygons, or any other data representing all or some of the surface of an object, as might be obtained through the capture and/or processing of three-dimensional scan data, unless a different meaning is explicitly provided or otherwise clear from the context.

[00128] A "three-dimensional representation" may include any of the three-dimensional surface representations described above, as well as volumetric and other representations, unless a different meaning is explicitly provided or otherwise clear from the context.

[00129] In general, the terms "render" or "rendering" refer to a two-dimensional visualization of a three-dimensional object, such as for display on a monitor. However, it will be understood that three-dimensional rendering technologies exist, and may be usefully employed with the systems and methods disclosed herein. As such, rendering should be interpreted broadly unless a narrower meaning is explicitly provided or otherwise clear from the context.

[00130] The term "dental object", as used herein, is intended to refer broadly to subject matter specific to dentistry. This may include intraoral structures such as dentition, and more typically human dentition, such as individual teeth, quadrants, full arches, pairs of arches which may be separate or in occlusion of various types, soft tissue (e.g., gingival and mucosal surfaces of the mouth, or perioral structures such as the lips, nose, cheeks, and chin), and the like, as well bones and any other supporting or surrounding structures. As used herein, the term "intraoral structures" refers to both natural structures within a mouth as described above and artificial structures such as any of the dental objects described below. While the design and fabrication of artificial dental structures is the subject of much of the following discussion, it will be

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understood that any of these artificial structures might be present in the mouth during a scan, either as a result of prior dental work (e.g., a previously restored tooth) or during an evaluation of fit and other aspects of a current procedure. Dental objects may include "restorations", which may be generally understood to include components that restore the structure or function of existing dentition, such as crowns, bridges, veneers, inlays, onlays, amalgams, composites, and various substructures such as copings and the like, as well as temporary restorations for use while a permanent restoration is being fabricated. Dental objects may also include a "prosthesis" that replaces dentition with removable or permanent structures, such as dentures, partial dentures, implants, retained dentures, and the like. Dental objects may also include "appliances" used to correct, align, or otherwise temporarily or permanently adjust dentition, such as removable orthodontic appliances, surgical stents, bruxism appliances, snore guards, indirect bracket placement appliances, and the like. Dental objects may also include "hardware" affixed to dentition for an extended period, such as implant fixtures, implant abutments, orthodontic brackets, and other orthodontic components. Dental objects may also include "interim components" of dental manufacture such as dental models (full and/or partial), wax-ups, investment molds, and the like, as well as trays, bases, dies, and other components employed in the fabrication of restorations, prostheses, and the like. As suggested above, dental objects may also be categorized as natural dental objects such as the teeth, bone, and other intraoral structures described above or as artificial dental objects such as the restorations, prostheses, appliances, hardware, and interim components of dental manufacture as described above. It will be understood that any of the foregoing, whether natural or artificial, may be an intraoral structure when present within the mouth. Thus, for example, a previous restoration or an implant for a crown might be present within the mouth, and may be an intraoral structure scanned during an intraoral scan.

[00131] Terms such as "digital dental model", "digital dental impression" and the like, are intended to refer to three-dimensional representations of dental objects that may be used in various aspects of acquisition, analysis, prescription, and manufacture, unless a different meaning is otherwise provided or clear from the context. Terms such as "dental model" or "dental impression" are intended to refer to a physical model, such as a cast, printed, or otherwise fabricated physical instance of

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a dental object. Unless specified, the term "model", when used alone, may refer to either or both of a physical model and a digital model.

[00132] Fig. 1 shows an image capture system. In general, the system 100 may include a scanner 102 that captures images from a surface 106 of a subject 104, such as a dental patient, and forwards the images to a computer 108, which may include a display 110 and one or more user input devices such as a mouse 112 or a keyboard 114. The scanner 102 may also include an input or output device 116 such as a control input (e.g., button, touchpad, thumbwheel, etc.) or a status indicator (e.g., LCD or LED display or light, a buzzer, or the like) to provide status information.

[00133] The scanner 102 may include any camera or camera system suitable for capturing images from which a three-dimensional point cloud may be recovered. For example, the scanner 102 may employ a multi-aperture system as disclosed, for example, in U.S. Pat. Pub. No. 20040155975 to Hart et al., the entire contents of which is incorporated herein by reference. While Hart discloses one multi-aperture system, it will be appreciated that any multi-aperture system suitable for reconstructing a three-dimensional point cloud from a number of two-dimensional images may similarly be employed. In one multi-aperture embodiment, the scanner 102 may include a plurality of apertures including a center aperture positioned along a center optical axis of a lens and any associated imaging hardware. The scanner 102 may also, or instead, include a stereoscopic, triscopic or other multi-camera or other configuration in which a number of cameras or optical paths are maintained in fixed relation to one another to obtain two-dimensional images of an object from a number of slightly different perspectives. The scanner 102 may include suitable processing for deriving a three-dimensional point cloud from an image set or a number of image sets, or each two-dimensional image set may be transmitted to an external processor such as contained in the computer 108 described below. In other embodiments, the scanner 102 may employ structured light, laser scanning, direct ranging, or any other technology suitable for acquiring three-dimensional data, or two-dimensional data that can be resolved into three-dimensional data.

[00134] In one embodiment, a second scanner such as a PMD[vision] camera from PMD Technologies, may be employed to capture real-time, three-dimensional data on dynamic articulation and occlusion. While this scanner employs different imaging technology (time-of-flight detection from an array of LEDs) than described above, and produces results with resolution generally unsuitable for reconstruction of

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dental models, such a scanner may be employed to infer motion of, e.g., opposing dental arches with sufficient resolution to select an axis for articulation or otherwise capture dynamic information that can be applied to two or more rigid bodies of a dental object scan. This data may be supplemented with more precise alignment data statically captured from digital or manual bite registration to provide reference or calibration points for continuous, dynamic motion data.

[00135] In one embodiment, the scanner 102 is a handheld, freely positionable probe having at least one user input device 116, such as a button, lever, dial, thumb wheel, switch, track ball, mini joystick, touchpad, keypad, or the like, for user control of the image capture system 100 such as starting and stopping scans, or interacting with a user interface on the display 110. In an embodiment, the scanner 102 may be shaped and sized for dental scanning. More particularly, the scanner 102 may be shaped and sized for intraoral scanning and data capture, such as by insertion into a mouth of an imaging subject and passing over an intraoral surface 106 at a suitable distance to acquire surface data from teeth, gums, and so forth. This may include a shape resembling an electric toothbrush or a dental tool, and including an elongated body with an optical port on one end that receives scan data, and user controls on (or near) the other end.

[00136] A physical offset may be provided for the optical port that physically maintains an appropriate distance from scanning subject matter. More particularly, the physical offset may prevent the optical port from getting too near the scanned subject matter, which permits a user to maintain proper distance through a steady application of pressure toward the subject matter. The physical offset may be adapted for particular subject matter and may include a simple rod or other rigid form extending toward the optical path of the scanner, or the physical offset may include contoured forms for mating with more complex surfaces. The physical offset may include wheels or plates for slidably engaging a surface of scanned subject matter, or other structures or surface treatments to improve operation in various applications.

[00137] The scanner 102 may, through a continuous acquisition process, capture a point cloud of surface data having sufficient spatial resolution and accuracy to prepare dental objects such as restorations, hardware, appliances, and the like therefrom, either directly or through a variety of intermediate processing steps. In other embodiments, surface data may be acquired from a dental model such as a

dental restoration, to ensure proper fitting using a previous scan of corresponding dentition, such as a tooth surface prepared for the restoration.

[00138] Although not shown in Fig. 1, it will be appreciated that a number of supplemental lighting systems may be usefully employed during image capture. For example, environmental illumination may be enhanced with one or more spotlights illuminating the subject 104 to speed image acquisition and improve depth of field (or spatial resolution depth). The scanner 102 may also, or instead, include a strobe, flash, or other light source to supplement illumination of the subject 104 during image acquisition.

[00139] The subject 104 may be any object, collection of objects, portion of an object, or other subject matter. More particularly with respect to the dental fabrication techniques discussed herein, the object 104 may include human dentition captured intraorally from a dental patient's mouth. A scan may capture a three-dimensional representation of some or all of the dentition according to particular purpose of the scan. Thus the scan may capture a digital model of a tooth, a quadrant of teeth, or a full collection of teeth including two opposing arches, as well as soft tissue or any other relevant intraoral and/or extraoral structures. In other embodiments where, for example, a completed fabrication is being virtually test fit to a surface preparation, the scan may include a dental restoration such as an inlay or a crown, or any other artificial dental object. The subject 104 may also, or instead, include a dental model, such as a plaster cast, wax-up, impression, or negative impression of a tooth, teeth, soft tissue, or some combination of these.

[00140] Although not depicted, it will be understood that the scanner 102 may have a two-dimensional field of view or image plane where optical data is acquired. It will be appreciated that the term "image plane" as used in this paragraph, refers to a plane in the imaging environment rather than a plane within an optical sensor (such as film or sensors) where an image is captured. The image plane may form any number of two-dimensional shapes according to the construction of the scanner 102, such as a rectangle, a square, a circle, or any other two-dimensional geometry. In general, the scanner 102 will have a depth of field or range of depth resolution for image acquisition within the image plane determined by the physical construction of the scanner 102 and environmental conditions such as ambient light.

[00141] The computer 108 may be, for example, a personal computer or other processing device. In one embodiment, the computer 108 includes a personal

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computer with a dual 2.8GHz Opteron central processing unit, 2 gigabytes of random access memory, a TYAN Thunder K8WE motherboard, and a 250 gigabyte, 10,000 rpm hard drive. This system may be operated to capture approximately 1,500 points per image set in real time using the techniques described herein, and store an aggregated point cloud of over one million points. As used herein, the term "real time" means generally with no observable latency between processing and display. In a video-based scanning system, real time more specifically refers to processing within the time between frames of video data, which typically vary according to specific video technologies between about fifteen frames per second and about thirty frames per second. However, it will also be understood that terms such as "video" or "video rate" imply a wide range of possible frame rates associated with such video. While most modern video formats employ a frame rate of 25 to 30 frames per second, early video employed frame rates as low as 8 frames per second, and movies of the early 1900's varied from 12 to 18 frames per second. In addition, it is common for specialized imaging equipment to employ a rate adapted to the computational demands of particular imaging and rendering techniques, and some video systems operate with frame rates anywhere from 4 frames per second (for computationally extensive imaging systems) to 100 frames per second or higher (for high-speed video systems). As used herein, the terms video rate and frame rate should be interpreted broadly. Notwithstanding this broad meaning, it is noted that useful and visually pleasing three-dimensional imaging systems may be constructed as described herein with frame rates of at least ten frames per second, frame rates of at least twenty frames per second, and frame rates between 25 and 30 frames per second.

[00142] More generally, processing capabilities of the computer 108 may vary according to the size of the subject 104, the speed of image acquisition, and the desired spatial resolution of three-dimensional points. The computer 108 may also include peripheral devices such as a keyboard 114, display 110, and mouse 112 for user interaction with the camera system 100. The display 110 may be a touch screen display capable of receiving user input through direct, physical interaction with the display 110.

[00143] Communications between the computer 108 and the scanner 102 may use any suitable communications link including, for example, a wired connection or a wireless connection based upon, for example, IEEE 802.11 (also known as wireless Ethernet), BlueTooth, or any other suitable wireless standard using, e.g., a radio

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frequency, infrared, or other wireless communication medium. In medical imaging or other sensitive applications, wireless image transmission from the scanner 102 to the computer 108 may be secured. The computer 108 may generate control signals to the scanner 102 which, in addition to image acquisition commands, may include conventional camera controls such as focus or zoom. In addition, the computer 108 may include a network communications interface for connecting to a network such as the dental network described below.

[00144] In an example of general operation of a three-dimensional image capture system 100, the scanner 102 may acquire two-dimensional image sets at a video rate while the scanner 102 is passed over a surface of the subject. The two-dimensional image sets may be forwarded to the computer 108 for derivation of three-dimensional point clouds. The three-dimensional data for each newly acquired two-dimensional image set may be derived and fitted or "stitched" to existing three-dimensional data using a number of different techniques. Such a system employs camera motion estimation to avoid the need for independent tracking of the position of the scanner 102. One useful example of such a technique is described in commonly-owned U.S. App. No. 11/270,135, filed on November 9, 2005, the entire contents of which is incorporated herein by reference. However, it will be appreciated that this example is not limiting, and that the principles described herein may be applied to a wide range of three-dimensional image capture systems.

[00145] The display 110 may include any display suitable for video or other rate rendering at a level of detail corresponding to the acquired data. Suitable displays include cathode ray tube displays, liquid crystal displays, light emitting diode displays and the like. In addition, where three-dimensional visualization is desired, the display 110 may include a three-dimensional display using a wide variety of techniques including stereo pair imaging, holographic imaging, and multiplanar or volumetric imaging, each with a number of rendering modalities that may be usefully employed with the systems described herein.

[00146] In some embodiments, the display may include a touch screen interface using, for example capacitive, resistive, or surface acoustic wave (also referred to as dispersive signal) touch screen technologies, or any other suitable technology for sensing physical interaction with the display 110.

[00147] The touch screen may be usefully employed in a dental office or other context to provide keyboardless processing and manipulation of scanning and

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any resulting three-dimensional representations. For example, the touch screen may be employed to permit user manipulation of a displayed model, such as panning, zooming, and rotating, through direct physical interaction with the displayed model and any corresponding controls within a user interface. For example, a user may touch a "rotate" button on the display 110, after which placing a finger on the screen and dragging may cause three-dimensional rotation of the displayed model around a corresponding axis (typically perpendicular to the direction of finger motion).

[00148] The touch screen may also provide tools for manipulating the digital model. For example, a user may define or specify a cementation void or die spacer. A user may define, edit, or annotate a margin line, such as a computer-generated margin line. A user may define a die and/or ditch a die by recessing one or more regions below the margin line. A user may place arches of a digital dental model into a virtual articulator and articulate the arches. The touch screen may provide one or more tools for virtually designing a dental restoration fitted to a dental model, including fitting to a prepared surface, adjacent teeth, and/or teeth of an opposing arch.

[00149] The touch screen may also provide case management controls providing functions such as transmitting a digital model to a dental laboratory, evaluating quality of a digital model or performing other quality control functions as described below, or creating a dental prescription as described, for example, below with reference to Fig. 3.

[00150] The image capture system 100 may generally be adapted for real time acquisition and display, e.g., at a video rate, of three-dimensional data, which may be rendered, for example, as a point cloud superimposed on a video image from the scanner 102. For certain types of data acquisition, there may be a significant difference in the processing time required for resolution of a three-dimensional image adequate for two-dimensional perspective rendering (faster) and maximum or optimum resolution that might be achieved with post-processing. In such circumstances, the image capture system 100 may include two different operating modes. In a first operating mode, a relatively low-quality three-dimensional representation may be obtained and rendered in real time, such as within the display 110. In a second operating mode, a relatively high-quality three-dimensional representation may be generated for the source scan data using any desired degree of processing. The second operating mode may recover, through additional post-

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processing steps, three-dimensional data having greater spatial resolution and/or accuracy. It will be understood that, while two different modes are described, it is not required that the two modes be mutually exclusive. For example, both modes may execute simultaneously on a computer as separate processes or threads, or the data from the first operating mode may be employed to seed the second operating mode with a model for refinement for post-processing. All such variations as would be apparent to one of ordinary skill in the art may be employed with the systems described herein. Either the high-quality representation or the low-quality representation, or both, may be transmitted to a dental laboratory for subsequent steps such as quality control and model fabrication, examples of which are provided below.

[00151] In another aspect, the system 100 may provide different levels of accuracy or spatial resolution, each associated with, for example, different degrees of post-processing, computing power, or rate of movement by the scanner 102 over a subject 104. Thus, for example, an entire dental arch may be scanned at a relatively low accuracy, while a surface preparation or other area of diagnostic or treatment significance may be scanned at a relatively higher accuracy which may, for example, require a slower scanning motion or additional post-processing delays. Similarly, certain areas such as the surface preparation may be designated for supplemental post-processing to achieve enhanced accuracy or spatial resolution.

[00152] The input or output device 116 may include a feedback device that provides warnings or indicators to an operator of the image capture system 100 with respect to scan quality or progress. The device 116 may include, for example, a buzzer, speaker, light emitting diode, an incandescent light, or any other acoustic, haptic, tactile, or visual signal to notify the operator of an event without requiring the operator to look at the display 110. For example, data quality may be continuously monitored by the system 100, and an alert may be generated when the data quality drops below a quantitative threshold, or data acquisition is lost completely (or different alerts may be provided for each of these events). The evaluation of data quality may depend, for example, on an ability of the system 100 to fit a new data set to existing three-dimensional data, or the ability to resolve two-dimensional image sets into three-dimensional data, or the density of acquired data, or any other objective criterion, either alone or in combination. The evaluation of data quality may also, or instead, be inferred from other parameters such as motion of the scanner 102 or distance from the subject 104. It will be understood that while a data quality indicator

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may be positioned on the scanner 102 as shown, the device 116 may also, or instead, be positioned at any other location suitable for alerting an operator, which may depend on the type of alert generated (i.e., a visual alert may have different positioning parameters than an audio alert or a tactile alert). In another aspect, the input or output device 116 may provide feedback when data quality is within an acceptable range. In another aspect, the input our output device 116 may provide both positive feedback (good data quality) and negative feedback (poor data quality) so that continuous feedback is available to the operator concerning an ongoing scan.

[00153] Fig. 2 shows entities participating in a digital dentistry network. As depicted, a network 200 may include a plurality of clients 202 and servers 204 connected via an internetwork 210. Any number of clients 202 and servers 204 may participate in such a system 200. The network 200 may include one or more local area networks ("LANs") 212 interconnecting clients 202 through a hub 214 (in, for example, a peer network such as a wired or wireless Ethernet network) or a local area network server 214 (in, for example, a client-server network). The LAN 212 may be connected to the internetwork 210 through a gateway 216, which provides security to the LAN 212 and ensures operating compatibility between the LAN 212 and the internetwork 210. Any data network may be used as the internetwork 210 and the LAN 212.

[00154] The internetwork 210 may include, for example, the Internet, with the World Wide Web providing a system for interconnecting clients 202 and servers 204 in a communicating relationship through the internetwork 210. The internetwork 210 may also, or instead, include a cable network, a satellite network, the Public Switched Telephone Network, a WiFi network, a WiMax network, cellular networks, and any other public, private, and/or dedicated networks, either alone or combination, that might be used to interconnect devices for communications and transfer of data.

[00155] An exemplary client 202 may include a processor, a memory (e.g. RAM), a bus which couples the processor and the memory, a mass storage device (e.g. a magnetic hard disk or an optical storage disk) coupled to the processor and the memory through an I/O controller, and a network interface coupled to the processor and the memory, such as modem, digital subscriber line ("DSL") card, cable modem, network interface card, wireless network card, or other interface device capable of wired, fiber optic, or wireless data communications. One example of such a client 202 is a personal computer equipped with an operating system such as Microsoft

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Windows XP, UNIX, or Linux, along with software support for Internet and other communication protocols. The personal computer may also include a browser program, such as Microsoft Internet Explorer, Netscape Navigator, or FireFox to provide a user interface for access to the internetwork 210. Although the personal computer is a typical client 202, the client 202 may also be a workstation, mobile computer, Web phone, VOIP device, television set-top box, interactive kiosk, personal digital assistant, wireless electronic mail device, or other device capable of communicating over the Internet. As used herein, the term "client" is intended to refer to any of the above-described clients 202 or other client devices, and the term "browser" is intended to refer to any of the above browser programs or other software or firmware providing a user interface for navigating through an internetwork 210 such as the Internet. The client 202 may also include various communications capabilities such as instant messaging, electronic mail, syndication (such as RSS 2.0), Web-based conferencing, Web-based application sharing, Web-based videoconferencing, Voice over IP ("VoIP"), and any other standards-based, proprietary, or other communication technologies, either in hardware, software, or a combination of these, to enable communications with other clients 202 through the internetwork 210.

[00156] An exemplary server 204 includes a processor, a memory (e.g. RAM), a bus which couples the processor and the memory, a mass storage device (e.g. a magnetic or optical disk) coupled to the processor and the memory through an I/O controller, and a network interface coupled to the processor and the memory. Servers may be clustered together to handle more client traffic, and may include separate servers for different functions such as a database server, an application server, and a Web presentation server. Such servers may further include one or more mass storage devices 206 such as a disk farm or a redundant array of independent disk ("RAID") system for additional storage and data integrity. Read-only devices, such as compact disk drives and digital versatile disk drives, tape drives, and the like may also be connected to the servers. Suitable servers and mass storage devices are manufactured by, for example, IBM, and Sun Microsystems. Generally, a server 204 may operate as a source of content, a hub for interactions among various clients, and platform for any back-end processing, while a client 202 is a participant in the dental activities supported by the digital dentistry systems described herein. However, it should be appreciated that many of the devices described above may be configured to

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respond to remote requests, thus operating as a server, and the devices described as servers 204 may participate as a client in various digital dentistry applications.

[00157] Focusing now on the internetwork 210, one embodiment is the Internet. The structure of the Internet 210 is well known to those of ordinary skill in the art and includes a network backbone with networks branching from the backbone. These branches, in turn, have networks branching from them, and so on. The backbone and branches are connected by routers, bridges, switches, and other switching elements that operate to direct data through the internetwork 210. For a more detailed description of the structure and operation of the Internet 210, one may refer to "The Internet Complete Reference," by Harley Hahn and Rick Stout, published by McGraw-Hill, 1994. However, one may practice the present invention on a wide variety of communication networks. For example, the internetwork 210 can include interactive television networks, telephone networks, wireless voice or data transmission systems, two-way cable systems, customized computer networks, Asynchronous Transfer Mode networks, and so on. Clients 202 may access the internetwork 210 through an Internet Service Provider ("ISP", not shown) or through a dedicated DSL service, ISDN leased lines, T1 lines, OC3 lines, digital satellite service, cable modem service, or any other connection, or through an ISP providing same. Further, the internetwork 210 may include a variety of network types including wide-area networks, local area networks, campus area networks, metropolitan area networks, and corporate area networks.

[00158] In an exemplary embodiment, a browser, executing on one of the clients 202, retrieves a Web document at an address from one of the servers 204 via the internetwork 210, and displays the Web document on a viewing device, e.g., a screen. A user can retrieve and view the Web document by entering, or selecting a link to, a URL in the browser. The browser then sends an http request to the server 204 that has the Web document associated with the URL. The server 204 responds to the http request by sending the requested Web document to the client 202. The Web document is an HTTP object that includes plain text (ASCII) conforming to the HyperText Markup Language ("HTML"). Other markup languages are known and may be used on appropriately enabled browsers and servers, including the Dynamic HyperText Markup Language ("DHTML"), the Extensible Markup Language ("XML"), the Extensible Hypertext Markup Language ("XHML"), and the Standard Generalized Markup Language ("SGML").

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[00159] Each Web document usually contains hyperlinks to other Web documents. The browser displays the Web document on the screen for the user and the hyperlinks to other Web documents are emphasized in some fashion such that the user can identify and select each hyperlink. To enhance functionality, a server 204 may execute programs associated with Web documents using programming or scripting languages, such as Perl, C, C++, C#, or Java, or a Common Gateway Interface ("CGI") script to access applications on the server. A server 204 may also use server-side scripting languages such as ColdFusion from MacroMedia or PHP. These programs and languages may perform "back-end" functions such as order processing, database management, and content searching. A Web document may also contain, or include references to, small client-side applications, or applets, that are transferred from the server 204 to the client 202 along with a Web document and executed locally by the client 202. Java is one popular example of a programming language used for applets. The text within a Web document may further include (non-displayed) scripts that are executable by an appropriately enabled browser, using a scripting language such as JavaScript or Visual Basic Script. Browsers may further be enhanced with a variety of helper applications to interpret various media including still image formats such as JPEG and GIF, document formats such as PS and PDF, motion picture formats such as AVI and MPEG, animated media such as Flash media, and sound formats such as MP3 and MIDI. These media formats, along with a growing variety of proprietary media formats, may be used to enrich a user's interactive and audio-visual experience as each Web document is presented through the browser. In addition, user interaction may be supplemented with technologies such as RSS (for syndication), OPML (for outlining), AJAX (for dynamic control of a web page), and so forth. The term "page" as used herein is intended to refer to the Web document described above, as well as any of the above-described functional or multimedia content associated with the Web document. A page may be employed to provide a user interface to the digital dentistry systems described herein. In addition, one or more applications running on a client 202 may provide a user interface for local and/or networked digital dentistry functions as described herein.

[00160] In Fig. 2, each client 202 represents a computing device coupled to the internetwork 210. It will be understood that a client 202 may be present at a location associated with digital dentistry such as a dental laboratory, a rapid manufacturing facility, a dental office, and/or a dental data center. Each of these

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potential participants in a digital dentistry system will now be described in greater detail.

[00161] One of the clients 202 may reside at a dental office. The dental office may include any office or other physical facility that provides dental care including individual dentist offices, dental group offices, retail dental centers, university dental schools, and the like. A dental patient may visit the dental office for a routine check up or cleaning, or for a visit scheduled due to oral discomfort, dental injury, or the like.

[00162] During the dental visit, a dentist may examine the dental patient and provide a dental assessment, such as the need for a restoration, tooth extraction, or the like. The dental office may include a three-dimensional scanner, such as any of the scanners described above, which the dentist may use to capture a three-dimensional digital representation of the dental patient's dentition including scans both before and after one or more tooth surfaces have been prepared for a dental object such as a restoration or the like. While a scan may be performed in the context of a specific dental issue, such as a planned restoration, the dentist may also capture scans during routine visits so that a dental history for the dental patient is accumulated over time. Using the client 202, which may include the image capture system 100 described above, the dentist may obtain one or more three-dimensional representations and, after discussing treatment with the dental patient, input any relevant dental prescription information. The dentist may then electronically transmit the three-dimensional representations, along with the prescription, to a dental laboratory or other fabrication facility using a network such as the internetwork 210 described above. In general, an electronic dental prescription, as used herein, includes a dental prescription in electronic form along with any three-dimensional data such as tooth surfaces before and after surface preparation, teeth in occlusion, and so forth. Additional data, such as x-ray, digital radiographic, or photograph data may be incorporated into the electronic dental prescription, or otherwise used with the systems and methods described herein. In certain instances, an electronic dental prescription may instead refer exclusively to the prescription data. In general, the meaning should be clear from the context, however, in the absence of explicit guidance, the broadest possible meaning is intended.

[00163] As a significant advantage, a practicing dentist may maintain a history of three-dimensional representations of dentition and surrounding soft tissue

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for each dental patient. Where a new procedure, such as a restoration, is scheduled for the patient, the dentist may pre-fabricate a temporary restoration using historic dental data. The temporary restoration may be fabricated for example, at the dental office where the procedure is scheduled using a three-dimensional printer and/or a copy milling machine, or at a remote facility such as the dental laboratory or rapid manufacturing facility described below. In one aspect, a scan may be obtained of a prepared surface during the scheduled visit, and the temporary restoration (or a final restoration) may be fabricated, such as at the dental office during the visit, by combining historical three-dimensional data with a three-dimensional representation of the prepared surface. In another embodiment, a treating dentist may shape the surface preparation to receive a pre-fabricated temporary restoration.

[00164] More generally, the client 202 at the dental office may be coupled in a communicating relationship with a client 202 at one or more of a dental laboratory, another dental office, a rapid manufacturing facility, and/or a dental data center for communication of three-dimensional representations of dental subject matter and related information. This dental network may be usefully employed in diagnosis, case planning, consultation, evaluation, and the like. Participation may include, for example, consultation, online or distance collaboration, approval, payment authorization, or any other collaborative or unilateral participation, examples of which are provided throughout this description. Thus there is disclosed herein methods and systems for sharing digital dental data, such as digital dental impressions captured using the techniques described above. This may permit a wide array of collaborative communications using a shared view of dentition or related digital models. For example, a dentist may collaborate with another dentist, a dental technician at a dental laboratory, an oral surgeon, a technician at a rapid manufacturing facility, or any other participant in a dental network at a remote location using a shared view of a patient's dentition. Various dental specialists may participate from remote (or local) locations, such as a periodontist, a prosthodontist, a pedodontist, an orthodontic specialist, an oral and maxillofacial surgery specialist, an oral and maxillofacial radiology specialist, an endodontist, and/or an oral and maxillofacial pathologist. Tools may be provided, such as collaborative tools, for sharing control of model manipulation, sectioning, rearranging, marking, and visualizing or simulating proposed clinical procedures. Each participant may view a rendering of the three-dimensional representation of dentition from a common or shared point of view. Control of the

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view and any modeling tools may be passed among participants, as well as a cursor or command prompt shared by participants within a user interface. In one aspect, this system forms a collaborative dental environment in which a three-dimensional representation of a dental patient's dentition is shared among participants. Communications among participants may include any network-supported communications protocol including electronic mail, instant messaging, Internet Relay Chat, Voice-over-IP, and the like, as well as conventional teleconferencing.

[00165] Turning next to the dental laboratory, a dental laboratory may provide a fabrication resource for dental practitioners. A conventional dental laboratory may have a number of production departments specializing in various dental objects such as complete dentures, partial dentures, crowns and bridges, ceramics, and orthodontic appliances. A dental laboratory may employ trained technicians to perform various tasks associated with filling a dental prescription such as preparing dental models, dies, articulated models, and the like from impressions and occlusal registrations received from dentists. Typically, a dentist submits an order with specific instructions (a prescription) to a dental laboratory, and the laboratory fabricates the corresponding dental object(s) for use by the dentist. A client 202 at a dental laboratory may be coupled in a communicating relationship with a client 202 at one or more of a dental office, another dental laboratory, a rapid manufacturing facility, and/or a dental data center for communication of three-dimensional representations of dental subject matter and related information. This dental network may be usefully employed in diagnosis, case planning, consultation, evaluation, and the like.

[00166] Dental laboratories may for example create restorative products such as crowns and bridges. A traditional crown formed of gold, other metal alloys, or ceramic may replace all visible areas of a tooth. An onlay is a partial crown that does not fully cover the visible tooth. Crowns may include a precision attachment incorporated into the design that may receive and connect a removable partial denture. Inlays are restorations fabricated to fit a prepared tooth cavity and then cemented into place. A bridge is a restoration of one or more missing teeth, such as a fixed partial, a three unit bridge, or the like. A bridge may be permanently attached to the natural teeth or attached to custom-made or prefabricated posts and cores that are first cemented into the roots.

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[00167] Another major area of dental objects includes reconstructive products, most typically dentures. Partial dentures are a removable dental prosthesis that replaces missing teeth and associated structures. Full dentures substitute for the total loss of teeth and associated structures. Some dental labs also make precision attachments that connect a crown to an artificial prosthesis. Implants are fixtures anchored securely in the bone of the mouth to which an abutment, crown or other dental object can be attached using screws, clips, or the like. This may include, for example, a titanium root replacement integrated with the bone, an abutment or transfer coping, and an implant secured to the abutment. Implant procedures also typically involve a healing abutment to assist with healing of affected soft tissue and to maintain positioning of teeth while the root replacement attaches to the bone (which may take several months). An additional impression may be taken of the implant using an impression coping or abutment after it has attached to the bone for preparation of a final restoration.

[00168] A dental laboratory may also manufacture cosmetic products such as ceramic or composite resin veneers and crowns. Veneers are thin coverings cemented to the front of the tooth for aesthetic affect. Crowns are designed to cover the entire tooth preparation and will resemble natural teeth. Composite or ceramic inlays and onlays may be manufactured to replace amalgams and give teeth a more natural appearance. Orthodontic appliances move existing teeth to enhance function and/or appearance.

[00169] In general, the procedures described above involve transfer of a dental impression to a laboratory for fabrication of the final dental object. In some cases, such as implants, a number of impressions may be taken over the course of treatment. Using a scanner such as that described above, a dentist may capture an accurate three-dimensional representation of dentition and surrounding tissue and transmit this digital version of the dental impression to a dental laboratory using a network such as the internetwork 210 described above. The dental laboratory may receive the data and proceed with any appropriate fabrication. In various procedures, the three-dimensional representation may include data from two or more scans, such as an initial three-dimensional representation of dentition prior to any dental work, and a prepared three-dimensional representation of the dentition after one or more tooth surfaces have been prepared for the dental object(s). The surface preparation may provide guidance to the laboratory concerning fit of the restoration or other

dental object to the tooth surface, and the initial scan may provide valuable information concerning the appropriate dimensions for the final dental object and its relationship to surrounding teeth. A dentist may also optionally specify a number of parameters for the dental laboratory as described in various examples below.

[00170] Where a particular dental object is temporary, or will be covered by another dental object at a subsequent dental visit, the object may be fabricated with one or more characteristics that improve scanning of any exposed surfaces once the object is placed within a dental patient's mouth. For example, an object such as an impression coping, fixture, or healing abutment may be fabricated with scanning-optimized surfaces such as an optical or textured finish. An optical finish may, for example, include randomly (or pseudo-randomly) distributed coloration such as black or other high-contrast dots. A textured finish may, for example, include a pseudo-random texture or one or more discrete landmarks.

[00171] It will be appreciated that in certain embodiments the dental laboratory may be an in-office dental laboratory physically located within or near a dental office where a dental patient is receiving treatment. In various embodiments, the in-office dental laboratory may provide facilities for a subset of dental objects described above, such as those most commonly used by a particular dentist.

[00172] Rapid manufacturing facilities may also be employed with the systems described herein. A rapid manufacturing facility may include equipment for designing and/or fabricating dental objects for use in dental procedures. A client 202 at a rapid manufacturing facility may be coupled in a communicating relationship with a client 202 at one or more of a dental office, another dental laboratory, a rapid manufacturing facility, and/or a dental data center for communication of three-dimensional representations of dental subject matter and related information. This dental network may be usefully employed in diagnosis, case planning, consultation, evaluation, and the like.

[00173] Rapid manufacturing facilities may include, for example one or more stereo lithography apparatuses, three-dimensional printers, computerized milling machines, or other three-dimensional rapid prototyping facilities or similar resources. A particular facility may include one or more of a number of different types of machines which may be scheduled for various fabrication jobs received through the internetwork 210. In one embodiment, a single facility may provide a large number of machines along with suitably trained technical personal to provide a centralized

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fabrication facility. In another embodiment, machines may be distributed at various locations, including one or more machines within dental offices and dental laboratories. Where copings, crowns, or the like are to be finished at the rapid manufacturing facility rather than, for example, a dental laboratory, the rapid manufacturing facility may also include machinery such as pressing machines and electroplating machines.

[00174] More generally, a dental fabrication facility may include one or more of the rapid manufacturing facilities, dental laboratory facilities, or in-office dental laboratories described above, either alone or in combination.

[00175] A dental data center may provide a hub for a digital dentistry network. A server 204 at a dental laboratory may be coupled in a communicating relationship with a client 202 at one or more of a dental office, a dental laboratory, a rapid manufacturing facility, and/or another dental data center for communication of three-dimensional representations of dental subject matter and related information. This dental network may be usefully employed in diagnosis, case planning, consultation, evaluation, and the like. The dental data center may, for example operate as an intermediary between dentists, laboratories, and fabrication facilities to provide a common repository for new dental jobs from a dental office, which may be distributed to available resources at one or more dental laboratories and/or rapid fabrication facilities. In addition to scheduling and workload allocation, the dental data center may provide various value-added services such as quality control for incoming three-dimensional representation, financial transaction management, insurance authorization and payment, and the like.

[00176] The dental data center may coordinate a number of transactions within a digital dentistry network. For example, the dental data center may engage in continuous bidding for fabrication work in order to ensure competitive pricing for fabrication facility and dental laboratory work sourced from the dental data center. As another example, the dental data center may provide status updates concerning a fabrication job to a dentist or other participant, including up-to-date information such as job received, job at fabrication facility, job at dental laboratory, model completed, waxing completed, investing completed, casting completed, porcelain build-up completed, restoration completed, finishing, shipping, and so forth. The dental data center may provide a web-based work-in-progress interface through which a dentist may monitor progress. Other known systems, such as electronic mail alerts or RSS

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updates, may be used to provide status updates to dentists or other interested parties. While a dental data center may be usefully employed with the digital dentistry systems described herein, it will also be understood that various dental networks may operate independently between parties, such as between a dental office and a dental laboratory or between a dental laboratory and a rapid manufacturing facility, or between a number of dental offices and a rapid manufacturing facility, without a centralized server at a dental data center. All such embodiments are intended to fall within the scope of this disclosure. Further, it will be understood that a wide array of software platforms, communications protocols, security protocols, user interfaces, and the like are known, and may be suitably adapted to a web-based, web-services based, or other dental data center as described herein.

[00177] A digital dentistry network may include other participants, such as a consulting dentist, and oral surgeon, an insurer, a federal or state regulator or oversight entity, or any other dental entity. Each of these participants may communicate with other participants in the digital dentistry network through use of a client 202. Through this digital dentistry network, various methods and systems may be deployed. For example, in one aspect a three-dimensional representation and a dental prescription may be electronically transmitted to an insurer through the network, and the insurer may respond with authorization to perform the specified dental procedure (or a denial, which may include any reasons for the denial), including fabrication of any related dental objects. The insurer may maintain an electronic copy of three-dimensional representations relevant to the authorization, such as an image of the tooth surface prepared for the procedure. The insurer may also render payment, or authorize payment, to a treating dentist. The insurer may also, or instead, render payment to related entities, such as a dental laboratory or rapid manufacturing facility, for fabrication services provided. In one common practice, the insurer makes a single payment to the treating dentist who may in turn contract desired vendors for fabrication services. However, the insurer may render payments separately to one or more parties involved including a dentist, a dental patient, a dental laboratory, a rapid manufacturing facility, and so on.

[00178] In one aspect, dental laboratory procedures may be improved by fabricating a kit of components for use by a dental laboratory in subsequent fabrication of a final restoration, prosthesis, or the like. For example, a kit may include one or more of a die, a quad model, an opposing quad model, a full arch

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model, an opposing arch model, a base, a pre-articulated base, a waxup, and so forth. More generally, the kit may include one or more pre-cut components, pre-indexed components, and pre-articulated components for assembly into a dental model, such as a model adapted for use with an articulator. The kit may also, or instead, include various interim components of dental manufacture, such as required or commonly used components for particular procedures, e.g., the PFM crown kit, the bridge kit, and so on. All or some of these components may be automatically fabricated as a kit by a production facility specializing in high-throughput such as the rapid manufacturing facility described above, and the kit may be forwarded to a dental laboratory specializing in creation of final restorations and the like. This approach leverages the relative expertise of these two participants in a digital dentistry network, and may achieve significant decreases in cost and time to a final restoration or other dental object. Alternatively, a dentist may determine and directly fabricated any required kit components using, for example, an in-house three-dimensional printer. In one aspect, a group of different kits may be established for different dental work, so that a dental prescription automatically triggers fabrication of the corresponding kit.

[00179] Fig. 3 shows a user interface that may be used in a digital dental system. The user interface may be presented, for example, as a Web page viewed using a Web browser, or as an application executing on one of the clients 202 described above, or as a remotely hosted application, or as a combination of these.

[00180] The interface 300 may include navigation features such as a home control 302, a name directory control 304, a toolbox control 306, and a security control 308. Each of these features may direct the interface 300 to a different functional area. For example, the home control 302 may access a top level menu that provides access to, for example, system login, data source selection, hardware/software configuration, administrative tools, and so forth. The name directory control 304 may access a directory of patients, physicians, dental laboratories, rapid manufacturing facilities and like, and permit searching, data input, and so forth. The directory may, for example, provide access to patient dental records and history, contact information, and the like. The toolbox control 306 may provide access to tools for scanning, case planning and management, scheduling, and the like. The security control 308 may provide access to account management, communications configuration, and other security-oriented features and functions of a digital dentistry system.

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[00181] Within each main area of top-level navigation, the interface 300 may provide a number of tabs, such as the scanning tab 310, the prescription tab 312, and the status tab 314 depicted in Fig. 3. The scanning tab 310 may, for example, invoke an interface for controlling operation of an image capture system 100 such as that described above in reference to Fig. 1. The prescription tab 312 may, for example, invoke an interface that permits specification of a restoration or other dental object, including a specification of teeth being treated, treatment type, manufacturer, and details of the dental object including color, material, texture, and so forth. The interface of the prescription tab 312 may also include tools for transmitting a prescription, along with any three-dimensional data obtained from scans of a patient, to a dental laboratory, dental data center, rapid manufacturing facility, or the like. The status tab 314 may, for example, invoke an interface for obtaining or updating status information on a case such as the fabrication status of a prescription (e.g., prescription and scan received, scan evaluated and approved, models complete, object fabricated, object shipped to dentist, and so forth).

[00182] Fig. 3 depicts in more detail a prescription window of the interface 300, as accessed by selecting the prescription tab 312. This window may show current data for a prescription within a text window 320. A scroll bar 322 or other control may be provided for selecting options relating to a prescription. In operation, and by way of example only, a feature of the prescription, such as the material or manufacturer, may be highlighted within the text window 320, and options for that feature may selected from the scroll bar 322. The window may also include additional navigational or process controls such as a next button 324, a back button 326, and a finish button 328, which may be used to navigate through one or more different windows of a prescription and/or case planning interface. This may include, for example, input of patient data, selection of a dental laboratory, scheduling of dental visits, and the like. It will be understood that the above interface 300 is an example only and that other hierarchical arrangements of functions, and/or arrangements of data and controls within a particular interface, are possible and may be employed with a digital dental system as described herein. For example, the interface may control scanning, marking or annotation of scanned models, case planning, access to databases of patient records and dental data, preparation of prescriptions, analysis of dentition, scheduling, management of patient data, communications with remote fabrication facilities, and so forth. Any user interface or

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combination of user interfaces and user interface technologies suitable for a digital dental system as described herein may be employed without departing from the scope of this disclosure. As such, a user interface 300 should be understood more generally with reference to the systems and methods described herein, and not by specific reference to the example interface shown in Fig. 3.

[00183] Having described a number of aspects of a digital dentistry system and network, along with various participants in such a network, specific uses of the system will now be discussed in greater detail.

[00184] Fig. 4 depicts a quality control procedure for use in a digital dental system. The process 400 may start 402 by obtaining a digital model, such as a three-dimensional representation of dental subject matter as described generally above.

[00185] The digital model may include a single model, such as a digital model of dentition prior to any dental work, such as for archival or comparison purposes. This may also, or instead, be a digital model of dentition including one or more prepared surfaces, such as a single tooth surface prepared for a crown, or a number of tooth surfaces prepared for a multi-unit bridge. This may also include a scan of bite registration. For example, a scan may be obtained of the teeth of a dental patient in centric relation, centric occlusion, or with maximum intercuspation, in protrusion (e.g., for sleep apnea guards), in lateral excursions, or in any other static orientation useful for any of the dental procedures described herein. As a significant advantage, the upper and lower arches may be treated as rigid bodies, thus permitting relative three-dimensional orientation for a full bite registration to be obtained from a scan of a relatively small region of the upper and lower arches while in occlusion, such as centric occlusion. Thus for example, a three-dimensional scan that spans the two arches, such as a scan of the exterior surfaces of one or two teeth in a buccal or labial area, may be used to register bite. In addition, the digital model may include motion information describing the relative motion of, e.g., an upper and lower jaw throughout one or more jaw motions such as opening and closing the mouth or simulated chewing. Such motion data may, for example, be obtained through a variety of techniques suitable for tracking three-dimensional motion, which may include extrapolation from video data, use of transmitters on the moving jaws, mechanical or electromechanical sensors and/or transmitters, and so forth. Motion data may also be inferred by capturing orientation data for the jaws in a variety of positions. Motion data may be employed, for example, to derive the position of TMJ

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condyle paths of rotation and translation, or to provide input to a virtual or conventional dental articulator.

[00186] In addition, dynamic three-dimensional data may be obtained and used. As noted elsewhere herein, some systems permit direct three-dimensional video capture. However, other techniques may be employed to capture dynamic data. For example, in one example process, two opposing arches may be brought into natural occlusion. The dental patient may then slide the arches forward and back and from side to side, during which the scanner may capture relative motion of the two rigid bodies defined by the two opposing arches. The captured data may be used to characterize and animate a three-dimensional transformation that captures the full excursion of the dentition. This data may, in turn, be registered to detailed scans of the opposing arches. As a further use of this type of data, the excursion data may be used in combination with detailed arch data to provide a cutting tool or path for occlusal surfaces of a restoration. Thus, occlusal surfaces may be measured or otherwise determined during a scan, and applied to define surfaces of a restoration. Using various CAD modeling tools, the restoration may be further refined, such as by shaping side walls of the restoration, adding visually appealing and/or functional cusps to the occlusal surfaces, and so forth. Thus in one aspect there is disclosed herein a method for determining one or more occlusal surfaces of a dental restoration using dynamic three-dimensional data acquired during a scan. The method may include obtaining a three dimensional model of two opposing arches of a patient's dentition, obtaining excursion data for the two opposing arches, preparing a tooth surface of the dentition for a restoration, and determining an occlusal surface of the restoration using the excursion data and the three-dimensional model.

[00187] More generally, any digital model or other data useful in dental procedures, restorations, and the like as described herein may be obtained in step 404.

[00188] Once a digital model (or models) is obtained in step 404, the process 400 may proceed to one or more quality control steps as depicted in steps 406-410.

[00189] This may include automated quality control, as shown in step 406, which may be simple quantitative analysis such as measures of accuracy, variability, or density of three-dimensional surface data for a digital model. This may also, or instead, include more sophisticated, automated analyses such as adequacy and/or suitability of margins and prepared surfaces for an anticipated restoration. For example, an automated quality control tool may examine a prepared tooth surface to

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ensure that a margin line is present all the way around a preparation, or examine the prepared surface to ensure that adequate material has been removed to accommodate a restoration. Similarly, an automated process may locate areas of potential problems, such as occlusal high spots, occlusal clearance, occlusal irregularities, areas of poor margin preparation, areas of inadequate tooth removal, improper taper, improper draw path or removal path for a multiple unit preparation, inappropriate contour, and so forth.

[00190] In one aspect, quality control may include real time feedback during a scan, or between successive scans. The feedback may be rendered with suitable visualizations on a display to permit immediate observation and correction by a dentist. Thus it will be appreciate that, while depicted in Fig. 4 as a post-scanning operation, quality control may be implemented at any time in a digital dentistry process, or throughout the entire process. Real time feedback may include for example, textual annotations identifying teeth as they are recognized within a scan, and providing one or more dimensions of a tooth, or an analysis of contour, clearance relative to adjacent teeth, or a position of the tooth relative to other teeth or relative to a global coordinate system. By providing this information in real time within the context of a single dental visit, treatment may be generally improved by reducing or eliminating a need for follow up scans.

[00191] In another aspect, quality control may include an evaluation of suitability of a surface preparation, or a restoration or other dental object prepare for the restoration, for manufacturing using one or more techniques, including three-dimensional printing, milling, stereo lithography, and or conventional dental fabrication, or various combinations of these.

[00192] Although not depicted in Fig. 4, it will be appreciated that quality control may be semi-automated. Thus, for example, a user interface may provide a number interactive, three-dimensional tools such as markup tools that a dentist or other dental professional may use to measure, mark, annotate, or otherwise manipulate a digital model to evaluate suitability for subsequent processing and the creation of a physical dental object such as a restoration.

[00193] As shown in step 408, quality control may include manual quality control. For example, a dentist may inspect a scan in an interactive, three-dimensional environment to visually identify, e.g., holes or areas of incomplete scan needed for an intended dental procedure. The dentist may employ various features,

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such as rotation, zooming, and panning to inspect various surfaces of the three-dimensional digital representation from a scan.

[00194] As shown in step 410, quality control may include remote quality control. For example, after completing a scan, a dental office may transmit a digital model to a dental laboratory or a fabrication facility for evaluation of adequacy of the scan. As a significant advantage, the recipient, such as a dental laboratory may provide immediate feedback to a dentist while a dental patient is still in the dental office, or still in a dentist's chair at a dental office, thus avoiding a need to schedule repeat visits for additional surface scanning or surface preparation. A dental laboratory may inspect a prepared surface to ensure that a restoration can be fit to the prepared surface, or that there is adequate space (especially thickness) for a restoration or other dental object. The dental laboratory may also evaluate color and suggest shade matching for a dentist. The dental laboratory may request manual marking of a margin by a dentist where the margin is not visible on a prepared tooth surface. The dental laboratory may also apply separate standards for data quality (density, accuracy, surface continuity, feature detail, etc.), and may request additional or new scan data consistent with its own specifications. The dental office may transmit a case plan prior to (or during) transmission of a scan, which may permit more detailed analysis of the scan data by the recipient. Thus, for example, a dental laboratory may evaluate suitability of the scan and/or surface preparation for a type of restoration and any prescribed components (e.g., full ceramic, porcelain-fused-to-metal, etc.). Where the dental laboratory can quickly generate an accurate or rough model for a restoration or other dental object according to any fabrication or end use constraints, the rough model may, in digital form, be virtually fit to the prepared surface, and feedback may be provided to a dentist such as an identification of regions requiring further reduction.

[00195] Quality control, whether automated or manual, and whether local or remote, may include a variety of different dental evaluations. For example, a prepared tooth in an arch that will receive a restoration may be evaluated to determine whether there is adequate space for cement to bond the restoration to the prepared tooth surface. As another example, a dentist may visually confirm accuracy of a scan by inspection for gross errors or omissions such as holes, gaps, distortions, twists, and the like. The dentist may also visually inspect margin lines on surface preparations, and may annotate margins for identification by a dental laboratory or other fabrication

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facility. Similarly, a dental laboratory may, during a quality control evaluation, request that the dentist identify the margins on a surface preparation where the margin lines are not self-evident.

[00196] Feedback from a quality control step, whether automated or manual, and whether remote or local, may include various forms of feedback. For example, an evaluation may conclude with an identification of regions of a prepared tooth surface requiring additional preparation or reduction, or regions of a digital model requiring additional or supplemental scanning due to incomplete, erroneous, or potentially erroneous data, which may be identified, for example, by comparison to models of expected shape for dentition, surface preparations, and the like. An evaluation from a dental laboratory may request new data, or additional shaping of a prepared surface. An evaluation from a dental laboratory may include a request for an oral consultation. In addition other dental professionals such as a consulting dentist, an oral surgeon, a dental specialist, or a laboratory technician may be called upon for evaluation, approval, and/or recommendations. Feedback may be presented to a dentist in a number of forms. For example, the feedback may include text or audible narrative concerning additional scanning, additional surface preparation, or requests for confirmation. The feedback may be graphical feedback provided by highlighting questionable or erroneous areas of a preparation within a rendered display of scan data. The feedback may identify corrective action on a scan or a surface preparation. The feedback may identify a margin line which may be displayed on a two-dimensional rendering of a three-dimensional representation, and a user interface may permit the margin line to be edited or confirmed. The feedback may include a visual display with regions of inadequate margin highlighted, such as through use of color, texture, or explicit annotations, arrows, callouts, or the like, and any combination of these.

[00197] It will be understood that the quality control steps indicated in Fig. 4 are not mutually exclusive. That is each of the quality control steps 406-410 may be performed during the process 400, such as in sequence or in parallel (as where a dentist and a laboratory evaluate a scan simultaneously), and all such variations are intended to fall within the scope of this disclosure.

[00198] Any of the quality control steps above may advantageously be performed while a dental patient is still present at a dental office, or while the patient

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is still in a dental chair, thus reducing or eliminating the need for follow up dental visits for additional scanning.

[00199] After one or more quality control steps 406-410, a determination may be made as to whether a scan and/or surface preparations are satisfactory. If the data is not satisfactory, the process 400 may proceed to step 414 where the digital model may be supplemented or replaced with new scan data. This may include, for example, new scanning to replace apparently erroneous or inadequate scan data, or a new scan of the dental subject matter following, e.g., additional surface preparation consistent with errors identified during quality control. The process 400 may then return to step 404 where a new digital model is obtained.

[00200] If it is determined in step 412 that the data is satisfactory, the process 400 may proceed to step 416 where a dentist may prepare a prescription. The prescription may include, for example, a dental patient identification, an identification of one or more teeth being treated, a type of treatment (e.g., for a restoration, one or more of a bridge, a crown, an inlay, a laminate veneer, an onlay, or a temporary), an identification of missing teeth (if appropriate), a material or fabrication technology (e.g., full ceramic, cast metal, PFM, etc.), an alloy type (e.g., for a PFM crown), a manufacturer (e.g., Cercon, Cerec, Empress, Everest, Lava, Procera, etc.), limited occlusal clearance (e.g., enamalplasty, reduction coping, etc.), a shade guide (e.g., Vita 3D Master, Vita Classical, etc.), a surface texture, a surface glaze, an opacity, an occlusal staining, dental notes, and any other information relevant to identification or preparation of the dental object. For example, for a crown the specification may include a material type, a design (such as metal band, 360-degree facial butt porcelain shoulder, facial butt porcelain shoulder, metal occlusal surface, or no metal showing), a return (e.g., biscuit bake, finish, metal try-in, etc.). Each specification may include subspecifications. For example, a metal band crown may be specified as having the metal band located at a buccal location, a lingual location, or 360-degree.

[00201] As shown in step 418, once the prescription has been completed, the digital model and prescription may be uploaded to a dental laboratory or other fabrication facility using, for example, the dental network described above. The process 400 may then end, as shown in step 420.

[00202] It will be understood that numerous variations and modifications to the above process 400 may be used. For example, the prescription may be prepared at a different point in the process, such as before scanning so that the prescription data

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may be used to evaluate sufficiency of the scan data. As another example, each digital model (e.g., native tooth surfaces, bit registration, prepared tooth surfaces) may be separately presented to one or more quality control steps, or the entire digital model may be obtained prior to any quality control analysis. All such variations and modifications are intended to fall within the scope of the methods and systems described herein.

[00203] Fig. 5 shows a dental laboratory procedure using a digital dental model. While described as a dental laboratory procedure, it will be understood that the fabrication and quality control procedures described with reference to Fig. 5 may be performed by any fabrication facility including a dental fabrication facility such as a dental laboratory equipped to receive digital dental data, a model production laboratory (such as a rapid fabrication facility, milling facility, and the like), an in-office dental laboratory at a dental office, or any other dental fabrication facility. The fabrication facility may include a remote facility accessible through the dental network, and digital dental data may be communicated to the fabrication facility directly or through a hub for dental data such as the dental data center described above.

[00204] As shown in step 504, the process 500 may start 502 by receiving a digital model from a dentist or other source. This may include, for example, a digital model, such as a digital surface representation obtained using the image capture system 100 described above, of a surface prepared for a restoration such as a crown, or any other dental object.

[00205] As shown in step 506, the dental laboratory may design and/or fabricate a restoration or other dental object based upon the digital model received in step 504. This may include a variety of fabrication techniques, including working from a physical cast of a dental impression created using conventional dentistry techniques, or three-dimensional printing or other fabrication techniques to manufacture various interim components of dental manufacture such as dies, casts, and the like, or direct fabrication of a virtually designed restoration, such as through computerized milling of the restoration from ceramic.

[00206] In one aspect, designing the restoration may include a step of virtually adding a die spacer to a digital model. It is known in dentistry to employ a die spacer – a thin layer painted onto regions of dental models – to improve the final fit between a prepared tooth surface in a dental patient's mouth and a restoration or

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other dental object. The die spacer may for example provide a small void between a cast of the prepared surface and a restoration constructed for the cast which may provide a void for cement used with the final fitting, or to account for size changes in the restoration fabrication process. The die spacer may be virtually added to a digital model of a prepared surface to achieve a similar effect with a restoration that is to be directly fabricated from the digital model, or an interim component such as a fabricated cast of a dental impression used to create the restoration. Similarly, where a cast dental model is to be fabricated from a digital model, the die spacer may be added to appropriate regions of the prepared surface and any other suitable surfaces to remove or reduce the need for use of die spacers in subsequent fabrication steps. More generally, a virtual die spacer may be added to a digital model of a conventional dental model, a die, a waxup, or any other interim component of dental manufacture to account for a cementation void or other physical variations in the design of a final restoration. This cementation void or virtual die spacer may be fabricated directly into a die, waxup, or other interim component that may be three-dimensionally printed or otherwise manufactured from the digital model.

[00207] Thus in one aspect, disclosed herein is a virtual die spacer. In fabricating a dental restoration, a virtual dies spacer or cementation void may be specified, either by an originating dental office or a dental laboratory, and this void may be automatically or manually added to appropriate regions of a digital model to provide a corresponding cementation void in a final restoration. As a significant advantage, the thickness of the virtual die spacer may be explicitly specified, and may be adjusted according to, for example, a dentist's preference or according to a type of cement to be used with the restoration. Dentist preferences concerning die spacer thickness may also be stored for reuse, and dentist feedback (e.g., "too tight" or "inadequate void") may be recorded to provide sizing for a final restoration or other dental object that more closely meets and individual dentist's expectations.

[00208] In another aspect, designing the restoration may include virtually ditching a die for a restoration. In conventional dentistry, a material may be cut away from a die below the margin line (which would otherwise include bone, soft tissue, and the like) prior to use as a restoration model. This operation may be performed virtually within a user interface that includes interactive tools for manipulating a three-dimensional representation of dentition. Initially, this may include an automated, semi-automated, or manual step of defining a die in three-dimensional

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space by identifying a plane, a point, or a line used to separate a die from a model in an operation analogous to physically cutting a die from a conventional dental model. This may be followed by additional steps such as separate steps of explicitly identifying a margin line with a first tool and then manipulating the digital model "below" the margin line, i.e., away from the tooth surface fitted to a restoration, with a second tool to remove unwanted or unneeded areas from a volume bounded by the digital surface representation. This process may be semi-automated or automated, such as by automatic identification of the margin line and removal of a predetermined amount of sub-margin volume. The ditched die may then be directly fabricated using techniques described above.

[00209] Regardless of the interim modeling and fabrication steps, this step may result in a restoration in physical form, such as a crown, bridge, inlay, onlay, or other dental object intended for use by a dental patient.

[00210] As shown in step 508, the restoration may be scanned using, for example, an image capture system 100 such as the system described above with reference to Fig. 1, to obtain a scanned restoration.

[00211] As shown in step 510, the scanned restoration may be test fit to the digital model received in step 504, such as by virtually superimposing the scanned restoration to the digital model. This may permit evaluation of a variety of fit criteria prior to an attempt to fit the physical restoration to a prepared surface in the dental patient's mouth. This includes, for example, an evaluation of margin fit, an evaluation of void space for cement used to affix the restoration to the prepared surface, and any other evaluation relating the prepared surface directly to the restoration or abutting tooth surfaces. This may also include an evaluation of bite, occlusions, lateral excursions and any other evaluation relating to jaw motion or the mating of lower and upper arches with the restoration in place.

[00212] In another aspect, test fitting may include measuring dimensional accuracy of the scanned restoration. For example, the restoration in this context may include a prosthesis, an implant, an appliance, a restorative component, an abutment, a fixture, or any other dental object. The scanned restoration may be measured for fit between adjacent teeth, or for evaluation of contact points with teeth of an opposing arch when the restoration is fitted to a prepared surface (or more specifically, when the scanned restoration is virtually fitted to a scan of the prepared surface), or a fit to the prepared surface, possibly including an allowance for die spacing on one or more

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surfaces. A dentist may specify a desired tightness of fit, which may be quantified objectively (e.g., in millimeters or microns) or subjectively (e.g., loose, average, tight, etc.).

[00213] In one aspect, feedback from specific dentists may be monitored, so that subsequent restorations may more closely meet each dentist's expectations for a desired tightness of fit.

[00214] In another aspect, measuring dimensional accuracy may include evaluating a quality of margin fit between a scanned restoration and a scanned surface preparation, in order to avoid fitting difficulties at the time of fitting the physical restoration to a patient's dentition.

[00215] As shown in step 512, the test fit of step 510 may be followed by a determination of whether the physical restoration is satisfactory. If the physical restoration is not satisfactory, the process 500 may proceed to step 514 where the physical restoration is reworked, or a new restoration prepared. If the physical restoration is satisfactory, the physical model may be sent to a dental office for a final fitting procedure in the dental patient's mouth. It may also be advantageous to also forward the scan of the restoration to the originating dental office in order to begin preparation for the final fitting procedure. The process 500 may then end 518.

[00216] It will be understood that numerous variations and modifications to the above process 500 may be used. For example, although not depicted in Fig. 5, in certain instances where it appears that a physical restoration cannot be properly fabricated to fit the restoration site, e.g., the prepare surface and surrounding dentition, the dental laboratory may contact the originating dental office to request additional preparation of the target surface. All such variations and modifications are intended to fall within the scope of the methods and systems described herein.

[00217] It will further be appreciated that, even in a system where the digital surface representation is used directly to fabricate a cast dental model to which subsequent, conventional dental laboratory techniques are applied, significant advantages may be realized through elimination or mitigation of physical handling and shipping of a dental impression. Thus in one aspect, there is disclosed herein a technique for acquiring a digital model, such as a digital surface representation, of a prepared surface and/or surrounding dentition, and transmitting the digital model to a dental laboratory or rapid manufacturing facility for preparation of a restoration or other dental object.

[00218] Fig. 6 illustrates a scan path that may be used with a three-dimensional image capture system. In a system that operates to continuously acquire three-dimensional data in real time, and fits or registers incremental three-dimensional data to an aggregate three-dimensional model, it may be advantageous to scan in a manner that increases registration to the aggregate model. Thus, for example, a scan path that runs adjacent to edges of the aggregate model may provide additional registration or fit information and improve overall accuracy, particularly over large surfaces. With respect to scans of human dentition, this general approach suggests an s-shaped scan that traces from interior to exterior (or exterior to interior) surfaces of one tooth, and then reverses direction to trace an exterior-to-interior path immediately adjacent to the initial path, which may reduce overall spatial error between extremities of the arch. Without loss of generality, a more detailed example of this approach is set out below.

[00219] A scan path 600 for obtaining three-dimensional data from a dental arch 602 using a scanner such as the scanner 102 described above with reference to Fig. 1 may begin at a first lingual point 604. The scan path may then traverse laterally over an occlusal point 606 or surface of a molar to a first buccal point 608, translate to a second buccal point 610 by moving forward along the gum line, and then traverse laterally over a second occlusal point to a second lingual point. The scan path may then translate forward once again to a third lingual point, traverse laterally over a third occlusal point to a third buccal point, and once again translate forward. By scanning in this s-shaped manner, each successive pass over occlusal surfaces may be fit to data from an adjacent pass over the occlusal surfaces, as well as to one or more immediately prior frames of data. While the remainder of a scan path is not illustrated in Fig. 6, it will be understood that the scan may continue along the entire arch in this manner, finally reaching a molar 612 at the opposite extremity of the arch.

[00220] It will be understood that the spacing of adjacent passes may be greater or less than illustrated. For example, a buccal-to-lingual pass may cover a portion of a tooth, an entire tooth, or a number of teeth depending upon, for example, the field of view for data acquisition with the scanner. It will also be understood that the starting and ending points of the generally s-shaped scan are somewhat arbitrary. A scan may begin, for example at a lingual point, at an occlusal point, or at a buccal point. Further, the scan may begin at a molar, or the scan may begin at an incisor, with two consecutive scans performed from this central location to each molar

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extremity of the arch. All such variations are intended to fall within the scope of the scan path described herein. In general, regardless of the starting point, a generally s-shaped scan may move along adjacent buccal-to-lingual passes in the manner described above. In one aspect, real-time feedback may be provided to a user by displaying on a display a next appropriate direction of motion for a scan that follows the generally s-shaped path.

[00221] Figs. 7A and 7B show a modeling environment for creating alignment guides for orthodontic hardware. A three-dimensional representation 702 of dentition and surrounding soft tissue may be acquired from a dental patient as described generally above, and rendered within a user interface 704 on a computer such as the image capture system 100 described above, or more generally, the client 202 described above. In various embodiments, orthodontic hardware may be virtually placed on the three-dimensional representation 702, which may be used to determine appropriate positions for one or more alignment guides, or brackets may themselves be virtually positioned on the three-dimensional representation 702 with corresponding alignment guides being generated by computer, or the alignment guides may be directly positioned on the three-dimensional representation 702. The user interface may include interactive tools for virtually positioning orthodontic hardware and/or brackets for orthodontic hardware and/or alignment guides onto the three-dimensional representation 702 within the user interface 704. The design of orthodontic hardware and any corresponding positioning of brackets or the like, may be performed by a dentist at a dental office and transmitted to a dental laboratory or other fabrication facility, or the unmodified three-dimensional representation may be transmitted to the dental laboratory along with a prescription for orthodontic hardware.

[00222] Fig. 7A shows a three-dimensional representation 702 with visual markings 706 that serve as alignment guides. This marked three-dimensional representation 702, or digital dental model, may serve as a basis for subsequent fabrication of custom orthodontic hardware. The markings 706 may be fabricated directly into a physical realization of the digital dental model, such as using pigmented printing techniques, or the markings 706 may be added to the physical realization after fabrication using additional computerized or manual marking techniques.

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[00223] Fig. 7B shows a three-dimensional representation 702 with supports 708 that serve as a physical alignment guide. This three-dimensional representation 702, or digital dental model, may serve as a basis for subsequent fabrication of custom orthodontic hardware. As depicted, each support 708 may include a horizontal top surface or shelf for supporting an orthodontic fixture or other hardware. However, it will be understood that any physical form capable of supporting or engaging the intended hardware may suitable by employed, and fabricated into a physical model. The supports 708 may be fabricated directly into a physical realization of the digital dental model using techniques such as three-dimensional printing, stereo lithography, or computerized milling.

[00224] The alignment guides may serve to guide positioning of an orthodontic fixture onto the physical realization of the digital dental model to assist in fabricating custom orthodontic hardware. In an additional processing step, once the corresponding orthodontic hardware, such as brackets, is positioned onto the physical model, the position of a number of brackets may be captured in a physical template such as a foam, a vacuum-formed appliance, or the like, for direct transfer to an arch within a dental patient's mouth. The appliance may, for example, be formed of a soft, clear material for easy handling by a dentist and/or greater comfort for a dental patient. In such a process, a treating dentist may perform an additional scan of the patient's dentition immediately prior to affixing the brackets to ensure that the natural dentition still corresponds closely to the model used for virtual bracket positioning.

[00225] In another embodiment, additional modeling may be employed to create a virtual bracket carrier model – a device to carry brackets in a specific relative orientation – that can be physically realized as a bracket positioning appliance through direct fabrication using any of the techniques described above. The bracket carrier model may include one or more alignment guides for brackets such as those described generally above. Brackets may then be attached to the bracket positioning appliance for transfer to an arch within a dental patient's mouth. The treating dentist may perform an additional scan of the patient's dentition immediately prior to affixing the brackets to ensure that the natural dentition still corresponds closely to the model used to create the bracket positioning appliance.

[00226] It will be appreciated that the processes and methods disclosed herein may be realized in hardware, software, or any combination of these suitable for the three-dimensional imaging and modeling techniques described herein. This includes

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realization in one or more microprocessors, microcontrollers, embedded microcontrollers, programmable digital signal processors or other programmable device, along with internal and/or external memory. The may also, or instead, include one or more application specific integrated circuits, programmable gate arrays, programmable array logic components, or any other device or devices that may be configured to process electronic signals. It will further be appreciated that a realization may include computer executable code created using a structured programming language such as C, an object oriented programming language such as C++, or any other high-level or low-level programming language (including assembly languages, hardware description languages, and database programming languages and technologies) that may be stored, compiled or interpreted to run on one of the above devices, as well as heterogeneous combinations of processors, processor architectures, or combinations of different hardware and software. At the same time, processing may be distributed across devices such as a camera and/or computer in a number of ways or all of the functionality may be integrated into a dedicated, standalone image capture device. All such permutations and combinations are intended to fall within the scope of the present disclosure.

[00227] It will also be appreciated that means for performing the steps associated with the processes described above may include any suitable components of the image capture system 100 described above with reference to Fig. 1, along with any software and/or hardware suitable for controlling operation of same. The user interfaces described herein may, for example, be rendered within the display 110 of the image capture system 100 of Fig. 1.

[00228] While the invention has been disclosed in connection with certain preferred embodiments, other embodiments will be recognized by those of ordinary skill in the art, and all such variations, modifications, and substitutions are intended to fall within the scope of this disclosure. Thus, the invention is to be understood with reference to the following claims, which are to be interpreted in the broadest sense allowable by law.

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CLAIMS:

What is claimed is:

1. A method comprising:

acquiring a three-dimensional representation of one or more intraoral structures of a dental patient using an intraoral scanner; and

providing the three-dimensional representation to a dental fabrication facility.

2. The method of claim 1, further comprising fabricating a dental restoration at the dental fabrication facility using the three-dimensional representation.

3. The method of claim 1, wherein the dental fabrication facility includes a dental laboratory.

4. The method of claim 1, wherein the one or more intraoral structures include at least one dental implant.

5. The method of claim 1, wherein the one or more intraoral structures include at least one tooth.

6. The method of claim 1, wherein the one or more intraoral structures include at least one tooth surface prepared for a dental restoration.

7. The method of claim 1, wherein the one or more intraoral structures include at least one area of soft tissue.

8. The method of claim 1, wherein the one or more intraoral structures include at least one previously restored tooth.

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9. The method of claim 1, further comprising fabricating a dental prosthesis at the dental fabrication facility using the three-dimensional representation.

10. The method of claim 1, further comprising transmitting the three-dimensional representation to a dental laboratory and, in response, receiving an assessment of quality for the three-dimensional representation from the dental laboratory.

11. The method of claim 10, wherein the assessment of quality is received before the dental patient leaves a dentist's office.

12. The method of claim 10, wherein the assessment of quality includes an assessment of acceptability of the three-dimensional representation.

13. The method of claim 6, further comprising transmitting the three-dimensional representation to a dental laboratory and, in response, receiving an assessment of quality of the at least one prepared tooth surface.

14. The method of claim 1, wherein providing the three-dimensional representation to a dental fabrication facility includes transmitting to a remote dental laboratory for fabrication of a dental restoration for the one or more intraoral structures.

15. The method of claim 14, further comprising transmitting the three-dimensional representation to a dental data hub.

16. The method of claim 14, further comprising transmitting a prescription for the dental restoration with the three-dimensional representation.

17. The method of claim 14, further comprising transmitting the three-dimensional representation to a model production laboratory.

18. The method of claim 17, wherein the model production laboratory is a milling facility.

19. The method of claim 17, wherein the model production laboratory is a manufacturing facility.

20. The method of claim 17, wherein the model production laboratory is a three-dimensional rapid prototyping facility.

21. The method of claim 1, wherein providing the three-dimensional representation to a dental fabrication facility includes providing the three-dimensional representation to an in-office dental laboratory for fabrication of a dental restoration for the one or more intraoral structures.

22. A computer program product comprising computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of:

acquiring one or more images of one or more intraoral structures of a dental patient from an intraoral scanner;

converting the one or more images into a three-dimensional representation of the one or more intraoral structures; and

transmitting the three-dimensional representation to a dental fabrication facility.

23. The computer program product of claim 22, further comprising computer code that performs the step of comparing quality of the three-dimensional representation to predefined quality criteria.

24. The computer program product of claim 23, wherein the predefined quality criteria includes acceptability of the three-dimensional representation for fabrication.

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25. The computer program product of claim 22, further comprising computer code that performs the steps of:

retrieving a prescription for at least one of a prosthesis or an appliance prepared by a dentist; and

combining the prescription with the three-dimensional representation prior to transmitting the three-dimensional representation.

26. The computer program product of claim 22, wherein the one or more intraoral structures include at least one dental implant.

27. The computer program product of claim 22, wherein the one or more intraoral structures include at least one tooth.

28. The computer program product of claim 22, wherein the one or more intraoral structures include at least one tooth surface prepared for a dental restoration.

29. The computer program product of claim 28, further comprising computer code that performs the step of comparing quality of the at least one prepared tooth surface to predefined quality criteria.

30. The computer program product of claim 22, wherein the one or more intraoral structures include at least one area of soft tissue.

31. A system comprising:

an intraoral scanner for acquiring a three-dimensional representation of one or more intraoral structures of a dental patient; and

a transmission means for transmitting the three-dimensional representation to a dental fabrication facility.

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32. The system of claim 31, further comprising a first fabrication means for fabricating a dental restoration at the dental fabrication facility using the three-dimensional representation.

33. The system of claim 31, wherein the one or more intraoral structures include at least one dental implant.

34. The system of claim 31, wherein the one or more intraoral structures include at least one tooth.

35. The system of claim 31, wherein the one or more intraoral structures include at least one tooth surface prepared for a dental restoration.

36. The system of claim 31, wherein the one or more intraoral structures include at least one area of soft tissue.

37. The system of claim 31, further comprising a second fabrication means for fabricating a dental prosthesis at the dental fabrication facility using the three-dimensional representation.

38. The system of claim 31, further comprising a quality assessment means for assessing quality of the three-dimensional representation.

39. The system of claim 38, wherein the quality assessment means includes a means for determining acceptability of the three-dimensional representation for use with the first fabrication means.

40. The system of claim 38, wherein the quality assessment means includes a means for determining acceptability of the three-dimensional representation for use with the second fabrication means.

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41. The system of claim 38, wherein the one or more intraoral structures include at least one tooth surface prepared for a dental restoration, and wherein the quality assessment means includes a means for determining quality of the at least one prepared tooth surface.

42. A method comprising:

receiving a three-dimensional representation of a tooth, the tooth prepared for a dental restoration;

specifying a cementation void between the tooth surface and the dental restoration; and

fabricating the dental restoration such that the dental restoration, when mated to the tooth surface, defines an empty space corresponding to the cementation void.

43. The method of claim 42, further comprising adjusting the cementation void.

44. The method of claim 43, wherein adjusting the cementation void includes adjusting the cementation void according to a dentist's preferences.

45. The method of claim 43, wherein adjusting the cementation void includes:

specifying a type of cement to be used in the cementation void; and

adjusting the cementation void according to the type of cement to be used in the cementation void.

46. The method of claim 42, wherein the cementation void is specified by a dentist.

47. The method of claim 46, wherein the dentist sends the specification of the cementation void to a dental laboratory.

48. The method of claim 47, wherein the cementation void is specified by a dental laboratory.

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49. The method of claim 42, further comprising three-dimensionally printing a die including the cementation void.

50. The method of claim 42, further comprising fabricating a die including the cementation void using a stereo lithography apparatus.

51. The method of claim 42, further comprising three-dimensionally printing a wax-up including the cementation void.

52. The method of claim 42, further comprising milling a die including the cementation void.

53. The method of claim 42, further comprising integrating the cementation void into a digital surface representation of the tooth.

54. The method of claim 42, further comprising integrating the cementation void into a dental model.

55. The method of claim 42, wherein the three-dimensional representation includes a digital surface representation of the tooth.

56. The method of claim 42, wherein fabricating the dental restoration includes fabricating the dental restoration in an in-house laboratory in a dentist's office.

57. The method of claim 42, further comprising fabricating an opposing arch for an arch including the tooth, the opposing arch including a die spacer having a predetermined thickness.

58. A computer program product comprising computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of:

acquiring one or more images of a tooth of a dental patient from an intraoral scanner, the tooth including a tooth surface prepared for a dental restoration;

converting the one or more images into a three-dimensional representation of the tooth;

specifying a cementation void between the tooth surface and the dental restoration;

combining the specification for the cementation void with the three-dimensional representation into a fabrication specification; and

transmitting the fabrication specification to a dental fabrication facility.

59. The computer program product of claim 58, wherein a dentist specifies the cementation void.

60. The computer program product of claim 58, further comprising computer code that performs the step of receiving a specification of the cementation void from the dental fabrication facility.

61. The computer program product of claim 58 further comprising code for three-dimensionally printing the cementation void to a die.

62. The computer program product of claim 58 further comprising code for three-dimensionally printing the cementation void to a wax up.

63. The computer program product of claim 58, further comprising computer code that performs the step of integrating the cementation void into a digital surface representation of the tooth.

64. A system comprising:

a first means for three-dimensionally representing a tooth, the tooth prepared for a dental restoration;

a second means for specifying a cementation void, the cementation void representing an empty space between the tooth surface and the dental restoration; and

a fabrication means for fabricating the dental restoration such that the dental restoration, when mated to the tooth surface, defines an empty space corresponding to the cementation void.

65. The system of claim 64, further comprising an adjustment means for adjusting the cementation void.

66. The system of claim 65, wherein the adjustment means includes means for incorporating a dentist's preferences.

67. The system of claim 65, wherein the adjustment means includes means for adjusting the cementation void according to a type of cement.

68. The system of claim 64, further comprising a first printing means for three-dimensionally printing a die including the cementation void.

69. The system of claim 64, further comprising a second printing means for three-dimensionally printing a wax-up including the cementation void.

70. The system of claim 64, further comprising a milling means for milling a die including the cementation void.

71. The system of claim 64, further comprising a milling means for milling an investment chamber for casting including the cementation void.

72. The system of claim 64, further comprising a model means for integrating the cementation void into a model of a dental impression.

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73. The system of claim 64, wherein the three-dimensional representation of a tooth includes a digital surface representation of the tooth.

74. A method comprising:
fabricating a dental object;
acquiring a first three-dimensional representation of the dental object; and
measuring a dimensional accuracy of the first three-dimensional representation.

75. The method of claim 74, wherein the first three-dimensional representation includes a digital surface representation.

76. The method of claim 74, wherein the dental object includes a dental prosthesis.

77. The method of claim 74, wherein the dental object includes a dental implant.

78. The method of claim 74, wherein the dental object includes a dental appliance.

79. The method of claim 74, wherein the dental object includes a restorative component.

80. The method of claim 74, wherein the dental object includes a dental restoration.

81. The method of claim 74, wherein the dental object includes an abutment.

82. The method of claim 74, further comprising acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy includes evaluating a fit between the item of the first three-dimensional representation and the at least one tooth surface of the second three-dimensional representation.

83. The method of claim 74, further comprising acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy includes evaluating one or more contact points between the item of the first three-dimensional representation and the one or more teeth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface.

84. The method of claim 74, further comprising acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object and at least one opposing tooth, wherein measuring a dimensional accuracy includes evaluating one or more contact points between the item of the first three-dimensional representation and the at least one opposing tooth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface.

85. The method of claim 74 wherein the second three-dimensional representation is acquired as a plurality of separate scans.

86. The method of claim 74 wherein the second three-dimensional representation is acquired as a continuous scan of the at least one tooth surface and the at least one opposing tooth in occlusion.

87. The method of claim 74, wherein a dentist specifies tightness of fit of the dental object.

88. The method of claim 74, wherein measuring a dimensional accuracy includes quantifying tightness of fit of the dental object.

89. The method of claim 74, wherein measuring a dimensional accuracy includes measuring quality of a margin.

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90. A computer program product comprising computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of:

acquiring one or more images of a dental object;

converting the one or more images of the dental object into a first three-dimensional representation of the item; and

measuring a dimensional accuracy of the first three-dimensional representation.

91. The computer program product of claim 90, wherein the first three-dimensional representation includes a digital surface representation.

92. The computer program product of claim 90, wherein the dental object includes a dental prosthesis.

93. The computer program product of claim 90, wherein the dental object includes a dental implant.

94. The computer program product of claim 90, wherein the dental object includes a dental appliance.

95. The computer program product of claim 90, wherein the dental object includes a restorative component.

96. The computer program product of claim 90, wherein the dental object includes an abutment.

97. The computer program product of claim 90, wherein the dental object includes a restoration.

98. The computer program product of claim 90, further comprising computer code that performs the steps of:

acquiring one or more images of one or more teeth including at least one tooth surface prepared for the dental object; and

converting the one or more images of the one or more teeth into a second three-dimensional representation of the one or more teeth, wherein measuring a dimensional accuracy includes evaluating a fit between the item of the first three-dimensional representation and the at least one tooth surface of the second three-dimensional representation.

99. The computer program product of claim 90, further comprising computer code that performs the steps of:

acquiring one or more images of one or more teeth including at least one tooth surface prepared for the dental object;

converting the one or more images of the one or more teeth into a second three-dimensional representation of the one or more teeth; and

generating one or more contact points between the item of the first three-dimensional representation and the one or more teeth of the second three-dimensional representation by virtually affixing the item to the at least one tooth surface, wherein measuring includes evaluating one or more contact points.

100. The computer program product of claim 90, further comprising computer code that performs the steps of:

acquiring one or more images of one or more teeth including at least one tooth surface prepared for the dental object and at least one opposing tooth;

converting the one or more images of the one or more teeth and the at least one opposing tooth into a second three-dimensional representation of the one or more teeth and the at least one opposing tooth; and

generating one or more contact points between the item of the first three-dimensional representation and the at least one opposing tooth of the second three-dimensional representation by virtually affixing the item to the at least one tooth surface, wherein measuring includes evaluating one or more contact points.

101. The computer program product of claim 90, wherein measuring a dimensional accuracy includes quantifying tightness of fit of the dental object.

102. The computer program product of claim 90, wherein measuring a dimensional accuracy includes measuring quality of a margin.

103. A system comprising:

a fabrication means for fabricating a dental object;

a first means for acquiring a first three-dimensional representation of the item; and

a measurement means for measuring a dimensional accuracy of the first three-dimensional representation.

104. The system of claim 103, wherein the first three-dimensional representation includes a digital surface representation.

105. The system of claim 103, wherein the dental object includes a dental prosthesis.

106. The system of claim 103, wherein the dental object includes a dental implant.

107. The system of claim 103, wherein the dental object includes a dental appliance.

108. The system of claim 103, wherein the dental object includes a restorative component.

109. The system of claim 103, wherein the dental object includes a dental restoration.

110. The system of claim 103, wherein the dental object includes an abutment.

111. The system of claim 103, further comprising a second means for acquiring a second three-dimensional representation of one or more teeth including at least one tooth

surface prepared for the dental object, wherein measuring a dimensional accuracy includes evaluating a fit between the item of the first three-dimensional representation and the at least one tooth surface of the second three-dimensional representation.

112. The system of claim 103, further comprising a second means for acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object, wherein measuring a dimensional accuracy includes evaluating one or more contact points between the item of the first three-dimensional representation and the one or more teeth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface.

113. The system of claim 103, further comprising a second means for acquiring a second three-dimensional representation of one or more teeth including at least one tooth surface prepared for the dental object and at least one opposing tooth, wherein measuring a dimensional accuracy includes evaluating one or more contact points between the item of the first three-dimensional representation and the at least one opposing tooth of the second three-dimensional representation when the item is virtually affixed to the at least one tooth surface.

114. The system of claim 103, wherein a dentist specifies tightness of fit of the dental object.

115. The system of claim 103, wherein measuring a dimensional accuracy includes quantifying tightness of fit of the dental object.

116. The system of claim 103, wherein measuring a dimensional accuracy includes measuring quality of a margin.

117. A method comprising:

acquiring a three-dimensional representation including three-dimensional surface data for at least two independent dental structures; and

acquiring motion data characterizing a relative motion of the at least two independent dental structures with respect to one another within a mouth.

118. The method of claim 117, further comprising deriving TMJ condyle paths of rotation and translation from the motion data and the three-dimensional surface data.

119. The method of claim 117, further comprising providing input to a virtual dental articulator.

120. The method of claim 117, further comprising providing specifications for a physical dental articulator.

121. The method of claim 117, further comprising providing specifications for a disposable dental articulator.

122. The method of claim 117, wherein acquiring the three-dimensional representation includes acquiring the three-dimensional representation using an intraoral scanner.

123. The method of claim 117, wherein acquiring motion data includes acquiring motion data from a video source.

124. A computer program product comprising computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of:

acquiring one or more images of at least two independent dental structures of a dental patient from an intraoral scanner;

converting the one or more images into a three-dimensional representation of the at least two independent dental structures; and

acquiring motion data characterizing a relative motion of the at least two independent dental structures with respect to one another.

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125. The computer program product of claim 124 further comprising code that performs the step of combining the three-dimensional representation with the motion data to derive TMJ condyle paths of rotation and translation.

126. The computer program product of claim 124, further comprising computer code that performs the steps of:

generating an image sequence of the combined three-dimensional representation and the motion data; and

generating a display signal of the image sequence.

127. The computer program product of claim 124, wherein acquiring motion data includes acquiring motion data from a video source.

128. A system comprising:

a first means for acquiring one or more images of at least two independent dental structures of a dental patient;

a conversion means for converting the one or more images into a three-dimensional representation of the at least two independent dental structures; and

a second means for acquiring motion data characterizing a relative motion of the at least two independent dental structures with respect to one another.

129. The system of claim 128, further comprising an analysis means for deriving TMJ condyle paths of rotation and translation using the three-dimensional representation and the motion data.

130. The system of claim 128, further comprising an action means for combining the three-dimensional representation and the motion data to generate an articulation input.

131. The system of claim 130, further comprising a first model means for virtually articulating the articulation input.

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132. The system of claim 130, further comprising a second model means for physically articulating the articulation input.

133. The system of claim 130, further comprising a disposable model means for physically articulating the articulation input.

134. The system of claim 128, wherein the first means includes a means for acquiring the one or more images using an intraoral scanner.

135. The system of claim 128, wherein the second means includes a means for acquiring the motion data from a video source.

136. A method comprising:

receiving an electronic dental prescription including prescription data, a first three-dimensional representation of one or more intraoral structures including at least one tooth surface prepared for an artificial dental object, and a second three-dimensional representation of the at least one tooth surface prior to preparation for the artificial dental object; and

fabricating the artificial dental object for the one or more intraoral structures using the electronic dental prescription.

137. The method of claim 136, wherein an electronic dental prescription includes receiving a three-dimensional representation from a dental data hub.

138. The method of claim 136, wherein an electronic dental prescription includes receiving a three-dimensional representation from a dentist.

139. The method of claim 136, wherein the electronic dental prescription includes a prescription for a dental restoration for the tooth surface.

140. The method of claim 136, wherein at least one of the first and second three-dimensional representations includes a digital surface representation of a full arch.

141. The method of claim 136, wherein the electronic dental prescription includes a prescription for one or more of an appliance, a prosthesis, or an item of dental hardware.

142. The method of claim 136, wherein fabricating an artificial dental object includes fabricating a dental restoration in an in-house laboratory in a dentist's office.

143. A system comprising:

a communication means for receiving an electronic dental prescription including prescription data, a first three-dimensional representation of one or more intraoral structures including at least one tooth surface prepared for an artificial dental object, and a second three-dimensional representation of the at least one tooth surface prior to preparation for the artificial dental object; and

a fabrication means for fabricating an artificial dental object for the one or more intraoral structures using the three-dimensional representation.

144. The system of claim 143, wherein the communication means includes a means for receiving the electronic dental prescription from a dental data hub.

145. The system of claim 143, wherein the communication means includes a means for receiving the electronic dental prescription from a dentist.

146. The system of claim 143, wherein the electronic dental prescription includes a prescription for a dental restoration.

147. The system of claim 143, wherein the three-dimensional representation includes a digital surface representation of a full arch.

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148. The system of claim 143, wherein the electronic dental prescription includes a prescription for one or more of an appliance, a prosthesis, and an item of dental hardware.

149. The system of claim 143, wherein the fabrication means includes an in-house laboratory in a dentist's office.

150. A method comprising, within a single dental visit, the steps of:

acquiring a three-dimensional representation of one or more intraoral structures from a dental patient, the intraoral structures including at least one tooth surface prepared for an artificial dental object; and

processing the three-dimensional representation to provide feedback to a dentist concerning the at least one tooth surface.

151. The method of claim 150, wherein the feedback identifies corrective action.

152. The method of claim 151, wherein the corrective action includes acquiring an additional three-dimensional representation of the one or more intraoral structures.

153. The method of claim 151, wherein the corrective action includes additional surface preparation of the at least one tooth.

154. The method of claim 150, wherein the feedback identifies a margin for fitting the dental restoration to the at least one tooth surface.

155. The method of claim 154, wherein the margin for fitting can be edited.

156. The method of claim 150, wherein the feedback includes a visual display of one or more regions of inadequate margin for fitting the dental restoration to the at least one tooth surface.

157. The method of claim 150, wherein the feedback includes a visual display recommending additional preparatory work required for the at least one tooth surface.

158. The method of claim 150, wherein the feedback includes a visual display recommending acquiring additional three-dimensional representations of one or more regions of the one or more intraoral structures.

159. The method of claim 150, wherein the feedback includes identifying an incomplete three-dimensional representation.

160. The method of claim 150, wherein the feedback includes identifying errors in the three-dimensional representation.

161. The method of claim 150, wherein the feedback includes visual highlighting of a margin line on a display of the three-dimensional representation.

162. A computer program product comprising computer executable code embodied in a computer readable medium that, when executed on one or more computer devices, performs the steps of:

acquiring one or more images of one or more intraoral structures of a dental patient, the intraoral structures including at least one tooth surface prepared for an artificial dental object;

converting the one or more images into a three-dimensional representation of the one or more intraoral structures;

analyzing the at least one tooth surface within the three-dimensional representation;

generating a feedback signal, the feedback signal representative of the result of analyzing the at least one tooth surface; and

outputting the feedback signal to provide feedback to a dentist.

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163. The computer program product of claim 162, wherein the feedback signal identifies corrective action.

164. The computer program product of claim 163, wherein the corrective action includes acquiring an additional one or more images of the one or more intraoral dental structures.

165. The computer program product of claim 163, wherein the corrective action includes additional surface preparation of the at least one tooth.

166. The computer program product of claim 162, wherein the feedback signal identifies a margin for fitting the dental restoration to the at least one tooth surface.

167. The computer program product of claim 162, wherein the margin for fitting can be edited.

168. A system comprising:

a scanning device configured to intraorally capture surface image data from a surface within a mouth of a dental patient, the scanning device adapted to provide real time feedback during a scan by superimposing surface image data onto a video image of the surface;

a computer coupled to the scanning device and receiving the surface image data therefrom, the computer configured to resolve the surface image data into a digital surface reconstruction, the computer further configured to generate a visualization of the digital surface reconstruction and provide the visualization as a display signal; and

a display coupled to the computer and receiving the display signal therefrom, the display converting the display signal into a viewable image of the visualization.

169. The system of claim 168, wherein the surface includes dentition.

170. The system of claim 168, further comprising a user interface controlled by the computer and rendered on the display, the user interface providing at least one tool for analyzing the surface.

171. The user interface of the system of claim 170, further comprising a tool that provides real time feedback to the user.

172. The user interface of the system of claim 171, wherein the real time feedback includes visual cues within the rendered image.

173. The system of claim 170, wherein the scanning device captures surface image data at a video frame rate.

174. The system of claim 170, wherein the at least one tool includes a distance measurement tool.

175. The system of claim 170, wherein the at least one tool includes a tool that evaluates adequacy of tooth structure removal from a dental restoration surface preparation.

176. The system of claim 170, wherein the at least one tool includes a tool that evaluates adequacy of margin preparations.

177. The system of claim 170, wherein the at least one tool includes a tool that evaluates taper.

178. The system of claim 170, wherein the at least one tool includes a tool that evaluates undercut.

179. The system of claim 170, wherein the at least one tool includes a tool that identifies scan deficiencies.

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180. The system of claim 179, wherein the scan deficiencies include holes in the surface.

181. The system of claim 170, wherein the at least one tool includes a tool that evaluates adequacy of removal path in multiple unit preparation.

182. The system of claim 170, wherein the at least one tool includes a tool that identifies irregularities in one or more occlusal surfaces requiring further preparation.

183. The system of claim 170, wherein analyzing the surface includes an evaluation of suitability for three-dimensional printing.

184. The system of claim 170, wherein analyzing the surface includes an evaluation of suitability for milling.

185. The system of claim 170, wherein analyzing the surface includes an evaluation of suitability for manual fabrication.

186. The system of claim 168, wherein the computer is further configured to automatically annotate the visualization with a visual indication of an evaluation.

187. The system of claim 186, wherein the visual indication includes an evaluation of contour of a surface preparation.

188. The system of claim 186, wherein the surface image data includes at least two tooth surfaces in occlusion.

189. The system of claim 186, wherein the visual indication includes an evaluation of margin of a surface preparation.

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190. The system of claim 186, wherein the visual indication includes an evaluation of occlusal clearance of a surface preparation.

191. The system of claim 186, wherein the surface includes at least one surface prepared for a dental prosthesis, the evaluation including an evaluation of an adequacy of the at least one surface for receiving the dental prosthesis.

192. The system of claim 186, wherein the visual indication includes display of a contour of an actual tooth and a computer-generated surface preparation.

193. The system of claim 192, wherein the computer-generated surface preparation is based upon intact configuration of the actual tooth prior to preparation.

194. A method comprising:

receiving a three-dimensional representation including three-dimensional surface data from an intraoral structure including at least one tooth having a tooth surface prepared for a dental restoration; and

presenting the three-dimensional representation in a user interface, the user interface including a first tool for identifying a margin line for the dental restoration on the at least one tooth and a second tool for recessing a region of the three-dimensional representation below the margin line.

195. The method of claim 194, wherein the first tool provides automated identification of the margin line.

196. The method of claim 194, further comprising removing a portion of the three-dimensional representation below the margin line with the second tool.

197. The method of claim 194, further comprising removing a portion of the three-dimensional representation below the margin line with the second tool to provide a virtual ditched die, and three-dimensionally printing the ditched die.

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198. A system comprising:

a means for receiving a three-dimensional representation including three-dimensional surface data from an intraoral structure including at least one tooth having a tooth surface prepared for a dental restoration; and

a user interface means for presenting the three-dimensional representation to a user, the user interface means including a first tool means for identifying a margin line for the dental restoration on the at least one tooth and a second tool means for recessing a region of the three-dimensional representation below the margin line.

199. The system of claim 198, wherein the first tool means includes a means for providing automated identification of the margin line.

200. The system of claim 198, further comprising a means for removing a portion of the three-dimensional representation below the margin line.

201. The system of claim 198, further comprising a means for removing a portion of the three-dimensional representation below the margin line to provide a virtual ditched die, and a means for three-dimensionally printing the ditched die.

202. A method comprising:

acquiring a digital dental impression including three-dimensional surface data for at least two independent dental structures; and

acquiring orientation data defining a relative position of at least a portion of each of the at least two independent dental structures while in occlusion.

203. The method of claim 202, wherein the orientation data includes three-dimensional surface data that spans the at least two independent dental structures while in occlusion.

204. The method of claim 202, wherein the orientation data includes three-dimensional surface data from each of the at least two independent dental structures while in occlusion.

205. The method of claim 202, wherein the occlusion includes a centric occlusion.

206. The method of claim 202, further comprising applying the orientation data to position a virtual model of the at least two independent dental structures in a virtual articulator.

207. The method of claim 202, further comprising fabricating models of each of the at least two independent dental structures and applying the orientation data to position the models within a dental articulator.

208. The method of claim 202, wherein acquiring orientation data includes acquiring three-dimensional data of a buccal side of dentition.

209. The method of claim202, wherein acquiring orientation data includes acquiring three-dimensional data of a labial side of dentition.

210. A system comprising:

a first acquisition means for acquiring a digital dental impression including three-dimensional surface data for at least two independent dental structures; and

a second acquisition means for acquiring orientation data defining a relative position of at least a portion of each of the at least two independent dental structures while in occlusion.

211. The system of claim 210, wherein the orientation data includes three-dimensional surface data that spans the at least two independent dental structures while in occlusion.

212. The system of claim 210, wherein the orientation data includes three-dimensional surface data from each of the at least two independent dental structures while in occlusion.

213. The system of claim 210, wherein the occlusion includes a centric occlusion.

214. The system of claim 210, further comprising a model means for virtually articulating the at least two independent dental structures.

215. The system of claim 210, further comprising:

a fabrication means for fabricating models of each of the at least two independent dental structures; and

a model means for physically articulating the fabricated models.

216. The system of claim 210, wherein the orientation data includes three-dimensional data of a buccal side of dentition.

217. The system of claim210, wherein the orientation data includes three-dimensional data of a labial side of dentition.

218. A method comprising:

providing an intraoral three-dimensional scanning device; and

scanning a plurality of teeth in an arch with the device in a scan path that includes a motion that begins at a first lingual point, traverses laterally over a first occlusal point and a first buccal point, translates to a second buccal point adjacent to the first buccal point, and then traverses laterally over a second occlusal point adjacent to the first occlusal point and a second lingual point adjacent to the first lingual point.

219. The method of claim 218, further comprising scanning the plurality of teeth in the arch with the device using a motion that translates to a third lingual point, and then

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