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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	B445 0014
First Inventor	HABIBI, Babak
Title	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [✔] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [ ] Applicant claims small entity status. See 37 CFR 1.27.
3. [✔] Specification [*Total Pages* 29] *(preferred arrangement set forth below)*
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (*if filed*)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [✔] Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 7]
5. Oath or Declaration [*Total Pages* 3]
   a. [✔] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [✔] Application Data Sheet. See 37 CFR 1.76

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7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (*Appendix*)
8. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

17858 U.S. PTO 10/634874 08/05/03

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [✔] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [✔] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: .....

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation [ ] Divisional [✔] Continuation-in-part (CIP) of prior application No.: 10/153680

Prior application information: *Examiner:* _____ *Group Art Unit:* 3661

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[✔] *Customer Number or Bar Code Label* 00720 *(Insert Customer No. or Attach bar code label here)* or [ ] *Correspondence address below*

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Signature		*Date*	08/05/2003

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FEE TRANSMITTAL for FY 2003

Effective 01/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 966

Complete if Known	
Application Number	not yet assigned
Filing Date	herewith
First Named Inventor	HABIBI, Babak
Examiner Name	
Art Unit	3661
Attorney Docket No.	B445 0014

METHOD OF PAYMENT *(check all that apply)*

☑ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☑ Deposit Account:

Deposit Account Number: 02-1037

Deposit Account Name: Oyen Wiggs Green & Mutala

The Director is authorized to: *(check all that apply)*

☐ Charge fee(s) indicated below ☑ Credit any overpayments

☑ Charge any additional fee(s) during the pendency of this application

☐ Charge fee(s) indicated below, **except for the filing fee** to the above-identified deposit account.

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	750	2001	375	Utility filing fee	750
1002	330	2002	165	Design filing fee	
1003	520	2003	260	Plant filing fee	
1004	750	2004	375	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 750

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

		Extra Claims		Fee from below	Fee Paid
Total Claims	32	-20** =	12	X 18	= 216
Independent Claims		- 3** =		X	=
Multiple Dependent					=

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	84	2201	42	Independent claims in excess of 3
1203	280	2203	140	Multiple dependent claim, if not paid
1204	84	2204	42	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 966

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	410	2252	205	Extension for reply within second month	
1253	930	2253	465	Extension for reply within third month	
1254	1,450	2254	725	Extension for reply within fourth month	
1255	1,970	2255	985	Extension for reply within fifth month	
1401	320	2401	160	Notice of Appeal	
1402	320	2402	160	Filing a brief in support of an appeal	
1403	280	2403	140	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,300	2453	650	Petition to revive - unintentional	
1501	1,300	2501	650	Utility issue fee (or reissue)	
1502	470	2502	235	Design issue fee	
1503	630	2503	315	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	750	2809	375	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	750	2810	375	For each additional invention to be examined (37 CFR 1.129(b))	
1801	750	2801	375	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)

SUBMITTED BY				(Complete *(if applicable)*)	
Name (Print/Type)	Bruce M. Green	*Registration No. (Attorney/Agent)*	30,524	*Telephone*	604-669-3432
Signature				*Date*	August 5, 2003

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This collection of information is required by 37 CFR 1.17 and 1.27. 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 12 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS **ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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[redacted]

METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Cross-Reference to Related Applications

This application is a continuation-in-part of United States patent application no. 10/153680, filed May 24, 2002 which is pending.

Technical Field

The invention relates to the field of vision guided robotics, and more particularly to a method and apparatus for single image three dimensional vision guided robotics.

Background

Robots have long been widely used in manufacturing processes for many applications. Many different types of sensors are used to guide robots but machine vision is increasingly being used to guide robots in their tasks. Typically such machine vision is used in a two-dimensional application wherein the target object need only be located in an x-y plane, using a single camera. For example see United States patent no. 4,437,114 LaRussa. However many robotic applications require the robot to locate and manipulate the target in three dimensions. In the past this has typically involved using two or more cameras. For example see United States patent no. 4,146,924 Birk et al.; and United States patent no. 5,959,425 Bieman et al. In order to reduce hardware costs and space requirements it is preferable to use a single camera. Prior single camera systems however have used laser triangulation which involves expensive specialized sensors, must be rigidly packaged to maintain geometric relationships, require sophisticated inter-tool calibration methods and tend to be susceptible to damage or misalignment when operating in industrial environments.

Target points on the object have also been used to assist in determining the location in space of the target object using single or multiple cameras. See United States patents no. 4,219,847 Pinkney et al. and United

States patents no. 5,696,673; 5,956,417; 6,044,183 and 6,301,763 all of Pryor and United States patent no. 4,942,539 of McGee et al. Typically these methods involve computing the position of the object relative to a previous position, which requires knowledge of the 3D pose of the object at the starting point. These methods also tend to not provide the accuracy and repeatability required by industrial applications. There is therefore a need for a method for calculating the 3D pose of objects using only standard video camera equipment that is capable of providing the level of accuracy and repeatability required for vision guidance of robots as well as other applications requiring 3D pose information of objects.

Summary of Invention

A method of three-dimensional object location and guidance to allow robotic manipulation of an object with variable position and orientation by a robot using a sensor array is provided. the method comprises: a) calibrating the sensor array to provide a Robot - Eye Calibration by finding the intrinsic parameters of said sensor array and the position of the sensor array relative to a preferred robot coordinate system ("Robot Frame") by placing a calibration model in the field of view of said sensor array; (b) training object features by: i) positioning the object and the sensor array such that the object is located in the field of view of the sensor array and acquiring and forming an image of the object; ii) selecting at least 5 visible object features from the image; iii) creating a 3D model of the object ("Object Model") by calculating the 3D position of each feature relative to a coordinate system rigid to the object ("Object Space"); (c) training a robot operation path by: (i) computing the "Object Space -> Sensor Array Space" transformation using the "Object Model" and the positions of the features in the image; (ii) computing the "Object Space" position and orientation in "Robot Frame" using the transformation from "Object Space-> Sensor Array Space" and "Robot – Eye Calibration"; (iii) coordinating the desired robot operation path with the "Object Space"; (d) carrying out object location and robot guidance by:

(i) acquiring and forming an image of the object using the sensor array, searching for and finding said at least 5 trained features;
ii) with the positions of features in the image and the corresponding "Object Model" as determined in the training step, computing the object location as the transformation between the "Object Space" and the "Sensor Array" and the transformation between the "Object Space" and "Robot Frame"; (iii) communicating said computed object location to the robot and modifying robot path points according to said computed object location.

The invention further provides a system for carrying out the foregoing method.

Brief Description of Drawings

In drawings which illustrate a preferred embodiment of the invention:

Fig. 1 is a perspective view of a vision-guided robot;

Fig. 2 is a schematic diagram illustrating the relative frames of reference for calculating the position of the object;

Fig. 3 is a schematic diagram illustrating the calculation of the intended operation path on the object;

Fig. 4 is a representation of the operator's computer screen for selecting reference features on the object;

Fig. 5 is a flow chart illustrating the calibration of the camera mounted on the robot arm;

Fig. 6 is a flow chart illustrating the method of teaching the object features and handling path; and

Fig. 7 is a flow chart illustrating the method of object positioning and handling.

Description

Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention.

However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

Fig. 1 shows a robot 10 having a manipulating arm 12, base 22 and attached tool 14 with camera 16 mounted thereon. Tool 14 is designed to manipulate a part or target object 18. Camera 16 is preferably a commercially available analog or digital video camera. Camera 16 and robot 10 are electrically connected to computer control station 24 for communication of data back and forth.

The method is performed in the main steps described as follows:

a) calibration of the camera;
b) teaching the features on the object; and
c) finding the three-dimensional pose of the object and using this information to guide the robot to approach the object to perform any operations (e.g. handling, cutting etc.).

In the following discussion the following terms have the following meanings, as illustrated in Fig. 2:

Transformation: three-dimensional rotation & translation between two spaces;
Tool 14: the tool the robot is using for performing the handling, cutting or other robotic operations, having an operating end or "end-effector";
Camera Space 26: a reference frame defined with respect to a point on, and therefore rigid to, the camera 16;
Tool Space 28: a reference frame defined with respect to a point on, and oriented along the direction of the end-effector and therefore rigid to, the tool 14;

Robot base Space 30: a reference frame defined with respect to the physical base of the robot arm and therefore rigid to, the robot base 30;

Robot Frame: a preferred robot coordinate system

Calibration Model or Calibration Pattern or Calibration Template: a physical object with features of whose relative geometry is known

Sensor Array: a collection of one or more sensors capable of forming a single image

Training Space 32: a reference frame defined with respect to a point on the calibration template 40, and aligned to its main axes;

Object Space 36: a reference frame defined with respect to, and therefore rigid to, the object 18;

Object Frame 34: a reference frame defined with respect to a point on, and therefore rigid to, the object 18;

Camera calibration intrinsic parameters: focal length, image center, real pixel size, and radial and tangential distortion for the lens;

Camera calibration extrinsic parameters: rotation and translation of an external space relative to the Camera Space 26.

Calibration

The calibration process involves: i) finding the camera intrinsic parameters and ii) the position of the camera relative to the tool of the robot ("hand- eye" calibration). The position of the camera in the "Training Space", which is a space rigid to the place where the object will be trained is also determined. A general explanation of the basic calibration algorithms and descriptions of the variables can be found in the following publications:

"An Efficient and Accurate Camera Calibration Technique for 3D Machine Vision", Roger Y. Tsai, Proceedings of

IEEE Conference on Computer Vision and Pattern Recognition, Miami Beach, FL, 1986, pages 364-374;

"A Versatile Camera Calibration Technique for High-Accuracy 3D Machine Vision Metrology Using Off-the-Shelf TV Cameras and Lenses", Roger Y. Tsai, IEEE Journal of Robotics and Automation, Vol. RA-3, No. 4, August 1987, pages 323-344.

"Tsai's Camera Calibration Method Revisited" http://www.ai.mit.edu/people/bkph/papers/tsaiexplain.pdf

Tsai's camera model is based on the pin-hole model of perspective projection. Given the position of a point in 3D world coordinates, the model predicts the position of the point's image in 2D pixel coordinates. Tsai's model has 11 parameters: five internal (also called intrinsic or interior) parameters:

i) f - effective focal length of the pin hole camera;

ii) kappa1 - 1st order radial lens distortion coefficient;

iii and iv) Cx, Cy - coordinates of center of radial lens distortion and the piercing point of the camera coordinate frame's Z axis with the camera's sensor plane;

v) sx - scale factor to account for any uncertainty due to framegrabber horizontal scanline resampling,

and six external (also called extrinsic or exterior) parameters:

i) Rx, Ry, Rz - rotation angles of the transformation between the world and camera coordinate frames, and

ii) Tx, Ty, Tz - translation components of the transformation between the world and camera coordinate frames.

The internal parameters describe how the camera forms an image while the external parameters describe the camera's pose (i.e. position and

orientation) in the world coordinate frame. Calibration data for the model consists of 3D (x,y,z) world coordinates of a feature point (in mm. for example) and corresponding 2D coordinates (Xf,Yf) (typically in pixels) of the feature point in the image. Two forms of calibration are possible:

coplanar - the calibration points lie in a single plane in 3D, and

non-coplanar - the calibration points occupy a 3D volume.

As illustrated in Fig. 2 and 5, the first step in calibration is to position the camera 16 on the robot arm 12 so it is orthogonal to a template 40 using the mirror approach, and defining the "Training Space" for the robot aligned with the template 40 used for calibration. A calibration template 40 is placed on the floor or other planar surface. It is a flat piece of paper, plastic or other medium having a series of fixed detectable features such as a grid of dots or squares. The camera 16 is positioned so that it is orthogonal to the plane of the calibration template 40, that is, so the camera's imaging plane is parallel to the template 40. The mirror approach for obtaining orthogonality comprises placing a flat mirror on the grid of the template 40 and centering the lens on the mirror in the center of the grid.

Next the camera intrinsic parameters and the "Camera -> Training Space " transformation are computed considering the Training Space. Next, the "Camera -> Tool" transformation is computed using the "Camera -> Training Space" transformation and inquiring the robot about the "Tool" position in "Training Space". To calculate the "Camera -> Tool" transformation manually, the operator first touches 3 identifiable points on the grid having known coordinates with the tool. Next the operator stores images of the grid from at least 2 and preferably 4 measured heights above the grid.

Alternatively, the calibration can be done automatically to compute both the camera intrinsic parameter and the hand-eye calibration. The technique requires the camera to observe a planar pattern shown at a plurality of (at least two) different orientations. The pattern can be printed on a laser printer and attached to a planar surface. The position of the tool at each station is acquired directly from the robot. The operator positions the calibration

pattern in front of the robot and camera and starts the procedure. The automatic calibration takes place in less than 5 minutes. The calibration can be carried out in a different location from the part training or manipulation. The calibration pattern can be mounted in a fixed position, out of the working space, and automatic calibration can take place at regular time intervals.

The following steps are carried out to perform the automatic calibration:

a) the calibration pattern is positioned in the field of view of the robot mounted camera 16;

b) the robot is moved to a plurality of stations in a predefined manner so that the calibration pattern is in the field of view at each station (see Roger Y. Tsai and Reimar K. Lenz, "A New Technique for Fully Autonomous and Efficient 3D Robotics Hand/Eye Calibration", *IEEE Transactions on Robotics and Automation*, Vol. 5, No. 3, June 1989 p. 345 at p. 350);

c) At each station the following operations are performed:
- the acquired image is processed to extract the calibration points from the image;
- the robot is asked for the tool position;

d) Using the calibration points information at each station, calibrate the camera intrinsic parameters and compute the extrinsic transformation from the pattern to the camera;

e) Using the extrinsic transformation at each station and the corresponding tool position, the camera to tool transformation is calculated (see Tsai and Lenz reference above at p. 350).

Teaching

Teaching the object is the process of:

a) Selection from the object's image of a set of at least 5 features, and determining the position of the features in the image. Features can be edges, holes, corners, blobs (extracted from the image) or simply a region of the image which will be used in a pattern match. Preferably, one or more unique features may be selected to be considered the "anchor features". The other selected features may be small, non-unique features relative to the anchor features.

b) Real world coordinates are computed for the selected features. The object is located in the Training Space, so that by using the features' heights relative to the Training Space, the 3D position of the object features inside the Training Space can be computed using the position in the image and the Training Space to Camera Space transformation calculated at calibration.

c) An Object Space is defined such that it is identical to the Training Space but is rigid to the object and moves with the object.

d) Also an Object Frame will be defined with a constant relationship to the object, in a position selected by the user. Three non-co-linear points may be used to define the Object Frame.

e) The Object Frame (computed in tool coordinates) is sent to the robot to be considered as the robot working space. To find this frame position, the transformation from Object Space to Camera Space is used, then from Camera Space to Tool Space.

f) Relative to the Object Frame, the operator can train the intended operation path (the tool path shown in Fig. 3) for the robot by moving the robot or alternatively by using an off-line robot programming software application to create the desired operation path with respect to the object.

As illustrated in Fig 3, 4 and 6, the first step in teaching the object features is to place the object in the "Training Space " and capture an

image with the robot in the calibration position (where the "Camera Space -> Training Space" transformation was calculated). Figure 4 illustrates the image 50 of the part as displayed on the operator's computer screen. Next, at least 5 visible features 54 are selected. Preferably at least one anchor feature 52 is selected from the image and a set of at least 4 other visible features 54 are selected and positioned relative to the anchor feature. The 3D position of each feature 54 is then calculated in "Training Space" using the height of the feature relative to the Training Space and "Camera Space -> Training Space" transformation. An "Object Space " is then defined as having a constant relationship with the "Training Space" but connected to the object and the 3D coordinates of the features are transferred into that space. The "Object Space -> Camera Space" transformation is computed using the 3D position of the features inside this space and the position in the image by computing an extrinsic calibration using the camera calibration from the previous step. Next an "Object Frame" inside "Object Space" is defined to be used for teaching the intended operation path. This Object Frame position and orientation in "Tool Frame" is computed using the transformation from "Object Frame-> Camera Space" and "Camera Space-> Tool Space". The "Object Frame" is then sent to the robot and the intended operation path is trained inside this space.

The following method may also be used for computing the 3D position of the selected features 54 automatically, without any prior knowledge about the part. The following algorithm is developed using the approach described in Guo-Quing Wei,. "Active Self-Calibration of Robotic Eyes and Hand-Eye Relationship with Model Identification", *IEEE Transactions on Robotics and Automation*, Vol. 14, No. 1, February 1999 p. 158. The camera is rigidly mounted on the robot gripper. The derived method computes the world coordinates of the features based on robot motion parameters, known camera to tool transformation, image coordinate measurements and intrinsic camera parameters. The robot tool will undergo a set of pure translations from a base position P_0 to a set of positions P_j.

The motion equations for a point p_i in the image are:

$$u_{ij} - u_0 = f_x \frac{R_{cg(0,0)} * t_{g0j0} + R_{cg(1,0)} * t_{g0j1} + R_{cg(2,0)} * t_{g0j2} + X_0}{R_{cg(0,2)} * t_{g0j0} + R_{cg(1,2)} * t_{g0j1} + R_{cg(2,2)} * t_{g0j2} + Z_0}$$

$$v_{ij} - v_0 = f_y \frac{R_{cg(0,1)} * t_{g0j0} + R_{cg(1,1)} * t_{g0j1} + R_{cg(2,1)} * t_{g0j2} + Y_0}{R_{cg(0,2)} * t_{g0j0} + R_{cg(1,2)} * t_{g0j1} + R_{cg(2,2)} * t_{g0j2} + Z_0}$$

Where:

j represents the index of the station where the measurement takes place;
R_{cg} are elements of the rotation matrix of the camera to tool transformation;
t_{g0j} represents the translation from the current station to the base position;
u_0, v_0 is the camera central point;
u_{ij}, v_{ij} are the undistorted image coordinates of the i-th feature in the image acquired at station j. To compute these values one uses the already calibrated cameras intrinsic parameters.

At least two stations are needed for the linear system to have unique solutions, but a set of at least 3 stations is used in order to compensate for the noise in the images and other perturbation factors that may occur.

X_0, Y_0, Z_0 are computed for all the features in camera space, but the values can be transposed in any other space that is related to it, such as training space, tool space or even robot base space. The space in which the coordinates are represented makes no difference as this space is only used to compute the current transformation to the camera and to transfer then the object frame points to the tool space.

The robot stations are located on a circle around the base to assure a uniform distribution.

The automatic feature position finding steps are as follows:

a) the part is positioned in front of the camera 16;

b) the features 54 that are going to be used for 3D part positioning are selected;

c) the automatic feature position finding procedure is started by:

i) moving the robot to a set of stations around the base 22;

ii) memorizing the tool position relative to base at each station;

iii) at each station acquiring an image, finding the visible features 54 and for those features calculating the undistorted image position;

d) for each feature solve a linear system of as many equations as the number of images the given feature was visible in;

e) the calculated positions are transformed in a space that suits the application.

Alternatively the location of the features can be sourced by using a CAD model of the part.

1. **Object Location & Robot Guidance**

To carry out object location and robot guidance, the following steps are carried out:

a) The tool 14 is positioned in any predefined position above the bin with objects 18.

b) An image of the object 18 is captured.

c) The trained features 54 are searched for. If any anchor features were selected, then a first search is done for the anchor features 52. Using the position and orientation of the anchor features 52 the rest of the features 54 can be found by their relative positions. This approach allows

similar features to be selected as features are searched in a relatively small region of interest. Otherwise, each feature is searched over the entire image.

d) The position (in the image 50 and in the Object Space) of the found features (at least 5) are used to calculate the transformation between the Object Space and the Camera Space using an extrinsic calibration algorithm. (See the Tsai article above). The found position is used to re-orient the camera to "look" at the object from an orthogonal position which is the one used at training. This last step may be necessary if the object has major rotations, since in this case the features may be distorted and the found position may not be completely accurate.

e) Steps c) and d) above are repeated.

f) The previous "Object Space to Camera Space" transformation is used in conjunction with the "Camera Space to Tool Space" transformation to find the position of the Object Frame in Tool Space.

g) The Object Frame is then sent to the robot to be used as the reference frame for the robot's operation path.

With reference to Fig. 7, the preferred steps to carry out object location and robot guidance are illustrated. First the robot is positioned in a predefined position above the bin or container that holds the target object. If no object is in the field of view, the robot is moved until at least one anchor feature is found in the image. Next, the position and orientation of the anchor feature is used to compute the position of the rest of the features. The position of all the visible features in the image is found. With the positions of features from the image and their corresponding positions in "Object Space" (calculated during teaching) the camera calibration is used to compute the transformation between the "Object Space" and "Camera Space". The camera extrinsic calibration is used as described in the Tsai article referenced above.

Next the transformation described above is used to calculate the movement of the robot to position the camera so that it "looks" orthogonally at the object, namely the same position as in training. In this way all the features will appear as similar as possible as at training. This will make the recognition and positioning more accurate. Next the "Object Space -> Camera Space" transformation is found in the same way as in the previous step (using the features positions). The Object Frame memorized at training is computed using the found transformation and "Camera Space-> Tool Space" transformation. Next, the commuted "Object Frame" is sent to the robot. The "Tool" position is used to define the frame in "Robot Space". The trained robot path is performed inside this space.

Thus methods for teaching robots and handling of objects by robots in three dimensions using one camera mounted on the robot arm are disclosed in which targets are used on objects. The targets are usually normal features of the object or could be created using markers, lighting, etc. It is not necessary to use the CAD model of the object according to this method. The objects need not be fixtured and can be placed anywhere within the workspace of the robot. While the method has been described for one trained object, the process can be used in the same manner to first recognize the object and then find its location in three dimensions. Also the method has been described for one visible set of features selected on one side of the object, but it can be extended to all the sides that can appear in a working situation.

In the method described above, the calibration step can be carried out with just the intrinsic and hand-eye calibration, and in that case, in teaching step b), the 3D position of features may be provided using the CAD model of the object. Similarly the 3D position of features can be calculated automatically, without any model or measurements on the part.

Further, training step c) can be accomplished by sending to the robot the positions of intended robot path points, with the positions computed using the object's current position and orientation. The robot path points can be sourced from an offline robot programming software application. Also, one or

more features on the object can be used as grasp points and the position of those points in robot coordinates sent to the robot to eliminate the need for manually teaching grasp points using the robot teach pendant. Alternatively the coordinates of the object frame points or other points of interest (e.g. robot path points) can be transformed using the transformation from tool to robot base and all the coordinates send to robot in the robot base coordinate frame instead.

Further, the calibration and teaching steps a) and b) can be combined by using a self calibration method of robotic eye and hand-eye relationship with model identification as described in "Active self-calibration method of robotic eye and hand-eye relationship with model identification " by Guo-Qing Wei, Klaus Arbter and Gerd Hirzinger. The result of such a method will give camera intrinsic parameters, hand-eye calibration and position of selected features in camera space; The rest of the path training and run time will still remain the same and in this preferred approach;

In accordance with the present invention the determination of object location in step c(i) and d(ii) can use any of the following algorithms:

a) 3D pose estimation using non linear optimization methods derived from the ones described in the already mentioned articles :

- "A Flexible New Technique for Camera Calibration " by Zhengyou Zhang;
- "An efficient and Accurate Camera Calibration Techniques for 3D Machine Vision" by Roger Y. Tsai;

b) 3D pose estimation from lines correspondence (in which case selected features will be edges) as described in "Determination of Camera Location from 2D to 3D Line and Point Correspondences" by Yucai Liu, Thomas S. Huang, Olivier D. Faugeras;

c) pose estimation using "orthogonal iteration" described in "Fast and Globally Convergent Pose Estimation from Video Images" by Chien_Ping Lu, Gregory D. Hager, Eric Mjolsness;

d) approximate object location under weak perspective conditions as demonstrated in "Uniqueness of 3D Pose Under Weak Perspective: A Geometric Proof" by Thomas Huang, Alfred Bruckenstein, Robert Holt, Arun Netravali;

e) approximate object location using Direct Linear Transformation (DLT) as described in "An investigation on the accuracy of three-dimensional space reconstruction using Direct Linear Transformation techniques" by Chen, Armstrong, Raftopoulos.

In addition to use in robotics, the described method can be applied to a variety of industrial and non-industrial processes whereby knowledge of the 3D pose of an object is required.

While the invention has been described using a single camera, the image may be formed using multiple sensors ("Sensor Array"). For instance, the formation of a single image may be accomplished using multiple cameras that are situated such that the origins of their camera spaces are coincident. In this fashion, each camera would view a different area of the part with some overlap with the areas viewed by adjacent cameras. A single image is then formed by "Mosaicing" the images from individual cameras similar to one described in Multiple View Geometry in Computer Vision by Richard Hartley and Andrew Zisserman, Cambridge University Press, 2000. The same image formation may be accomplished by mounting a single camera on a robot and rotating the camera about its origin of the camera space and capturing the multiple images needed for Mosaicing. The object features may be extracted from multiple images captured by the same sensor array located in the same position whereby each image is formed under a different combination of lighting and filters to highlight a group of object features that are not apparent in other images. The object features themselves may be created using markers, lighting or other means.

The calibration and teaching steps may be accomplished by using a self calibration method of robotic eye and hand-eye relationship with model identification.

The creation of the Object Model may be accomplished by using the relative heights of features and the "Robot – Eye Calibration" or by the operator entering the 3D position of each feature manually from a CAD model, measurement or other source.

While the invention has been described with the camera mounted on the robot, the same approach is valid for cases whereby the camera is fixed onto a stationary structure. Similarly although the object has been described to be at rest on a surface, the same approach is valid for cases when the object is stationary but grasped by a robot. Also during the operation of the system there may exist a relative velocity between the sensor array and the object wherein step d) is executed in a continuous control loop and provides real time positional feedback to the robot for the purpose of correcting the intended robot operation path.

Where the camera is mounted on the robot, the calibration step is accomplished by: i) the operator moving the "Calibration Model" relative to the camera and capturing images at multiple positions to determine camera intrinsic parameters; ii) the operator taking an image of the "Calibration Model" at a stationary position to determine the extrinsic calibration parameters; iii) the operator determining the position of the "Calibration Model" in the robot space using the robot end-effector while the "Calibration Model" is at the same position as in step ii); and iv) calculating the "Robot – Eye Calibration" using results of i), ii), iii). The step of creating the Object Model is accomplished by using the relative heights of features and the "Robot – Eye Calibration".

Where the camera is fixed onto a stationary structure and the object is at rest upon a surface, the calibration step is accomplished by mounting the "Calibration Model" on the robot and using the robot to automatically move the "Calibration Model" relative to the camera and capturing images at multiple known robot positions. The step of creating the Object Model is accomplished by the operator entering the 3D position of each feature manually from a CAD model, measurement or other source.

Where the camera is fixed onto a stationary structure and the object is in a robot's grasp such that the position and orientation of the object can be modified by known values, the calibration step is accomplished by mounting the "Calibration Model" on the robot and using the robot to automatically move the "Calibration Model" relative to the camera and capturing images at multiple known robot positions. The step of creating the Object Model is accomplished by using the robot to automatically move the object relative to the camera and capturing images at multiple known robot positions. If when locating the features a sufficient number of features are not found in the field of view of the camera, the relative position and/or orientation of the object is changed until sufficient features are found. Prior to communicating the object location to the robot, the necessary movement of the object relative to the camera is calculated using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training; the relative movement is executed as calculated in previous step; and the "Object Space -> Sensor Array Space" transformation is found in the same way as in step d) ii).

Where the object is at rest and stationary and the camera is attached onto the robot such that its position and orientation can be modified by known values, the calibration step is accomplished by placing the "Calibration Model" in the camera's field of view and using the robot to automatically move the camera relative to the "Calibration Model" and capturing images at multiple known robot positions. The step of creating the Object Model is accomplished by using the robot to automatically move the camera relative to the object and capturing images at multiple known robot positions. If when locating the features a sufficient number of features are not found in the field of view of the camera, then the relative position and/or orientation of the camera is changed until sufficient features are found. In this case the step of (step b) iii)) is accomplished by using the robot to automatically move the camera relative to the object and capturing images at multiple known robot positions, and wherein step c) iii) is accomplished by creating a new frame called the "Object Frame" that is in constant relationship with the "Object Space" and sending the "Object Frame" to the robot and training the intended operation path relative to the "Object Frame" and step d) iii) is

accomplished by computing the "Object Space" inside the "Robot Frame" using the transformation between the "Object Space" and the "Sensor Array" and the "Robot – Eye Calibration" and calculating and sending the "Object Frame" to the robot and executing the robot path relative to the "Object Frame", and

wherein the following steps are preceded by d) ii) and followed by d) iii):

a. calculating the necessary movement of the object relative to the camera using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training;

b. executing the relative movement as calculated in previous step;

c. finding the "Object Space -> Sensor Array Space" transformation in the same way as in step d) ii), and

wherein step d) i) the search area for some of the features is based upon the position and orientation of some other features. Prior to communicating the object location to the robot, the necessary movement of the object relative to the camera is calculated using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training; the relative movement is executed as calculated in previous step; and the "Object Space -> Sensor Array Space" transformation is found in the same way as in step d) ii).

Where the object is in a robot's grasp such that its position and orientation can be modified by known values and the camera is attached onto another robot such that its position and orientation can be modified by known values, the calibration step is accomplished by placing the "Calibration Model" in the camera's field of view and using the robot to automatically move the camera relative to the "Calibration Model" and capturing images at multiple known robot positions. The step of creating the Object Model is accomplished by changing the relative position of the object and camera using movement of one or both robots and capturing images at multiple known robots' positions. If when locating the features a sufficient number of features are not found in the field of view of the

camera, then the relative position and/or orientation of the camera and/or object is changed until sufficient features are found. Prior to communicating the object location to the robot, the necessary movement of the object relative to the camera is calculated using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training; and the relative movement is executed as calculated in previous step; and the "Object Space -> Sensor Array Space" transformation is found in the same way as in step d) ii).

Various means are possible for communicating the object location data to the robot. The "Object Space " may be communicated to the robot and the intended operation path trained relative to the "Object Space" and then communication of the object location to the robot is accomplished by computing the "Object Space" inside the "Robot Frame" using the transformation between the "Object Space" and the "Sensor Array" and the "Robot – Eye Calibration" and sending the "Object Space" to the robot and executing the robot path relative to the "Object Space". Alternatively the "Object Space" may be memorized and step d) iii) is accomplished by calculating the transformation between the memorized "object space" and the current "object space" and communicating this transformation to the robot to be used for correcting the operation path points. Or the "Object Space" may be memorized and step d) iii) is accomplished by calculating the transformation between the memorized "object space" and the current "object space" and using this transformation to modify the robot operation path points and communicating the modified path points to the robot for playback.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

WHAT IS CLAIMED IS:

1. A method of three-dimensional object location and guidance to allow robotic manipulation of an object with variable position and orientation by a robot using a sensor array, comprising:

(a) calibrating the sensor array to provide a Robot - Eye Calibration by finding the intrinsic parameters of said sensor array and the position of the sensor array relative to a preferred robot coordinate system ("Robot Frame") by placing a calibration model in the field of view of said sensor array;

(b) training object features by:

(i) positioning the object and the sensor array such that the object is located in the field of view of the sensor array and acquiring and forming an image of the object;

(ii) selecting at least 5 visible object features from the image;

(iii) creating a 3D model of the object ("Object Model") by calculating the 3D position of each feature relative to a coordinate system rigid to the object ("Object Space");

(c) training a robot operation path by:

(i) computing the "Object Space -> Sensor Array Space" transformation using the "Object Model" and the positions of the features in the image;

(ii) computing the "Object Space" position and orientation in "Robot Frame" using the transformation from "Object Space-> Sensor Array Space" and "Robot – Eye Calibration";

(iii) coordinating the desired robot operation path with the "Object Space";

(d) carrying out object location and robot guidance by:

(i) acquiring and forming an image of the object using the sensor array, searching for and finding said at least 5 trained features;

(ii) with the positions of features in the image and the corresponding "Object Model" as determined in the training step, computing the object location as the transformation between the "Object Space"

and the "Sensor Array" and the transformation between the "Object Space" and "Robot Frame";

(iii) communicating said computed object location to the robot and modifying robot path points according to said computed object location.

2. The method of claim 1 wherein the sensor array is a single camera.

3. The method of claim 2 wherein said camera is fixed onto a stationary structure and the object is at rest upon a surface.

4. The method of claim 2 wherein said camera is fixed onto a stationary structure and the object is in a robot's grasp such that the position and orientation of the object can be modified by known values.

5. The method of claim 2 wherein the object is at rest and stationary and the camera is attached onto the robot such that its position and orientation can be modified by known values.

6. The method of claim 2 whereby the object is in a robot's grasp such that its position and orientation can be modified by known values and the camera is attached onto another robot such that its position and orientation can be modified by known values.

7. The method of claim 2 whereby step a) is accomplished by:

I) the operator moving the "Calibration Model" relative to the camera and capturing images at multiple positions to determine camera intrinsic parameters;

II) the operator taking an image of the "Calibration Model" at a stationary position to determine the extrinsic calibration parameters;

III) the operator determining the position of the "Calibration Model" in the robot space using the robot end-effector while the "Calibration Model" is at the same position as in step II);

IV)calculating the "Robot – Eye Calibration" using results of I), II) and

III).

8. The method of claim 3 wherein step a) is accomplished by mounting the "Calibration Model" on the robot and using the robot to automatically move the "Calibration Model" relative to the camera and capturing images at multiple known robot positions.

9. The method of claim 4 wherein step a) is accomplished by mounting the "Calibration Model" on the robot and using the robot to automatically move the "Calibration Model" relative to the camera and capturing images at multiple known robot positions.

10. The method of claim 5 wherein step a) is accomplished by placing the "Calibration Model" in the camera's field of view and using the robot to automatically move the camera relative to the "Calibration Model" and capturing images at multiple known robot positions.

11. The method of claim 6 wherein step a) is accomplished by placing the "Calibration Model" in the camera's field of view and using the robot to automatically move the camera relative to the "Calibration Model" and capturing images at multiple known robot positions.

12. The method of claim 2 wherein step b) iii) is accomplished by using the relative heights of features and the "Robot – Eye Calibration".

13. The method of claim 3 wherein step b) iii) is accomplished by the operator entering the 3D position of each feature manually from a CAD model, measurement or other source.

14. The method of claim 4 wherein step b) iii) is accomplished by using the robot to automatically move the object relative to the camera and capturing images at multiple known robot positions.

15. The method of claim 5 wherein step b) iii) is accomplished by using the robot

to automatically move the camera relative to the object and capturing images at multiple known robot positions.

16. The method of claim 6 wherein step b) iii) is accomplished by changing the relative position of the object and camera using movement of one or both robots and capturing images at multiple known robots' positions.

17. The method of claim 1 wherein step c) iii) is accomplished by sending the "Object Space " to the robot and training the intended operation path relative to the "Object Space" and step d) iii) is accomplished by computing the "Object Space" inside the "Robot Frame" using the transformation between the "Object Space" and the "Sensor Array" and the "Robot – Eye Calibration" and sending the "Object Space" to the robot and executing the robot path relative to the "Object Space".

18. The method of claim 1 wherein step c) iii) is accomplished by memorizing the "Object Space" and step d) iii) is accomplished by calculating the transformation between the memorized "object space" and the current "object space" and communicating this transformation to the robot to be used for correcting the operation path points.

19. The method of claim 1 wherein step c) iii) is accomplished by memorizing the "Object Space" and step d) iii) is accomplished by calculating the transformation between the memorized "object space" and the current "object space" and using this transformation to modify the robot operation path points and communicating the modified path points to the robot for playback.

20. The method of claim 1 wherein step c) i) and d) ii) are accomplished by a model-based pose estimation methods selected from the following group:

(a) 3D pose estimation using non linear optimization refinement based on maximum likelihood criteria

(b) 3D pose estimation from lines correspondence in which selected features are edges using image Jacobian

(c) 3D pose estimation using "orthogonal iteration"

(d) 3D pose approximation under weak perspective conditions

(e) 3D pose approximation using Direct Linear Transformation (DLT).

21. The method of claim 4 wherein in step d) i) if a sufficient number of features are not found in the field of view of the camera, the relative position and/or orientation of the object is changed until sufficient features are found.

22. The method of claim 5 wherein in step d) i) if a sufficient number of features are not found in the field of view of the camera, changing the relative position and/or orientation of the camera until sufficient features are found.

23. The method of claim 6 wherein in step d) i) if a sufficient number of features are not found in the field of view of the camera, changing the relative position and/or orientation of the camera and/or object until sufficient features are found.

24. The method of claim 4 wherein the following steps are carried out after step d) ii) and before step d) iii):

(a) calculating the necessary movement of the object relative to the camera using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training;

(b) executing the relative movement as calculated in previous step;

(c) finding the "Object Space -> Sensor Array Space" transformation in the same way as in step d) ii).

25. The method of claim 5 wherein the following steps are carried out after step d) ii) and before step d) iii):

(a) calculating the necessary movement of the object relative to the camera using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training;

(b) executing the relative movement as calculated in previous step;

(c) finding the "Object Space -> Sensor Array Space" transformation in the same way as in step d) ii).

26. The method of claim 6 wherein the following steps are carried out after step d) ii) and before step d) iii):

(a) calculating the necessary movement of the object relative to the camera using the transformation between the "Object Space" and "Robot Frame" such that the relative position and orientation of the object and the camera is similar to that at the time of training;

(b) executing the relative movement as calculated in previous step;

(c) finding the "Object Space -> Sensor Array Space" transformation in the same way as in step d) ii).

27. The method of claim 1 wherein in steps b) and d) the object features are extracted from multiple images captured by the same sensor array located in the same position and each image is formed under a different combinations of lighting and filters to highlight a group of object features that are not apparent in other images.

28. The method of claim 2 wherein steps a) and b) are accomplished by using a self calibration method of robotic eye and hand-eye relationship with model identification.

29. The method of claim 10 wherein step b) iii) is accomplished by using the robot to automatically move the camera relative to the object and capturing images at multiple known robot positions, and wherein step c) iii) is accomplished by creating a new frame called the "Object Frame" that is in constant relationship with the "Object Space" and sending the "Object Frame" to the robot and training the intended operation path relative to the "Object Frame" and step d) iii) is accomplished by computing the "Object Space" inside the "Robot Frame" using the transformation between the "Object Space" and the "Sensor Array" and the "Robot – Eye Calibration" and calculating and sending the "Object Frame" to the robot and executing the robot path relative to the "Object Frame", and wherein the following steps are preceded by d) ii) and followed by d) iii):

(a) calculating the necessary movement of the object relative to the camera using the transformation between the "Object Space" and "Robot Frame"

such that the relative position and orientation of the object and the camera is similar to that at the time of training;

(b) executing the relative movement as calculated in previous step;

(c) finding the "Object Space -> Sensor Array Space" transformation in the same way as in step d) ii), and

wherein step d) i) the search area for some of the features is based upon the position and orientation of some other features.

30. A system for three-dimensional object location and guidance to allow robotic manipulation of an object with variable position and orientation by a robot using a sensor array, comprising:

(a) a sensor array;

(b) a robot;

(c) means for calibrating the sensor array to provide a Robot - Eye Calibration by finding the intrinsic parameters of said sensor array and the position of the sensor array relative to a preferred robot coordinate system ("Robot Frame") by placing a calibration model in the field of view of said sensor array;

(d) means for training object features by:

(i) positioning the object and the sensor array such that the object is located in the field of view of the sensor array and acquiring and forming an image of the object;

(ii) selecting at least 5 visible object features from the image;

(iii) creating a 3D model of the object ("Object Model") by calculating the 3D position of each feature relative to a coordinate system rigid to the object ("Object Space");

(e) means for training a robot operation path by:

(i) computing the "Object Space -> Sensor Array Space" transformation using the "Object Model" and the positions of the features in the image;

(ii) computing the "Object Space" position and orientation in "Robot Frame" using the transformation from "Object Space-> Sensor Array Space" and "Robot – Eye Calibration";

(iii) coordinating the desired robot operation path with the "Object Space";

(f) means for carrying out object location and robot guidance by:

(i) acquiring and forming an image of the object using the sensor array, searching for and finding said at least 5 trained features;

(ii) with the positions of features in the image and the corresponding "Object Model" as determined in the training step, computing the object location as the transformation between the "Object Space" and the "Sensor Array" and the transformation between the "Object Space" and "Robot Frame";

(iii) communicating said computed object location to the robot and modifying robot path points according to said computed object location.

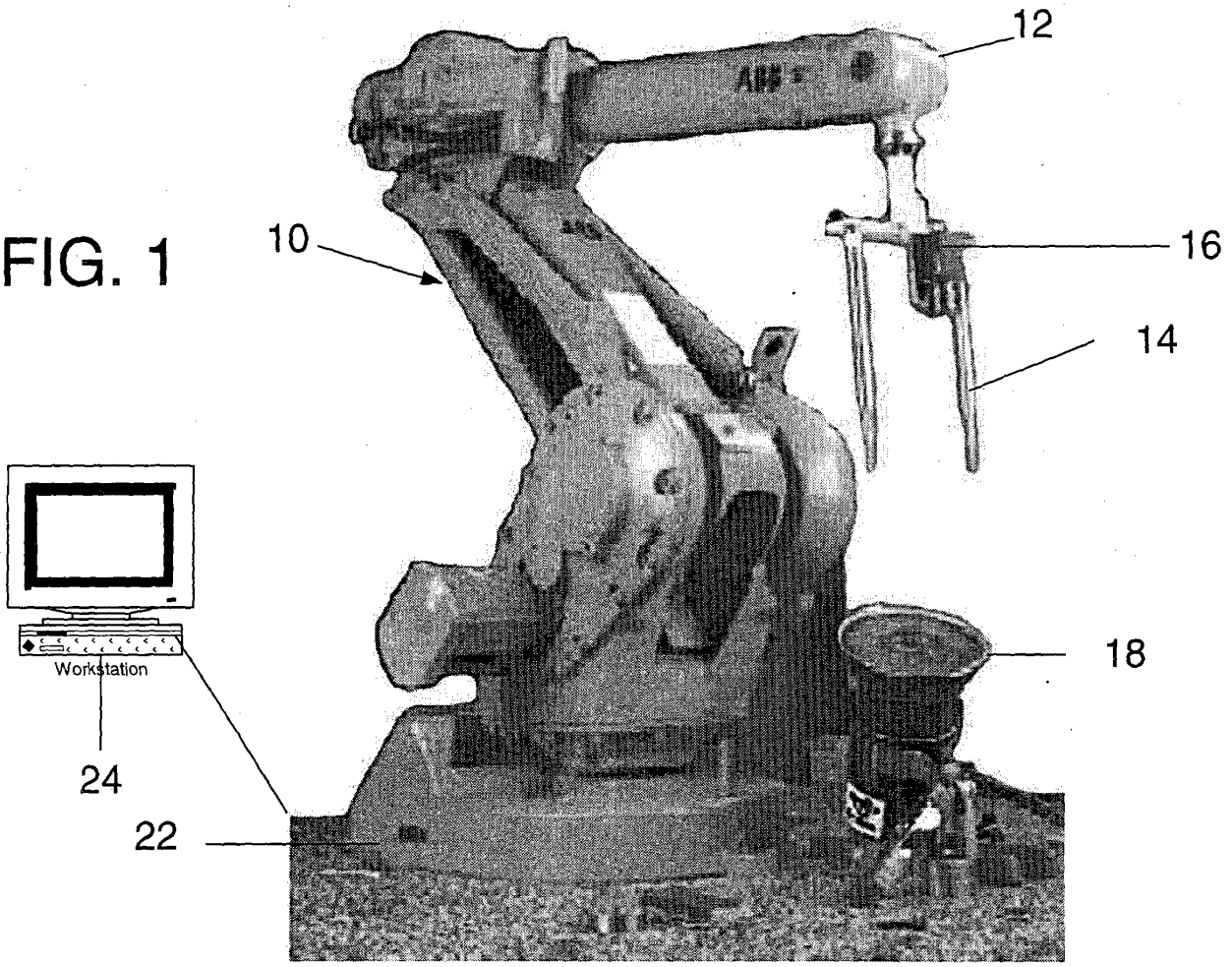
31. The method of claim 1 whereby during the operation of the system there exists a relative velocity between the sensor array and the object wherein step d) is executed in a continuous control loop and provides real time positional feedback to the robot for the purpose of correcting the intended robot operation path

32. The method of claim 1 whereby the object features are created using markers, lighting or other means.

Abstract of the Disclosure

A method of three-dimensional object location and guidance to allow robotic manipulation of an object with variable position and orientation using a sensor array which is a collection of one or more sensors capable of forming a single image.

FIG. 1



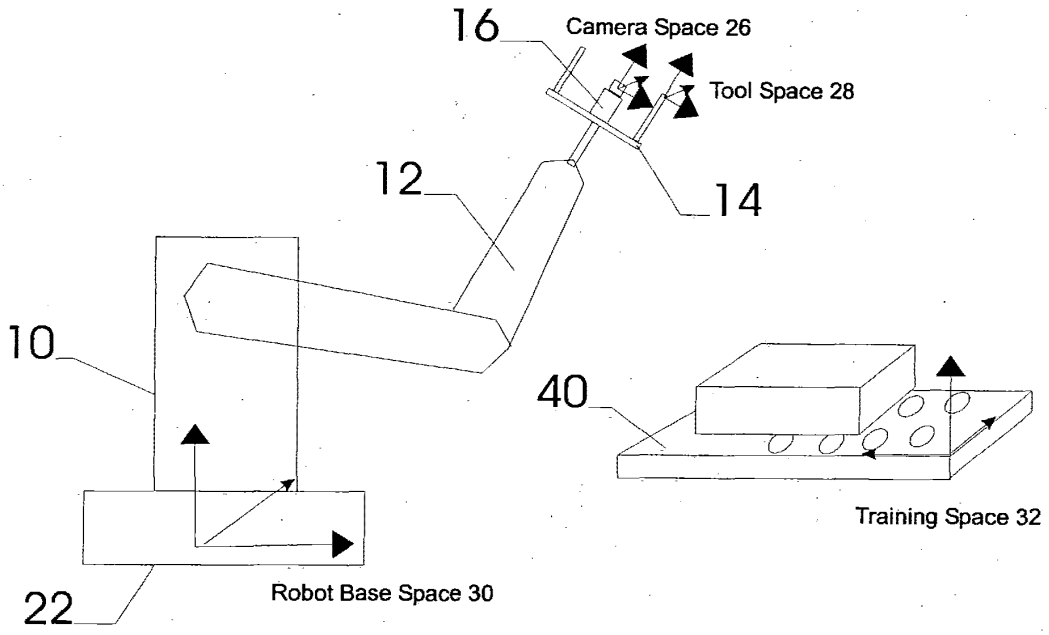
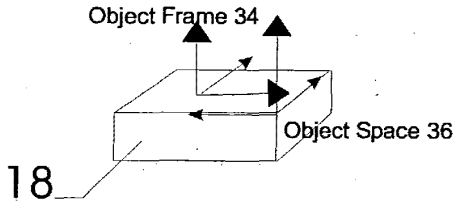

16
Camera Space 26
Tool Space 28
12
14
10
40
Training Space 32
22
Robot Base Space 30

Fig. 2


Object Frame 34
Object Space 36
18

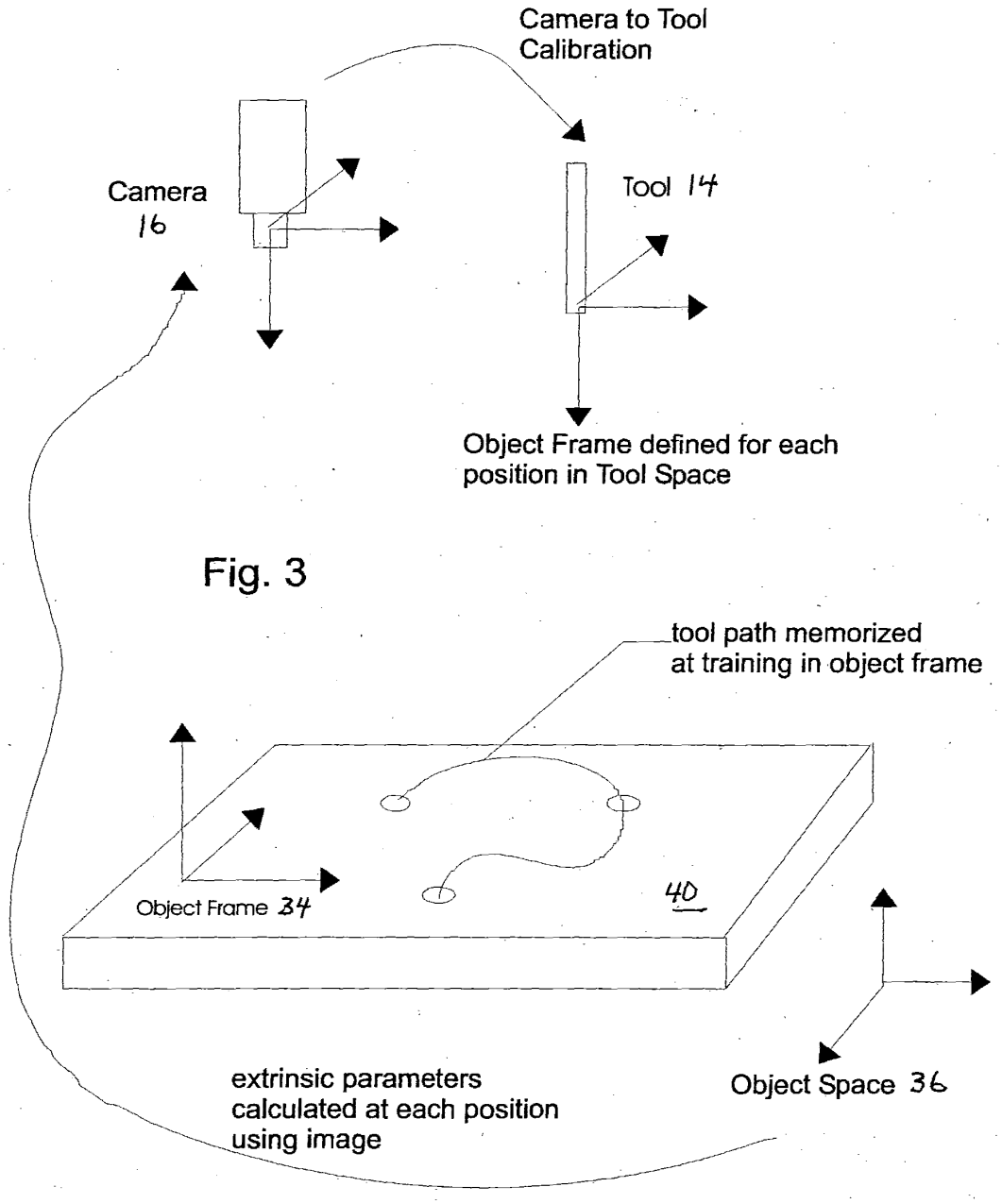
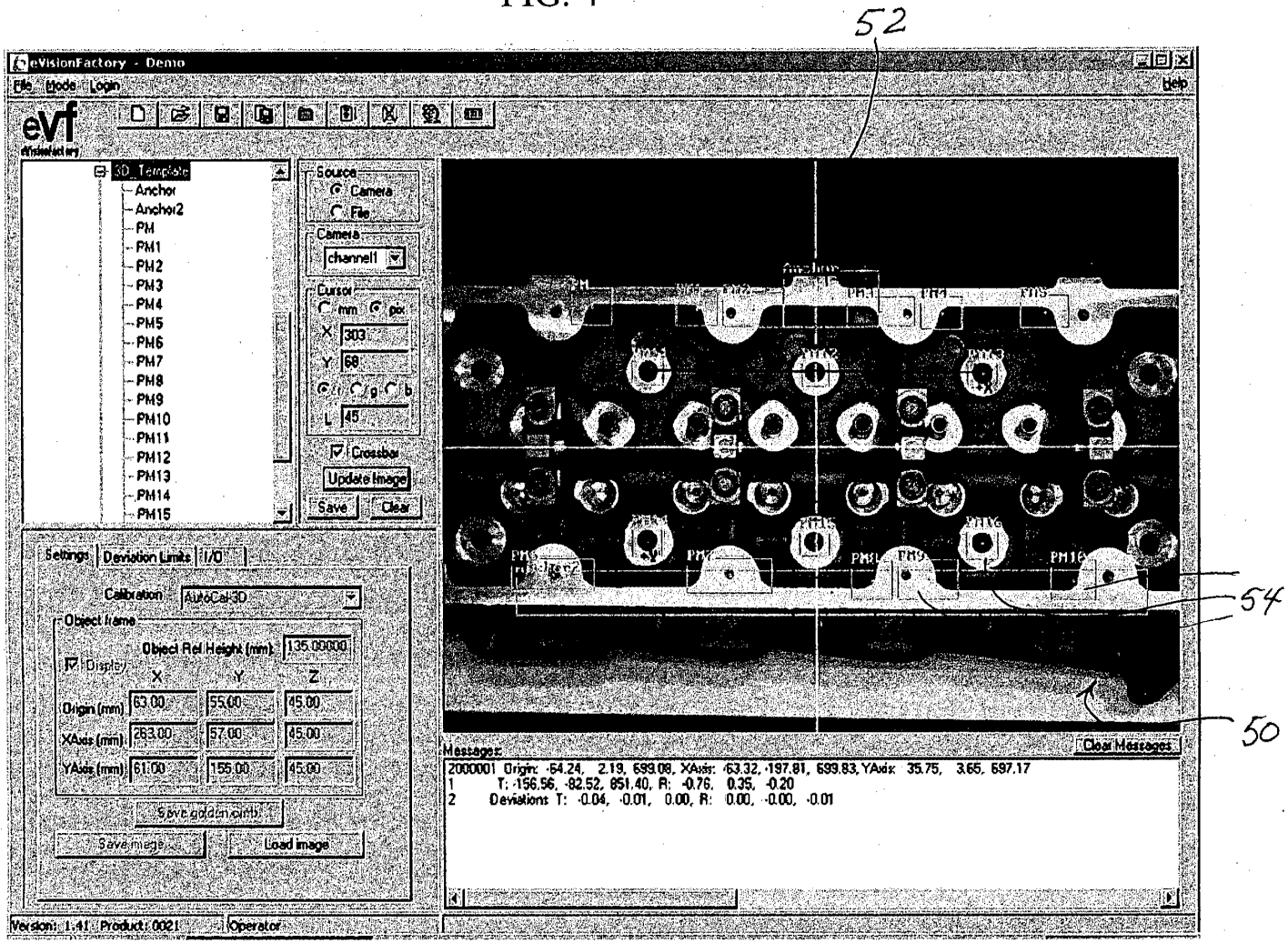

Camera to Tool
Calibration
Camera
16
Tool 14
Object Frame defined for each
position in Tool Space
tool path memorized
at training in object frame
Object Frame 34
40
extrinsic parameters
calculated at each position
using image
Object Space 36

Fig. 3

FIG. 4


52
eVisionFactory - Demo
File Mode Login
Help
3D_Template
Anchor
Anchor2
PM
PM1
PM2
PM3
PM4
PM5
PM6
PM7
PM8
PM9
PM10
PM11
PM12
PM13
PM14
PM15
Source
Camera
File
Camera
channel1
Cursor
mm pix
X 303
Y 68
L 45
Crossbar
Update Image
Save
Clear
Settings
Deviation Limits
I/O
Calibration
AutoCal-3D
Object Frame
Object Ref Height (mm) 135.00000
Display
X
Y
Z
Origin (mm) 63.00 55.00 45.00
XAxis (mm) 283.00 57.00 45.00
YAxis (mm) 61.00 155.00 45.00
Save golden orig
Save image
Load image
Version: 1.41 Product: 0021
Operator
Messages
Clear Messages
2000001 Origin: -54.24, 2.19, 699.08, XAxis: -63.32, -197.81, 699.83, YAxis: 35.75, 3.65, 697.17
1 T: -156.56, -82.52, 651.40, R: -0.76, 0.35, -0.20
2 Deviations T: -0.04, -0.01, 0.00, R: 0.00, -0.00, -0.01
54
50

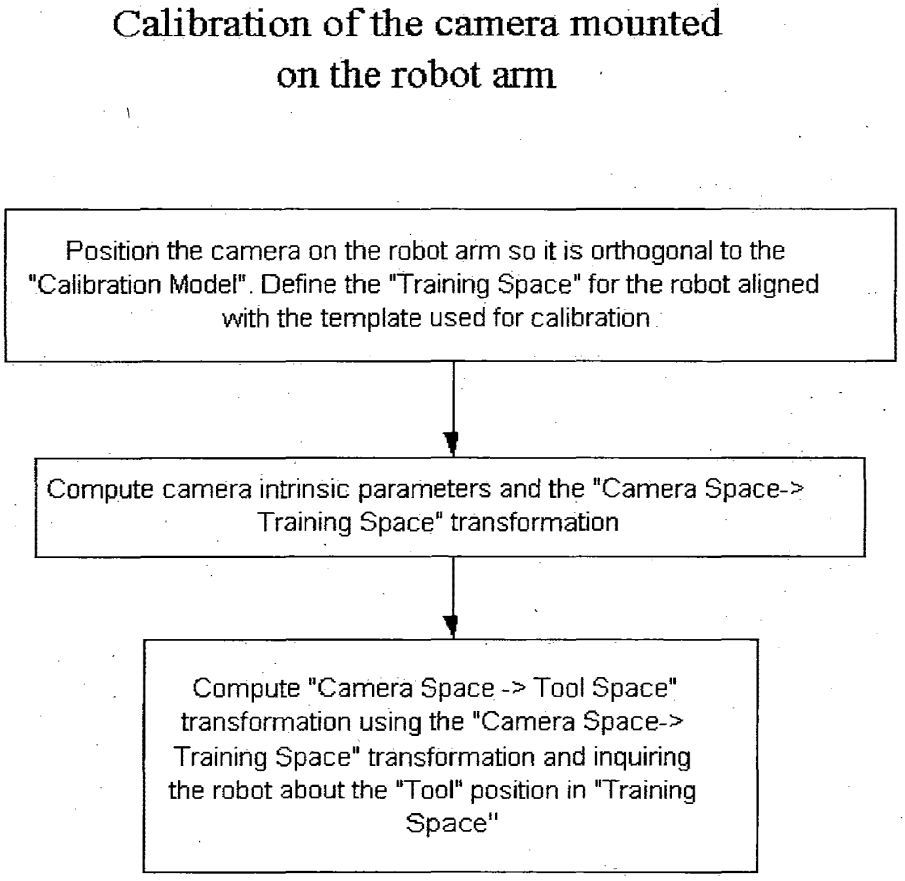

Calibration of the camera mounted on the robot arm
Position the camera on the robot arm so it is orthogonal to the "Calibration Model". Define the "Training Space" for the robot aligned with the template used for calibration
Compute camera intrinsic parameters and the "Camera Space-> Training Space" transformation
Compute "Camera Space -> Tool Space" transformation using the "Camera Space-> Training Space" transformation and inquiring the robot about the "Tool" position in "Training Space"

FIG. 5

Teaching The Object Features & Robot Operation Path

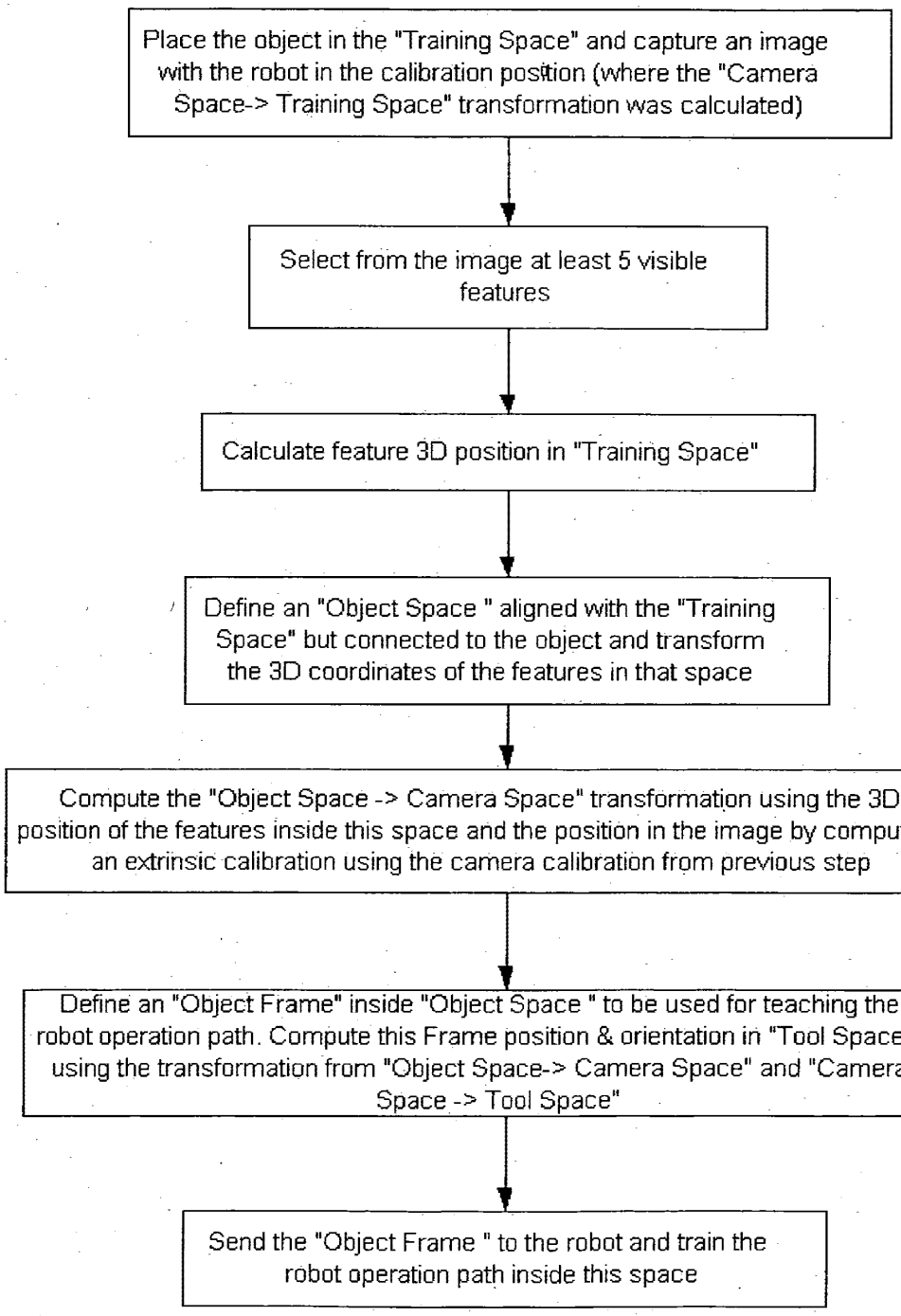


FIG. 6

Object Positioning and Robot Guidance

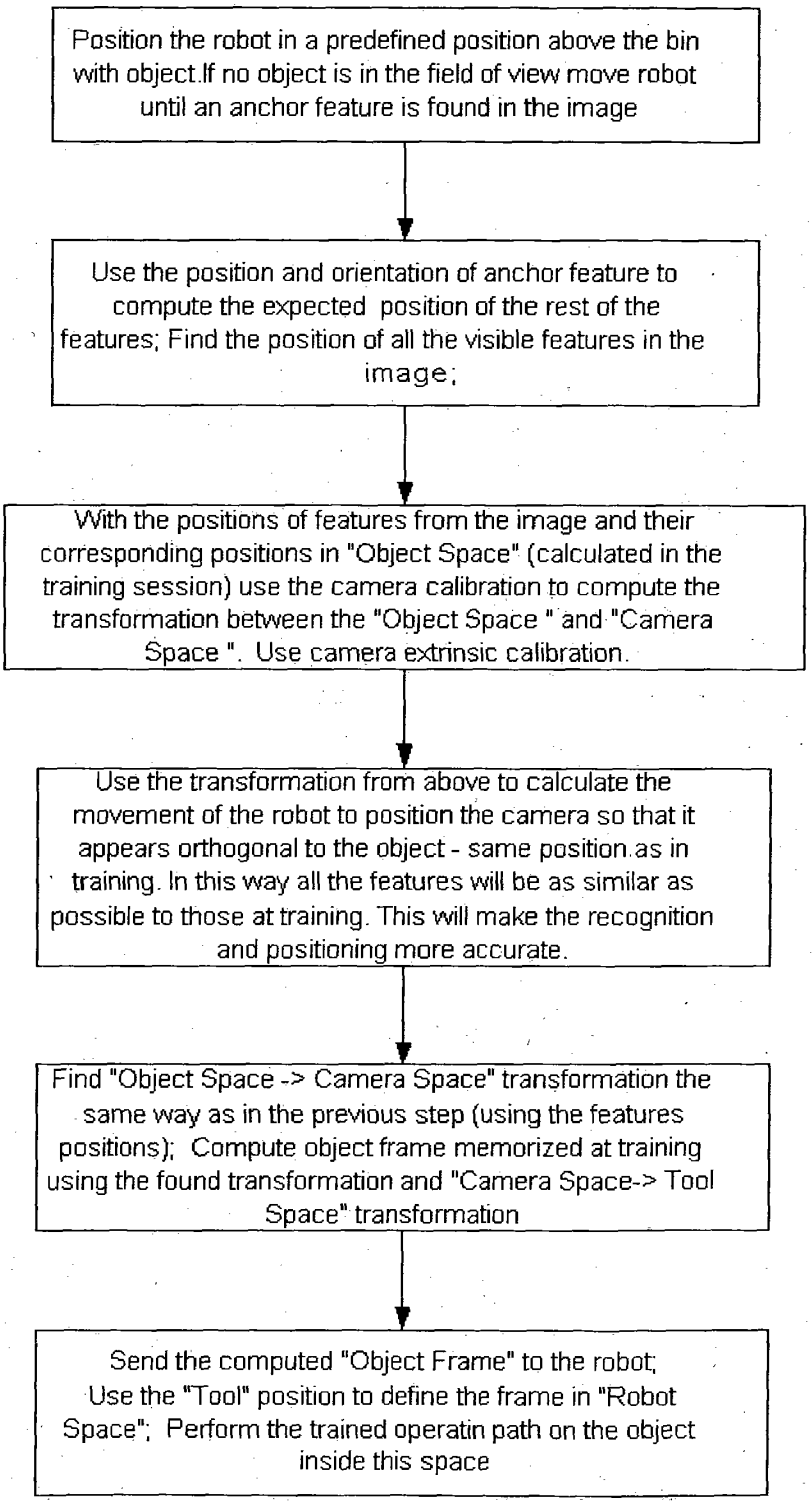


FIG. 7

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BMG/cnr

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name; that I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention entitled:

METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

which is described and claimed in the attached specification.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge my duty to disclose information which is material to the patentability of this invention in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application on which priority is claimed:

Prior Foreign/PCT Application(s)			Priority Claimed?	
Serial No.	Country	Filing Date	Yes	No
2,369,845	Canada	31 January, 2002	X	

ABB Inc. Exhibit 1002, Page 39 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

I hereby claim the benefit, under 35 U.S.C. §120, of any United States application(s) or any PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose material information as defined in 37 C.F.R. §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

U.S. Patent Applications		Status (Check One)		
Serial No.	Filing Date	Patented	Pending	Abandoned
10/153,680	05/24/2002		X	

I hereby appoint the following attorney(s) and/or agent(s), with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Name	Regn. No.	Name	Regn. No.
Gerald O.S. Oyen	27,280	Gavin N. Manning	36,412
Blake R. Wiggs	29,505	George F. Kondor	40,477
Bruce M. Green	30,524	Craig A. Ash	48,228
David J. McGruder	32,375	Hilton W.C. Sue	51,325
Thomas W. Bailey	36,411		

Please direct all telephone calls to Oyen Wiggs Green & Mutala at Tel. No. 604-669-3432. Please direct all faxes to Oyen Wiggs Green & Mutala at Fax No. 604-681-4081. Please address all correspondence to:

Oyen Wiggs Green & Mutala
Suite 480—The Station
601 West Cordova Street
Vancouver, British Columbia
Canada V6B 1G1

ABB Inc. Exhibit 1002, Page 40 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full name of sole or first Inventor:	Babak HABIBI
Inventor's signature:	_____
Date:	_____
Residence Address:	3308 Manning Crescent North Vancouver, B.C. V7H 2R6 Canada
Citizenship:	Canadian
Mailing Address:	Same as above
Full name of second Inventor:	Dr. Simona PESCARU
Inventor's signature:	_____
Date:	_____
Residence Address:	113 - 980 West 1st Street North Vancouver, B.C. V7P 3N4 Canada
Citizenship:	Canadian
Mailing Address:	Same as above

ABB Inc. Exhibit 1002, Page 41 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Full name of third Inventor: Mohammad SAMETI

Inventor's signature: _____

Date: _____

Residence Address: 2608 Sandstone Court
Coquitlam, B.C.
V3E 2T9 Canada

Citizenship: Canadian

Mailing Address: Same as above

Full name of fourth Inventor: Remus Florinel BOCA

Inventor's signature: _____

Date: _____

Residence Address: 512 - 2012 Fullerton Avenue
North Vancouver, B.C.
V7P 3E3 Canada

Citizenship: Canadian

Mailing Address: Same as above

ABB Inc. Exhibit 1002, Page 42 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

APPLICATION DATA SHEET

Application Information

Application Type::	Regular
Subject Matter::	Utility
Suggested Classification::	
Suggested Group Art Unit::	
CD-ROM or CD-R?	None
Title::	
Attorney Docket Number::	B445 0014
Request for Early Publication?::	No
Request for Non-Publication?::	No
Suggested Drawing Figure::	2
Total Drawing Sheets::	7
Small Entity::	Yes
Petition included?	No
Secrecy Order in Parent Application?	No

Applicant Information

Applicant Authority type::	Inventor
Primary Citizenship Country::	Canada
Status::	Full capacity
Given Name::	Habibi
Family Name::	Babak
City of Residence::	North Vancouver
State or Province of Residence::	British Columbia
Country of Residence::	Canada
Street of mailing address::	3308 Manning Crescent

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

City of mailing address:: North Vancouver
State or Province of mailing address:: British Columbia
Postal or Zip Code of mailing address:: V7H 2R6

Applicant Authority type:: Inventor
Primary Citizenship Country:: Canada
Status:: Full capacity
Given Name:: Simona
Family Name:: Pescaru
City of Residence:: North Vancouver
State or Province of Residence:: British Columbia
Country of Residence:: Canada
Street of mailing address:: 113 - 980 West 1st Street
City of mailing address:: North Vancouver
State or Province of mailing address:: British Columbia
Postal or Zip Code of mailing address:: V7H 2R6

Applicant Authority type:: Inventor
Primary Citizenship Country:: Canada
Status:: Full capacity
Given Name:: Mohammad
Middle Name::
Family Name:: Sameti
City of Residence:: Coquitlam
State or Province of Residence:: British Columbia
Country of Residence:: Canada
Street of mailing address:: 2608 Sandstone Court
City of mailing address:: Coquitlam
State or Province of mailing address:: British Columbia
Postal or Zip Code of mailing address:: V3E 2T9

ABB Inc. Exhibit 1002, Page 44 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Applicant Authority type::	Inventor
Primary Citizenship Country::	Canada
Status::	Full capacity
Given Name::	Remus
Middle Name::	Florinel
Family Name::	Boca
City of Residence::	North Vancouver
State or Province of Residence::	British Columbia
Country of Residence::	Canada
Street of mailing address::	512 - 2012 Fullerton Avenue
City of mailing address::	North Vancouver
State or Province of mailing address::	British Columbia
Postal or Zip Code of mailing address::	V7P 3E3

Correspondence Information

Name::	Oyen Wiggs Green & Mutala
Street of mailing address::	Suite 480 - 601 West Cordova Street
City of mailing Address::	Vancouver
State or Province of mailing address::	British Columbia
Postal or zip code of mailing address::	V6B 1G1
Telephone::	(604) 669-3432
E-mail address::	owgm@patentable.com
Correspondence Customer Number::	000720

Representative Information

Representative Designation::	Registration Number::	Name::
Primary	30,524	Bruce M. Green, Esq.
Associate	–	–

ABB Inc. Exhibit 1002, Page 45 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Domestic Priority Information

Application::	Continuity Type::	Parent Application::	Parent Filing Date::
This Application	Continuation-in-Part	10/153,680	05/24/2002

Foreign Priority Information

Country::	Application Number::	Filing Date::	Priority Claimed::
Canada	2369845	01/31/2002	Yes

Assignee Information

This application has no assignee data

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B445 0014
BMG/cnr

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

Inventors:	HABIBI, Babak; PESCARU, Simona, SAMETI, Mohammad, BOCA, Remus Florinel.
Title:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Filed:	Herewith
Date:	5 August 2003

Commissioner for Patents
Washington, D.C. 20231

Dear Sir/Madam:

Disclosure Statement Pursuant to 37 C.F.R. §1.56

Preliminary to the examination of this application, the applicant wishes to draw the Examiner's attention to the references listed on the attached copy of form PTO-1449. For the Examiner's convenience, copies of each of the listed references are submitted herewith.

REMARKS

This submission does not represent that a search has been made or that no better art exists and does not constitute an admission that each or all of the listed documents are material or constitute "prior art". If the Examiner applies any of the documents as prior art against any claim in the application and applicant determines that the cited documents do not constitute "prior art" under United States law, applicant reserves the right to present the relevant facts and law regarding the appropriate status of such documents.

Applicant further reserves the right to take appropriate action to establish the patentability of the disclosed invention over the listed documents, should one or more of the documents be applied against the claims of the present application.

Respectfully submitted,

By: _____

Bruce M. Green
Registration No.: 30,524
Tel. No.: (604) 669-3432 extn. 223
Fax No.: (604) 681-4081
email: *bgreen@patentable.com*

Vancouver, B.C.
CANADA

B445 0014
BMG/cnr

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

Inventors: HABIBI, Babak; PESCARU, Simona, SAMMETI, Mohammad, BOCA, Remus Florinel

Title: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Filed: Herewith

Date: 5 August 2003

Commissioner for Patents
Washington, D.C. 20231

Dear Sir/Madam:

LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT

[Form PTO-1449 (Modified)]

United States Patent Documents

Examiner	ID	Patent No.	Issue Date	Inventor(s)	Class	Sub-Cl	Filing Date
	US: 1	3,986,007	12 Oct 1976	Ruoff, Jr.			
	US: 2	4,146,924	27 Mar 1979	Birk et al.			
	US: 3	4,219,847	26 Aug 1980	Pinkney et al.			
	US: 4	4,305,130	8 Dec 1981	Kelley et al.			
	US: 5	4,334,241	8 Jun 1982	Kashioka et al.			
	US: 6	4,437,114	13 Mar 1984	LaRussa			
	US: 7	4,613,942	23 Sep 1986	Chen			
	US: 8	4,654,949	7 Apr 1987	Pryor			
	US: 9	4,942,539	17 Jul 1990	McGee et al.			
	US: 10	5,696,673	9 Dec 1997	Pryor			
	US: 11	5,956,417	21 Sep 1999	Pryor			
	US: 12	5,959,425	28 Sep 1999	Bieman et al.			
	US: 13	6,044,183	28 Mar 2000	Pryor			
	US: 14	6,141,863	7 Nov 2000	Hara et al.			

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IPR2023-01426

	US: 15	6,167,607	2 Jan 2001	Pryor			
	US: 16	6,211,506	3 Apr 2001	Pryor et al.			
	US: 17	6,301,763	16 Oct 2001	Pryor			

Other Art

Examiner	ID	Author, Title, Date, Pertinent Pages, etc.
	OA: 1	Roger Y. Tsai and Reimar K. Lenz, "A New Technique for Fully Autonomous and Efficient 3D Robotics Hand/Eye Calibration", *IEEE Transactions on Robotics and Automation*, Vol. 5, No. 3, June 1989 p. 345
	OA: 2	Zhengyou Zhang, "A Flexible New Technique for Camera Calibration", http://research.microsoft.com/scripts/pubs/view.asp?TR_ID=MSR-TR-98-71
	OA: 3	Guo-Qing Wei, Klaus Arbter, and Gerd Hirzinger, "Active Self-Calibration of Robotic Eyes and Hand-Eye Relationship with Model Identification", *IEEE Transactions on Robotics and Automation*, Vol 14, No. 1, February 1998 p. 158
	OA: 4	Yuncai Liu, Thomas S. Huang and Olivier D. Faugeras, "Determination of Camera Location from 2-D to 3-D Line and Point Correspondences", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 12, No. 1, January 1990 p. 28
	OA: 5	Chien-Ping Lu, Gregory D. Hager and Eric Mjolsness, "Fast and Globally Convergent Pose Estimation from Video Images", *IEEE Transactions on Pattern Analysis and Machine Intelligence,* Vol. 22, No. 6, June 2000 p. 610
	OA: 6	Thomas Huang, Alfred M. Bruckstein, Robert J. Holt, and Arun N. Netravali, "Uniqueness of 3D Pose Under Weak Perspective: A Geometrical Proof", *IEEE Transactions on Pattern Analysis and Machine Intelligence,* Vol. 17, No. 12, December 1995 p. 1220

Examiner: _____

Date Considered: _____

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

ABB Inc. Exhibit 1002, Page 49 of 996
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PATENT APPLICATION FEE DETERMINATION RECORD
Effective January 1, 2003

Application or Docket Number: 10,634,827

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	32	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	32 minus 20=	*
INDEPENDENT CLAIMS	2 minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	375.00	OR	BASIC FEE	750.00
X$ 9=		OR	X$18=	216
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL		OR	TOTAL	966

CLAIMS AS AMENDED - PART II

AMENDMENT A	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

30

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

ABB Inc. Exhibit 1002, Page 50 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PTO/SB/05 (03-01)
Approved for use through 10/31/2002. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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.

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	B445 0014
First Inventor	HABIBI, Babak
Title	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [✔] Fee Transmittal Form (e.g., PTO/SB/17) *(Submit an original and a duplicate for fee processing)*
2. [ ] Applicant claims small entity status. See 37 CFR 1.27.
3. [✔] Specification [*Total Pages* 29] *(preferred arrangement set forth below)*
   - Descriptive title of the invention
   - Cross Reference to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to sequence listing, a table, or a computer program listing appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (*if filed*)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
4. [✔] Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 7]
5. Oath or Declaration [*Total Pages* 3]
   a. [✔] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63 (d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [✔] Application Data Sheet. See 37 CFR 1.76

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

7. [ ] CD-ROM or CD-R in duplicate, large table or Computer Program (*Appendix*)
8. Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all necessary*)
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or
      ii. [ ] paper
   c. [ ] Statements verifying identity of above copies

17858 U.S. PTO 10/634874 08/05/03

ACCOMPANYING APPLICATION PARTS

9. [ ] Assignment Papers (cover sheet & document(s))
10. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
11. [ ] English Translation Document *(if applicable)*
12. [✔] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
13. [ ] Preliminary Amendment
14. [✔] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [ ] Nonpublication Request under 35 U.S.C. 122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or its equivalent.
17. [ ] Other: .....

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment, or in an Application Data Sheet under 37 CFR 1.76:*

[ ] Continuation [ ] Divisional [✔] Continuation-in-part (CIP) of prior application No.: 10/153680

Prior application information: *Examiner:* *Group Art Unit:* 3661

For CONTINUATION OR DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 5b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

19. CORRESPONDENCE ADDRESS

[✔] *Customer Number or Bar Code Label* 00720 *(Insert Customer No. or Attach bar code label here)* or [ ] *Correspondence address below*

Name					
Address					
City		*State*		*Zip Code*	
Country		*Telephone*		*Fax*	

Name (Print/Type)	Bruce M. Green	*Registration No. (Attorney/Agent)*	30,524
Signature		*Date*	08/05/2003

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

08/06/03 698 U.S. PTO

PTO/SB/17 (05-03)
Approved for use through 04/30/2003. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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.

FEE TRANSMITTAL for FY 2003

Effective 01/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 966

Complete if Known	
Application Number	not yet assigned
Filing Date	herewith
First Named Inventor	HABIBI, Babak
Examiner Name	
Art Unit	3661
Attorney Docket No.	B445 0014

METHOD OF PAYMENT *(check all that apply)*

☑ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☑ Deposit Account:

Deposit Account Number: 02-1037

Deposit Account Name: Oyen Wiggs Green & Mutala

The Director is authorized to: *(check all that apply)*

☐ Charge fee(s) indicated below ☑ Credit any overpayments

☑ Charge any additional fee(s) during the pendency of this application

☐ Charge fee(s) indicated below, **except for the filing fee** to the above-identified deposit account.

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	750	2001	375	Utility filing fee	750
1002	330	2002	165	Design filing fee	
1003	520	2003	260	Plant filing fee	
1004	750	2004	375	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 750

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

		Extra Claims		Fee from below	Fee Paid
Total Claims	32	-20** =	12	X 18	= 216
Independent Claims		- 3** =		X	=
Multiple Dependent					=

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	84	2201	42	Independent claims in excess of 3
1203	280	2203	140	Multiple dependent claim, if not paid
1204	84	2204	42	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 966

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	410	2252	205	Extension for reply within second month	
1253	930	2253	465	Extension for reply within third month	
1254	1,450	2254	725	Extension for reply within fourth month	
1255	1,970	2255	985	Extension for reply within fifth month	
1401	320	2401	160	Notice of Appeal	
1402	320	2402	160	Filing a brief in support of an appeal	
1403	280	2403	140	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,300	2453	650	Petition to revive - unintentional	
1501	1,300	2501	650	Utility issue fee (or reissue)	
1502	470	2502	235	Design issue fee	
1503	630	2503	315	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	750	2809	375	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	750	2810	375	For each additional invention to be examined (37 CFR 1.129(b))	
1801	750	2801	375	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)

SUBMITTED BY				(Complete *(if applicable)*)	
Name (Print/Type)	Bruce M. Green	*Registration No. (Attorney/Agent)*	30,524	*Telephone*	604-669-3432
Signature				*Date*	August 5, 2003

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

This collection of information is required by 37 CFR 1.17 and 1.27. 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 12 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS **ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

[redacted]

PATENT APPLICATION FEE DETERMINATION RECORD
Effective January 1, 2003

Application or Docket Number: 10634874

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	37	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	32 minus 20=	* 12
INDEPENDENT CLAIMS	2 minus 3 =	* 0
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	375.00	OR	BASIC FEE	750.00
X$ 9=	108	OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL	483	OR	TOTAL	

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

ABB Inc. Exhibit 1002, Page 53 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

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 NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NUMBER
10/634,874	08/06/2003	Babak Habibi	B445 0014

CONFIRMATION NO. 7619

000720
OYEN, WIGGS, GREEN & MUTALA
480 - THE STATION
601 WEST CORDOVA STREET
VANCOUVER, BC V6B 1G1
CANADA

FORMALITIES LETTER

OC000000011250519

Date Mailed: 11/13/2003

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is unsigned.
- To avoid abandonment, a late filing fee or oath or declaration surcharge as set forth in 37 CFR 1.16(e) of $65 for a small entity in compliance with 37 CFR 1.27, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is **$65** for a Small Entity

- **$65** Late oath or declaration Surcharge.

Replies should be mailed to: Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

A copy of this notice MUST be returned with the reply.

Customer Service Center
Initial Patent Examination Division (703) 308-1202
PART 3 - OFFICE COPY

O I P E JC67 MAY 12 2004 PATENT & TRADEMARK

B445 0014
BMG/cnr

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name; that I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the invention entitled:

METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

which is described and claimed in the attached specification.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge my duty to disclose information which is material to the patentability of this invention in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application on which priority is claimed:

Prior Foreign/PCT Application(s)			Priority Claimed?	
Serial No.	Country	Filing Date	Yes	No
2,369,845	Canada	31 January, 2002	X	

ABB Inc. Exhibit 1002, Page 56 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

I hereby claim the benefit, under 35 U.S.C. §120, of any United States application(s) or any PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose material information as defined in 37 C.F.R. §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

U.S. Patent Applications		Status (Check One)		
Serial No.	Filing Date	Patented	Pending	Abandoned
10/153,680	05/24/2002		X	

I hereby appoint the following attorney(s) and/or agent(s), with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Name	Regn. No.	Name	Regn. No.
Gerald O.S. Oyen	27,280	Gavin N. Manning	36,412
Blake R. Wiggs	29,505	George F. Kondor	40,477
Bruce M. Green	30,524	Craig A. Ash	48,228
David J. McGruder	32,375	Hilton W.C. Sue	51,325
Thomas W. Bailey	36,411		

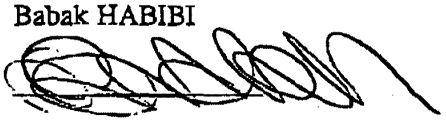
Please direct all telephone calls to Oyen Wiggs Green & Mutala at Tel. No. 604-669-3432. Please direct all faxes to Oyen Wiggs Green & Mutala at Fax No. 604-681-4081. Please address all correspondence to:

Oyen Wiggs Green & Mutala
Suite 480—The Station
601 West Cordova Street
Vancouver, British Columbia
Canada V6B 1G1

ABB Inc. Exhibit 1002, Page 57 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full name of sole or first Inventor: Babak HABIBI

Inventor's signature: 

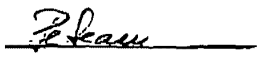
Date: May 07, '04

Residence Address: 3308 Manning Crescent
North Vancouver, B.C.
V7H 2R6 Canada

Citizenship: Canadian

Mailing Address: Same as above

Full name of second Inventor: Dr. Simona PESCARU

Inventor's signature: 

Date: May 6 2004

Residence Address: 113 - 980 West 1st Street
North Vancouver, B.C.
V7P 3N4 Canada

Citizenship: Canadian

Mailing Address: Same as above

ABB Inc. Exhibit 1002, Page 58 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Full name of third Inventor: Mohammad SAMETI

Inventor's signature: M. Sameti

Date: May 7, 2004

Residence Address: 2608 Sandstone Court
Coquitlam, B.C.
V3E 2T9 Canada

Citizenship: Canadian

Mailing Address: Same as above

Full name of fourth Inventor: Remus Florinel BOCA

Inventor's signature:

Date: May 07 2004

Residence Address: 512 - 2012 Fullerton Avenue
North Vancouver, B.C.
V7P 3E3 Canada

Citizenship: Canadian

Mailing Address: Same as above

ABB Inc. Exhibit 1002, Page 59 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

OIPE JC67 MAY 12 2004

PTO/SB/22 (08-03)
Approved for use through 7/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARMENT OF COMMERCE
Under the paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless if displays a valid OMB control number.

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)	Docket Number (Optional) B445 0014

In re Application of	Babak HABIBI et al.
Application Number	10/634,874 — Filed 08/06/2003
For	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Art Unit	3661 — Examiner

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above identified application.

The requested extension and appropriate non-small-entity fee are as follows (check time period desired):

- ☐ One month (37 CFR 1.17(a)(1)) $ _____
- ☐ Two months (37 CFR 1.17(a)(2)) $ _____
- ☐ Three months (37 CFR 1.17(a)(3)) $ _____
- ☒ Four months (37 CFR 1.17(a)(4)) $ 1,480
- ☐ Five months (37 CFR 1.17(a)(5)) $ _____

☒ Applicant claims small entity status. See 37 CFR 1.27. Therefore, the fee amount shown above is reduced by one-half, and the resulting fee is: $ 740.

☒ A check in the amount of the fee is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number _____.

I have enclosed a duplicate copy of this sheet.

I am the ☐ applicant/inventor.

☐ assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) is enclosed (Form PTO/SB/96).

☐ attorney or agent of record. Registration Number _____

☐ attorney or agent under 37 CFR 1.34(a).
Registration number if acting under 37 CFR 1.34(a) _____

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

May 11, 2004
Date

Signature

604 669-3432
Telephone Number

Bruce M. Green
Typed or printed name

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.

☐ Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.136(a). 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 6 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

05/13/2004 SMINASS1 00000048 10634874

02 FC:2254 740.00 OP

WEST Search History

Hide Items | Restore | Clear | Cancel

DATE: Monday, February 21, 2005

Hide?	Set Name	Query	Hit Count
		DB=PGPB,USPT,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=ADJ	
☐	L7	eye robot	134
☐	L6	('6301763' |'6167607' |'6141863' |'6044183' |'5959425' |'5956417' |'5696673' |'4942539' |'4654949' |'4613942' |'4437114' |'4305130' |'4146924')!.ABPN1,NRPN,PN,TBAN,WKU.	29
☐	L5	robot$6 and camera$ and L1	22
☐	L4	robot$6 and camera$ and senor and L1	0
☐	L3	robot$6 and camera$ and senor and array and L1	0
☐	L2	robot$6 and camera$ and senor same array and L1	0
☐	L1	(39860007 | 4146924 | 4219847 | 4305130 | 4334241 | 4437114 | 4613942 | 4654949 | 4942539 | 5696673 | 5956417 | 5959425 | 6044183 | 6141863 | 6167607 | 6211506 | 6301763).pn.	37

END OF SEARCH HISTORY

ABB Inc. Exhibit 1002, Page 61 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

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.
10/634,874	08/06/2003	Babak Habibi	B4450014	7619

720 7590 02/24/2005

OYEN, WIGGS, GREEN & MUTALA
480 - THE STATION
601 WEST CORDOVA STREET
VANCOUVER, BC V6B 1G1
CANADA

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	**PAPER NUMBER**
3661	

DATE MAILED: 02/24/2005

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

PTO-90C (Rev. 10/03)

JE

Office Action Summary	Application No.	Applicant(s)	
	10/634,874	HABIBI ET AL.	
	Examiner	Art Unit	
	McDieunel Marc	3661	

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

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-30* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-30* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

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

a)☐ All b)☐ Some * c)☐ None of:

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)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date *8/6/2003*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

DETAILED ACTION

1. Claims 1-30 are presented for examination.

2. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

3. Claims 1-30 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

4. Claim 1 recites the limitation "the object ("Object Model")" in line 14. There is insufficient antecedent basis for this limitation in the claim.

5. Claim 1 recites the limitation "the object ("Object Space") in line 16. There is insufficient antecedent basis for this limitation in the claim.

6. Claim 1 recites the limitation "the object ("Object Model")" in line 16. There is insufficient antecedent basis for this limitation in the claim.

7. Claim 1 recites the limitation "the object ("Object Space") in line 18. There is insufficient antecedent basis for this limitation in the claim.

Dependent claims not specifically rejected are rejected as being dependent upon a rejected base claim.

Double Patenting

8. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. **See *In re Goodman***, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); ***In re Longi***, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); ***In re Van Ornum***, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); **In re Vogel**, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and, ***In re Thorington***, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent is shown to be commonly owned with this application. See 37 CFR 1.130(b).

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

9. Claims 1-30 are rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-19 of U.S. Patent No. 6,816,755. Although the conflicting claims are not identical, they are not patentably distinct from each other because the claims of the application encompass the claims of the patent because they are broader.

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to McDieunel Marc whose telephone number is (703) 305-4478. The examiner can normally be reached on 6:30-5:00 Mon-Thu.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black can be reached on (703) 305-8233. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

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).

McDieunel Marc
February 21, 2005
MM/

THOMAS G. BLACK
SUPERVISORY PATENT EXAMINER
GROUP 3600

B445 0014
BMG/cnr

10/634,874

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

Inventors: HABIBI, Babak; PESCARU, Simona, SAMMETI, Mohammad, BOCA, Remus Florinel

Title: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Filed: Herewith

Date: 5 August 2003

Commissioner for Patents
Washington, D.C. 20231

Dear Sir/Madam:

Art Unit 3661

LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT

[Form PTO-1449 (Modified)]

United States Patent Documents

Examiner	ID	Patent No.	Issue Date	Inventor(s)	Class	Sub-Cl	Filing Date
m.m	US: 1	3,986,007	12 Oct 1976	Ruoff, Jr.			
	US: 2	4,146,924	27 Mar 1979	Birk et al.			
	US: 3	4,219,847	26 Aug 1980	Pinkney et al.			
	US: 4	4,305,130	8 Dec 1981	Kelley et al.			
	US: 5	4,334,241	8 Jun 1982	Kashioka et al.			
	US: 6	4,437,114	13 Mar 1984	LaRussa			
	US: 7	4,613,942	23 Sep 1986	Chen			
	US: 8	4,654,949	7 Apr 1987	Pryor			
	US: 9	4,942,539	17 Jul 1990	McGee et al.			
	US: 10	5,696,673	9 Dec 1997	Pryor			
	US: 11	5,956,417	21 Sep 1999	Pryor			
	US: 12	5,959,425	28 Sep 1999	Bieman et al.			
	US: 13	6,044,183	28 Mar 2000	Pryor			
	US: 14	6,141,863	7 Nov 2000	Hara et al.			

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

mm	US: 15	6,167,607	2 Jan 2001	Pryor			
	US: 16	6,211,506	3 Apr 2001	Pryor et al.			
	US: 17	6,301,763	16 Oct 2001	Pryor			

Other Art

Examiner	ID	Author, Title, Date, Pertinent Pages, etc.
mm	OA: 1	Roger Y. Tsai and Reimar K. Lenz, "A New Technique for Fully Autonomous and Efficient 3D Robotics Hand/Eye Calibration", *IEEE Transactions on Robotics and Automation*, Vol. 5, No. 3, June 1989 p. 345
	OA: 2	Zhengyou Zhang, "A Flexible New Technique for Camera Calibration", http://research.microsoft.com/scripts/pubs/view.asp?TR_ID=MSR-TR-98-71
	OA: 3	Guo-Qing Wei, Klaus Arbter, and Gerd Hirzinger, "Active Self-Calibration of Robotic Eyes and Hand-Eye Relationship with Model Identification", *IEEE Transactions on Robotics and Automation*, Vol 14, No. 1, February 1998 p. 158
	OA: 4	Yuncai Liu, Thomas S. Huang and Olivier D. Faugeras, "Determination of Camera Location from 2-D to 3-D Line and Point Correspondences", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 12, No. 1, January 1990 p. 28
	OA: 5	Chien-Ping Lu, Gregory D. Hager and Eric Mjolsness, "Fast and Globally Convergent Pose Estimation from Video Images", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 22, No. 6, June 2000 p. 610
	OA: 6	Thomas Huang, Alfred M. Bruckstein, Robert J. Holt, and Arun N. Netravali, "Uniqueness of 3D Pose Under Weak Perspective: A Geometrical Proof", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 17, No. 12, December 1995 p. 1220

Examiner: McDieunel Marc

Date Considered: 2-20-05

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

ABB Inc. Exhibit 1002, Page 68 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Notice of References Cited	Application/Control No. 10/634,874	Applicant(s)/Patent Under Reexamination HABIBI ET AL.	
	Examiner McDieunel Marc	Art Unit 3661	Page 1 of 2

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
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	Examiner McDieunel Marc	Art Unit 3661	Page 2 of 2

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(54) **Apparatus and method for robot calibration.**

(57) Robotic apparatus is guided by a computer 14 which is calibrated by cameras 20, 21, 22 mounted on the robot arm 11 which view targets 15, 16 fixed at a work station 13 and comprising a pattern of four dots. The viewing takes place as the robot arm approaches the work station to carry out the intended operation and the sensing of any deviation relative to a predetermined target pattern is transmitted to the computer 14 to re-set the robot's computerized guidance system.

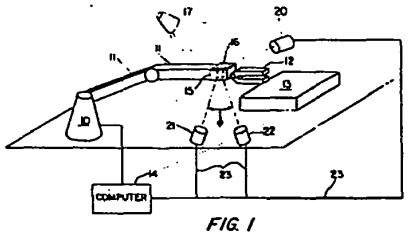


FIG. 1

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GJE/10/2179/02

DIFFRACTO LTD.

Apparatus and method for robot calibration

This invention relates to robotics, and in particular it relates to a method and apparatus for calibrating a robot.

The very essence of a robotic apparatus is that its movements are accurately predetermined so as to accurately carry out an intended operation such as handling or working on an object, the latter including, for example, welding or inspecting an object. Systems for guiding the robots through the course of their intended movements, to further enhance the accuracy of such movements have therefore been proposed.

However, no matter how perfect the original predetermined movements or no matter how accurate the guidance systems for enhancing the robot's movements, the nature of the environment in which the robots are utilised, including environmental conditions exterior to the robot make it virtually impossible to assure perfect positional accuracy at all times.

For example, many robots, particularly multi-joint articulated robots, are generally not capable of maintaining their positional actions over a long period of time. Furthermore, when approaching a given desired position from different paths, they often provide different results, even when functioning as a result of the same computer input commands. This can be extremely difficult in a fully flexible automatic factory situation where different path commands

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may have to be generated by the computer and the robot is expected to follow them under all conditions. Apparatus quite suitable for the purpose of enhancing the accuracy of the predetermined robot movements is shown in U.S. patent no: 4,219,847.

Hence, notwithstanding the improved means discussed above and known heretofore for enhancing guiding of the robot arm, there still exists a need to correct inaccuracies in the robot's position which cannot be corrected using known predetermined and improved guidance means and the primary object of the invention is to satisfy this need.

In principle this is achieved in accordance with the present invention by calibrating the robot's position as it approaches the work station, utilizing sensing means independent from the robot's own system for predetermining and guiding the robot's movements, and then sensing any deviation between a calibration signal and a reference signal. This deviation is then used to re-set the robot's basic computer guidance system. As a result thereof, as the robot's operative end approaches the work station, any error signals in its basic computerized program are re-set so that the robot's arm with its operating end are essentially given a fresh start from the location at which the calibration occurred, which will be in close proximity to the object, thereby in effect cancelling out any errors which preceded the point of calibration.

Apparatus in accordance with the invention and having an arm with an operative end for automatically handling or working on an object at a work station is thus characterised by a computerized guidance means for controlling movements of the arm and operative end for carrying out an intended handling or working on the object, a calibration means for checking and if

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necessary re-setting the guidance means, the calibration means comprising means for sensing the position of the arm and operative end independently of the guidance means, as the arm and operative end approach the work station, for generating a calibration signal, and means for comparing the calibration signal against a reference signal and noting any deviation therebetween and for re-setting the computerized guidance means in response to the deviation.

In a preferred arrangement, the calibration means comprises at least one target mounted on the arm and operative end, and including at least one camera mounted at a location independent of the arm and operative end appropriate for viewing the target as the arm and operative end approach the work station. In one arrangement, one or more cameras are located on the robot's arm while the target or targets are located at fixed locations in the vicinity of the work station such as on the floor, on a pillar, on the fixed part of a conveyor, or the like. In lieu of being mounted on the robot's arm, the cameras can be mounted at a remote location and in communication with sensing points on the robot's arm through fiber optics.

In another arrangement, the targets can be mounted on the robot's arm and the cameras located at fixed positions on the floor, pillars, or the like in the vicinity of the work station.

Examples in accordance with the present invention will now be described in more detail, with reference to the accompanying drawings, in which:-

Figure 1 is a perspective, schematic view of a robot and its work station, utilizing the features

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of the present invention;

Figure 2 is a schematic, perspective view similar to Figure 1 but showing a modification thereof; and

Figures 3A and 3B are diagrammatic views of the target, illustrating the operation of the invention.

There follows a detailed description of the preferred embodiments of the invention, to be read together with the accompanying drawings, wherein like elements are represented by like numerals throughout the several views.

Figure 1 illustrates a first preferred embodiment of the invention wherein a robotic apparatus 10 fixed to the floor includes an arm 11, in this case a multi-joint arm having an operative end 12. While this operative end can take any form for the purpose of handling or working on an object, including a camera which inspects an object, in the illustrated example there is shown an end effector 12. The work station 13, shown schematically in Figure 1, represents the area at which the operative end 12 would perform its function on the object.

In a known manner, the movements of the computer for purposes of carrying out the intended operation are controlled by computer 14. However, since it is impossible to guarantee positional accuracy of the operative end 12 under all conditions, there is provided in accordance with the present invention a system for checking and calibrating the position of the robot as it approaches the work station 13. In this embodiment this system includes one or more targets mounted on the robot arm 11, as illustrated at 15 and 16, and one or more cameras, as illustrated at 20, 21 and 22, each of which cameras are fixed relative to the surrounding environment, as illustrated by the floor level, independently of the robot arm 11. The cameras communicate

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through lines 23 with the computer 14.

In the embodiment of Figure 1, as the robot's operative end 12 approaches the work station 13, it passes its target 15 over a camera unit, for example, camera 21 which may be fixed with respect to the floor and in fact buried in the floor of the plant at a location which is presighted with respect to the robot's own coordinate axis. Alternatively, if repeatability is the only factor in question, camera 21 does not have to be presighted but it can be assured that the camera is returned to a certain initial condition point or in any event, its position relative to the robot can be determined.

As illustrated, the target 15 has four dots. Three dots are the minimum for checking the position of the robot arm 11 up to six axes of coordinate data including X, Y, Z, roll, pitch and yaw. The fourth dot in the pattern provides a check and hence a more accurate calibration. Hence, as the target 15 approached the view of camera 21 the computer 14 dictated that the arm 11 should be in a certain predetermined position. Camera 21 will either confirm this position or note a deviation therein. If a deviation is noted, camera 21 will convey this information back to the computer 14 through lines 23, whereupon the computer 14 will make the corrections in the robot's memory for that position. Since the calibrating system is performing its function in a very limited area, i.e. only in the area close to the work station as the operative end 12 approaches same, it is only correcting the robot position over a very small range. This enables the system to have a high resolution, typically 0.02mm.

For further resolution, especially in other axes, a two camera solution may be desirable. In this case, a second camera 22 would be provided, which camera also views the target 15, this camera being spaced from the target 15 by an acute included angle ϕ . In the

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alternative, the second camera can be located at position 20 which is 90° and in this case the camera would view a duplicate target 16. There may be provided a cube at the end of the robot arm having a plurality of these targets fixed thereon and of course geometrically fixed in reference with respect to each other. The targets may take many different forms such as white dots on a black background, illuminated points of diode lasers or light emitting diodes, fiber ends illuminated from a remote light source, etc. The camera units are typically solid state photo detector arrays of the type having a large number of separate photo detectors, and having an intrinsic digital measuring capability. Such units may have at least ten but preferably over a hundred separate photo detectors.

A flashed (strobe)target illumination light 17 or flashed target points (diode lasers or light emitting diodes) may be used. This provides the advantage of reading the dots and making the correction while the robot is in motion, i.e."on-the-fly". If such a flashed light source is utilized, then a position sensing analogue photo detector such as a UDT SC-10 can be used. However, this is drift prone and therefore not necessarily suited to the most accurate mensuration. For calibration over larger zones of the work area, it may be necessary to mechanically sweep the field of view.

Figure 2 illustrates a calibration system according to the present invention in which the basic features thereof have been reversed, i.e. in this case, the robot arm carries the cameras while the dotted targets are fixed with respect to the work station,i.e. on the floor, on pillars or the like, independently of the robot arm 11. Figure 2 illustrates a pair of cameras 25 and 26 mounted on the robot arm 11 and targets 28

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and 29 fixed to the floor and to a pillar 30, respectively. A larger target 31 is mounted on a more distant pillar 32.

Adding the cameras to the robot arm has the disadvantage of adding additional weight thereto. However, these cameras are relatively light. Moreover, as an improvement thereof, the camera can be located at a remote position, as illustrated diagrammitically at 35, and connected to viewing points at the end of the robot arm 11 through fiber optics 36.

As illustrated in Figure 2, the robot arm 11 with the cameras thereon moves toward the work station 13 and as it approaches the work station the targets 28 or 29 come within view of the cameras 26 and 25, respectively. As in Figure 1, four dot matrix targets are desirable, although the system is operable for correcting in all six directions utilizing a minimum of three dots. In the embodiment of Figure 2, since the targets are not carried by the robot arm, the targets may be larger. Consequently, the accuracy of the solution may be considerably higher than in the case of a single closely spaced target. This is particularly true in range and angle dimensions.

In this embodiment with the targets fixed at selected locations in the vicinity of the work station, additional targets may be provided at especially advantageous points. For example, a target may be located directly behind a work object being conveyed such that when the work is transferred out, the target remains and is viewed by a camera, thus indicating removal of the object. Also, in the embodiment of Figure 2, many more target views can easily be utilized. Hence, the robot can be calibrated and hence corrected from a variety of angles by simply looking at the same target plate with different cameras or different points in

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time. This can give improved resolution as encoder errors are statistically averaged and the average of multiple transform equations are used. Since targets are cheap, one or more target plates can be used very easily. In addition, more than one camera can be used on the robot. Two are illustrated in this embodiment. Given the fiber optic system for remotely locating the camera, each camera can view different directions simultaneously.

Also, in Figure 2, a strobe target illumination light 17 may be used for making readings on-the-fly. This can be important for maximum cycle rate since the robot need not stop. The flash source "freezes" the target image on the photodetector (for example, the matrix array) which then is read out subsequently. To accomplish this on the present matrix arrays, it may be necessary to provide a dump pulse to clear the array moments before the flash.

In this case the trigger to flash generally would come from the robot axis controller which would convey a signal indicating that the robot is at the calibration position. Use of flash sources also provides good background light level discrimination. Where laser or light emitting diode sources are used, further discrimination results by using wave length band pass filters in front of the detector.

It will be noted that the targets may also be located on pallets, on automation equipment or on the objects themselves to provide a very local calibration to the robot axes.

Figure 3 illustrates a practical example of the present invention using a typical four dot matrix target to correct in all six directions, X, Y, Z, θ, ϕ, γ. Figure 3A illustrates the correct reference position of the matrix, i.e. the view of the matrix if the robot arm 11 were perfectly positioned as the target came into

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the view of the camera. However, Figure 3B illustrates the matrix as actually viewed by the camera. The target image, as viewed on the computer screen is off center and tilted such that the distances a' and b' are less than the reference distances a and b. This indicates a tilt and also a Z axis range lengthening. These variables can be solved independently given equations such as are known in the photogrammetric art and referred to in the above noted Pinkney et al U.S. patent no. 4,219,847.

In addition, the dots in Figure 3B illustrate that the target is off center in both axes. All of the correction data is then fed into the computer 14 to reset the memory which controls the computers movements, whereupon the servos operating the robot arm 11 are actually moved to reposition the robot so that its target appears as in Figure 3A. This new position of the correct reading is then locked into the memory and becomes a new reference point from which the robot goes forward.

It is noted that the calibration system does not have to be permanently attached to the robot but can be brought up to it at any time, assuming that some reliable procedure exists for accurately positioning the calibration system for each subsequent application. Thus, once the system has been operated, periodic calibration of may robots in a plant can be done with a single calibration system.

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CLAIMS

1. Robotic apparatus having an arm with an operative end for automatically handling or working on an object at a work station characterised by a computerized guidance means for controlling movements of the arm and operative end for carrying out an intended handling or working on the object, a calibration means for checking and if necessary re-setting the guidance means, the calibration means comprising means for sensing the position of the arm and operative end independently of the guidance means, as the arm and operative end approach the work station, for generating a calibration signal, and means for comparing the calibration signal against a reference signal and noting any deviation therebetween and for re-setting the computerized guidance means in response to the deviation.

2. Apparatus according to claim 1 in which the calibration means comprises at least one target mounted on the arm and operative end, and including at least one camera mounted at a location independent of the arm and operative end and appropriate for viewing the target as the arm and operative end approach the work station.

3. Apparatus according to claim 2 including a plurality of cameras positioned to view a single target.

4. Apparatus according to claim 1 in which the calibration means comprises at least one camera means on the arm and operative end, and at least one target mounted in the vicinity of the work station, independently of the arm and operative end.

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5. Apparatus according to claim 4 in which the camera means comprises a camera device located remote from the arm and operative end, and fiber optics located on the arm and operative end and communicating with the camera device.

6. Apparatus according to any one of claims 2 to 5 in which the target comprises a pattern of at least three dots positioned to be viewed by the camera to ascertain the position of the arm and operative end in the X, Y, Z pitch, roll and yaw directions.

7. Apparatus according to claim 6 in which the target includes four dots arranged in a rectangular pattern.

8. A method for calibrating a robotic apparatus of the type having an arm and operative end for automatically handling or working on an object at a work station, characterised by the steps of guiding movements of the arm and operative end by means of a programmed guidance computer to carry out an intended handling or working on the object, and calibrating movements of the computerized arm and operative end as the arm and operative end approach the work station, by sensing the position of the arm and operative end, as they approach the work station, independently of the guidance means, to generate a calibration signal, comparing the calibration signal with a predetermined reference signal and re-setting the guidance computer in response to any deviation between the calibration signal and the reference signal.

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9. A method according to claim 8 wherein the calibration step comprises viewing a target with a camera, either the camera or the target being located on the arm and operative end and the other being located in the vicinity of the work station and fixed independently of the arm and operative end.

10. A method according to claim 9 wherein at least one camera means is located on the arm and operative end and views at least one target located at the work station.

11. A method according to claim 9 wherein at least one camera is located at the work station, independently of the arm and operative end and at least one target is mounted on the arm and operative end.

12. A method according to claim 10 or claim 11 wherein the target comprises a pattern of at least three dots, and the deviation signal represents a distortion of this pattern of dots.

13. A method according to any one of claims 9 to 12 wherein the step of viewing the target with the camera is carried out under flashed light (strobe) illumination.

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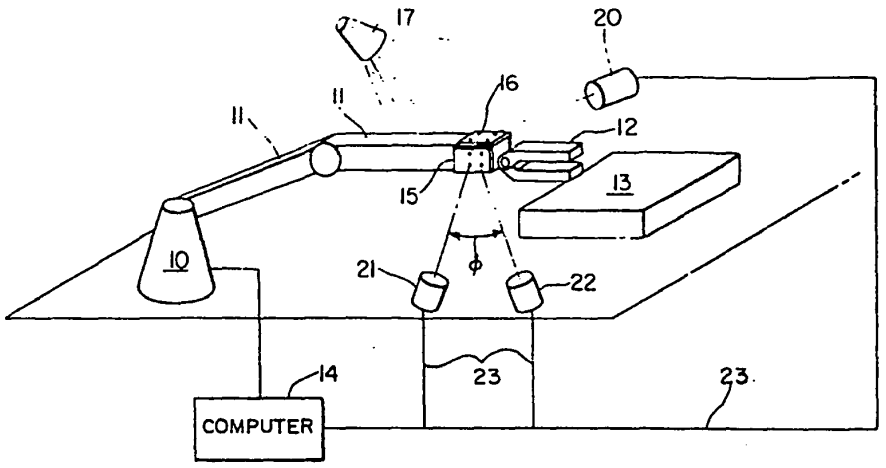


FIG. 1

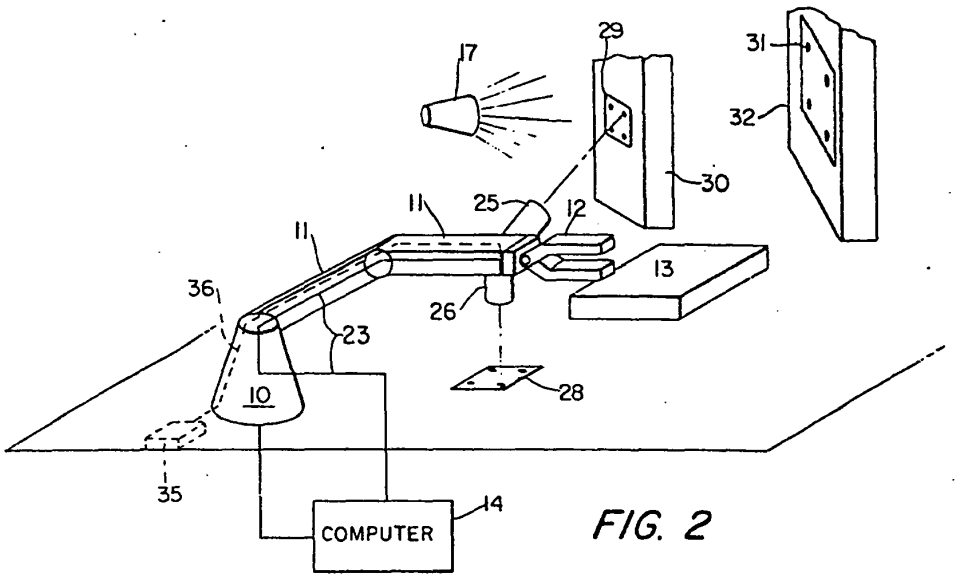


FIG. 2

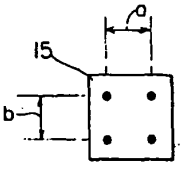


FIG. 3A



FIG. 3B

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EUROPEAN SEARCH REPORT

0114505
Application number

EP 83 30 7827

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-04-1984	LAMMINEUR P.C.G.

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CATEGORY OF CITED DOCUMENTS

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EUROPEAN SEARCH REPORT

0114505
Application number

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	US-A-4 356 554 (SUSNJARA et al.) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-04-1984	LAMMINEUR P.C.G.

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	Examiner	Art Unit	
	McDieunel Marc	3661	2

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Search Notes

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29	720	2/21/2005	MM
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318	568.15	2/21/2005	MM
318	568.13	2/21/2005	MM
318	568.16	2/21/2005	MM
318	640	2/21/2005	MM

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
Palm inventors search	2/21/2005	MM
West search see attached listing	2/21/2005	MM
NPL search see attached listing	2/21/2005	MM

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ABB Inc. v. Roboticvisiontech, Inc.
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Express Mail No. EV335546775US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Examiner	:	McDieunel Marc
Art Unit	:	3661
Docket No.	:	170154.401C1
Date	:	June 23, 2005

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

AMENDMENT

Commissioner for Patents:

In response to the Office Action dated February 24, 2005, please extend the period of time for response one month, to expire on June 24, 2005. Enclosed are a Petition for an Extension of Time and the requisite fee. Please amend the application as follows:

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks/Arguments begin on page 9 of this paper.

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Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1-32. (Canceled)

33. (New) A method useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of a robot, the method comprising:

capturing a number of images of a calibration object by the camera;

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and

determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame.

34. (New) The method of claim 33, further comprising:

positioning the camera with respect to the calibration object.

35. (New) The method of claim 34 wherein positioning the camera with respect to the calibration object comprises positioning the camera orthogonally with respect to a ruled template with a number of features, where a known or determinable physical relationship exists between at least some of the features.

36. (New) The method of claim 34 wherein positioning the camera with respect to the calibration object comprises positioning the camera with respect to a sample of a

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type of object the robot will manipulate, the sample having a number of features, where a known or determinable physical relationship exists between at least some of the features.

37. (New) The method of claim 34 wherein capturing a number of images of a calibration object by the camera comprises capturing at least one image at each of a plurality of positions spaced perpendicularly from the calibration object.

38. (New) The method of claim 34 wherein capturing a number of images of a calibration object by the camera comprises capturing at least one image at each of a plurality of different orientations with respect to the calibration object.

39. (New) The method of claim 33 wherein determining a set of intrinsic parameters of the camera from the at least one of the number of images of the calibration object captured by the camera comprises determining at least one of a focal length, a first order radial lens distortion coefficient, a set of coordinates of a center of a radial lens distortion, or a scale factor indicative of a framegrabber scanline resampling uncertainty.

40. (New) The method of claim 33 wherein determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame comprises determining a respective translation component along three orthogonal axes, and a respective rotation component about the three orthogonal axes.

41. (New) The method of claim 33, further comprising:

determining a camera space-to-tool space transformation based at least in part on at least two of the number of images captured by the camera of the calibration object.

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42. (New) The method of claim 33, further comprising:

determining a camera space-to-tool space transformation based on single one of the number of images captured by the camera of the calibration object and on a number of physical coordinates of at least one feature of the calibration object.

43. (New) The method of claim 33, further comprising:

capturing an image of a teaching object of a type of object that will be manipulated by the robot;

selecting a number of features from the captured image of the teaching object;

determining a set of object space coordinates for each of the selected features from the captured image of the teaching object; and

44. (New) The method of claim 43 wherein selecting a number of features from the captured image of the teaching object comprises selecting six features from the captured image of the teaching object.

45. (New) The method of claim 43, further comprising:

determining an object space-to-camera space transformation defining a transformation between an object space reference frame and the camera space reference frame.

46. (New) The method of claim 45, further comprising:

determining a position and an orientation of an object frame in the tool frame reference frame based at least in part on the object frame-to-camera space and camera space-to-tool space transformations.

47. (New) The method of claim 46, further comprising:

providing the position and orientation of the object frame to the robot; and

training an intended operation path inside the object frame.

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48. (New) The method of claim 43, further comprising:

capturing a two-dimensional image of a volume containing a target object; and

locating a number of features in the captured image of the target object.

49. (New) The method of claim 48, further comprising:

adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features.

50. (New) The method of claim 48, further comprising:

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using an algorithm that employs a known or determinable physical relationship between at least some of the located features.

51. (New) The method of claim 50, further comprising:

determining at least one movement of the robot that orients the camera orthogonally with respect to the target object based at least on part on the object space-to-camera space transformation.

52. (New) The method of claim 51, further comprising:

determining a position of the object frame in the tool space reference frame; and

providing an object frame to the robot.

53. (New) An apparatus useful in robotics, the apparatus comprising:

a single camera operable to capture at a number of images of a calibration object by the camera;

means for calibrating the camera, by:

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and

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determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame; and

means for estimating a pose of a target object, by:

capturing a two-dimensional image of an volume containing a target object; and

locating at least six features in the captured image of the target object; and

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using an algorithm that employs a known or determinable physical relationship between at least some of the located features.

54. (New) The apparatus of claim 53, further comprising:

means for training, comprising:

capturing an image of a teaching object of a type of object that will be manipulated by the robot;

selecting a number of features from the captured image of the teaching object;

determining a set of object space coordinates for each of the selected features from the captured image of the teaching object; and

determining an object space-to-camera space transformation defining a transformation between an object space reference frame and the camera space reference frame.

55. (New) The apparatus of claim 54 wherein the means for calibrating, the means for estimating a pose, and the means for training comprises at least one programmed computer.

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56. (New) The apparatus of claim 54 wherein the means for calibrating, the means for estimating a pose, and the means for training comprises at least one computer-readable medium storing instructions operating at least one computer.

57. (New) The apparatus of claim 53 wherein the pose estimating means estimates the pose of the target object further by:

adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features.

58. (New) An apparatus useful in robotics, the apparatus comprising:

a single camera operable to capture a number of images of a calibration object by the camera;

means for calibrating the camera, by:

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and

determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame; and

means for estimating a pose of a target object, by:

capturing a two-dimensional image of an volume containing a target object; and

locating at least five features in the captured image of the target object;

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using an algorithm that employs a known or determinable physical relationship between at least some of the located features.

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59. (New) The apparatus of claim 58 wherein the means for calibrating and the means for estimating a pose comprises at least one programmed computer.

60. (New) The apparatus of claim 58 wherein the means for calibrating and the means for estimating a pose comprises at least one computer-readable medium storing instructions operating at least one computer.

61. (New) The apparatus of claim 58 wherein the pose estimating means estimates the pose of the target object further by:

adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features.

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REMARKS/ARGUMENTS

This is a Response to the Office Action mailed February 24, 2005, in which a three (3) month Shortened Statutory Period for Response has been set, due to expire May 24, 2005. Enclosed is our check to cover the fee for a one-month extension of time, to June 24, 2005. Thirty-two (32) claims, including two (2) independent claims, were paid for in the application. Claims 1-32 have been canceled. New claims 33-61 have been added. No new matter has been added to the application. No fee for additional claims is due by way of this Amendment. The Director is authorized to charge any additional fees due by way of this Amendment, or credit any overpayment, to our Deposit Account No. 19-1090. Claims 33-61 are pending.

Objections

Claims 2-29 and 31-32 were objected to as being dependent on a rejected base claim. Claims 2-29 and 31-32 are hereby canceled.

Rejections Under 35 U.S.C. § 112, Second Paragraph

Claims 1-30 were rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to point out and distinctly claim the subject matter which the applicant regards as his invention. Claims 1-30 are hereby canceled.

Obviousness-Type Double Patenting Rejections

The Examiner has rejected claims 1-30 under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-19 of U.S. Patent No. 6,816,755 to Habibi et al. Claims 1-30 are hereby canceled.

Conclusion

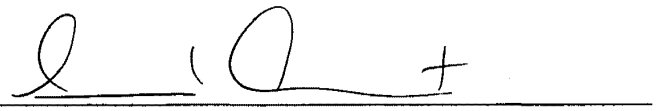
In light of the above amendments and remarks, Applicants respectfully submit that all pending claims are allowable. Applicants, therefore, respectfully request that the Examiner reconsider this application and timely allow all pending claims. Examiner Marc is

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encouraged to contact Mr. Abramonte by telephone to discuss the above and any other distinctions between the claims and the applied references, if desired. If the Examiner notes any informalities in the claims, the Examiner is encouraged to contact Mr. Abramonte by telephone to expediently correct such informalities.

Respectfully submitted,

Seed Intellectual Property Law Group PLLC



Frank Abramonte
Registration No. 38,066

FA:lrw

Enclosure:
Postcard

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ABB Inc. Exhibit 1002, Page 99 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

EXPRESS MAIL NO. EV335546775US

PTO/SB/22 (10-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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.

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a) **FY 2005** **(Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).)**	Docket Number 170154.401C1
Application Number 10/634,874	Filed August 6, 2003
For METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS	
Art Unit 3661	Examiner McDieunel Marc

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

	Fee	Small Entity Fee	
[X] One month (37 CFR 1.17(a)(1))	$120	$60	$60
[ ] Two months (37 CFR 1.17(a)(2))	$450	$225	$_____
[ ] Three months (37 CFR 1.17(a)(3))	$1020	$510	$_____
[ ] Four months (37 CFR 1.17(a)(4))	$1590	$795	$_____
[ ] Five months (37 CFR 1.17(a)(5))	$2160	$1080	$_____

[X] Applicant claims small entity status. See 37 CFR 1.27.

[X] A check in the amount of the fee is enclosed.

[ ] Payment by credit card. Form PTO-2038 is attached.

[ ] The Director has already been authorized to charge fees in this application to a Deposit Account.

[ ] The Director is hereby authorized to charge any fees which may be required or credit any overpayment, to Deposit Account Number 19-1090. I have enclosed a duplicate copy of this sheet.

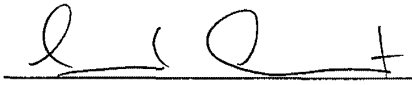
WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the [ ] applicant/inventor.

[ ] assignee of record of the entire interest. See 37 CFR 3.71
Statement under 37 CFR 3.73(b) is enclosed (Form PTO/SB/96).

[ ] attorney or agent of record. Registration No. _____

[X] attorney or agent under 37 CFR 1.34.
Registration number if acting under 37 CFR 1.34. 38,066 .



Signature — June 23, 2005 (Date)

Frank Abramonte — Typed or printed name

(206) 622-4900 — Telephone Number

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required.

This collection of information is required by 37 CFR 1.136(a). 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 1.11 and 1.14. This collection is estimated to take 6 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

06/28/2005 EAREGAY1 00000028 10634874
02 FC:2251 60.00 OP

OIPE JC26
JUN 23 2005
PATENT & TRADEMARK OFFICE

EXPRESS MAIL NO. EV335546775US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Examiner	:	McDieunel Marc
Art Unit	:	3661
Docket No.	:	170154.401C1
Date	:	June 23, 2005

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

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents:

In accordance with 37 CFR 1.56 and 1.97 through 1.98, applicants wish to make known to the Patent and Trademark Office the 21 references set forth on the attached Form PTO-1449. This application relies, under 35 U.S.C. § 120, on the earlier filing date of prior Application No. 10/153,680, filed May 24, 2002. References AA-AG, AK-AN and AP-AQ were submitted to and/or cited by the Patent and Trademark Office in this prior application and, therefore, are not required to be provided in this application. If the Examiner wishes, copies will be provided upon request. Copies of cited U.S. patent 6,804,416 (reference AH) and published patent application 2004/0114033 (reference AI) are not required and accordingly have not been provided. Copies of all other cited references (references AJ, AO, BA and BP-BR) are enclosed. As to any reference supplied, applicants do not admit that it is "prior art" under 35 U.S.C. §§ 102 or 103, and specifically reserve the right to traverse or antedate any such reference, as by a showing under 37 CFR 1.131 or other method. Although the aforesaid references are made known to the Patent and Trademark Office in compliance with applicants' duty to disclose all information they are aware of which is believed relevant to the examination of the above-identified application, applicants believe that their invention is patentable.

06/28/2005 EAREGAY1 00000028 10634874
01 FC:1806 180.00 OP

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Please acknowledge receipt of this Supplemental Information Disclosure Statement and kindly make the cited references of record in the above-identified application.

A fee of $180 is submitted in accordance with 37 CFR 1.97(c). The Director is authorized to charge any other fees which may be required, or credit any overpayment to Deposit Account No. 19-1090.

Respectfully submitted,
Seed Intellectual Property Law Group PLLC

Frank Abramonte
Registration No. 38,066

FXA:lrw
Enclosures:
Postcard
Check
Form PTO-1449
Cited References (6)

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IPR2023-01426

FORM PTO-1449 (REV. 7-80)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTY. DOCKET NO.	APPLICATION NO.
		170154.401C1	10/634,874
		APPLICANTS	
	INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	Babak Habibi et al.	
		FILING DATE	GROUP ART UNIT
		August 6, 2003	3661

OIPE JC26 JUN 23 2005 PATENT & TRADEMARK OFFICE

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	AA	4,578,561	03/25/86	Corby, Jr. et al.	219	124.34	
	AB	4,835,450	05/30/89	Suzuki	318	568.13	
	AC	5,083,073	01/21/92	Kato	318	577	
	AD	5,350,269	09/27/94	Azuma et al.	414	416	
	AE	5,454,775	10/03/95	Cullen et al.	483	16	
	AF	6,341,246	01/22/02	Gerstenberger et al.	700	245	
	AG	6,466,843	10/15/02	Bonanni et al.	700	245	
	AH	6,804,416	10/12/04	Bachelder et al.	382	294	
	AI	2004/0114033	06/17/04	Eian et al.	348	42	
	AJ	60/413,180		Eian et al.			09/23/02

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	TRANSLATION YES	TRANSLATION NO
	AK	0151417	08/14/85	EP		
	AL	0493612	07/08/92	EP		
	AM	0951968	10/27/99	EP		
	AN	401124072	05/89	JP		
	AO	0911603 B1	04/28/99	EP (with machine translation)	X	

OTHER PRIOR ART *(Including Author, Title, Date, Pertinent Pages, Etc.)*

	AP		Denzler, J., et al., "Learning, Tracking and Recognition of 3D Objects," *Proceedings of the IEEE/RSJ/GI, International Conference on Intelligent Robots and Systems*. (No date available.)
	AQ		"Advanced Robotic Systems and the Real World," *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, XP000512662, Vol. 1, Munich, September 12, 1994, pp. 89-96.

EXAMINER	DATE CONSIDERED

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

599816_1

Date: June 23, 2005

FORM PTO-1449 (REV.7-80)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTY. DOCKET NO. 170154.401C1	APPLICATION NO. 10/634,874
INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)		APPLICANTS Babak Habibi et al.	
		FILING DATE August 6, 2003	GROUP ART UNIT 3661

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	BA	60/587,488		Boca et al.			07/14/04
	BB						
	BC						
	BD						
	BE						
	BF						
	BG						
	BH						
	BI						
	BJ						

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	TRANSLATION YES	TRANSLATION NO
	BK					
	BL					
	BM					
	BN					
	BO					

OTHER PRIOR ART *(Including Author, Title, Date, Pertinent Pages, Etc.)*

	BP		W. Meyer, "One-Eyed Robots With 3D Vision," ISRA Vision Systems AG, Press News, Release No. 16, June 15, 2004, pp 1-7.
	BQ		"3D Robot Guidance with a Single Camera," ISRA Vision Systems AG. (No date available.)
	BR		3D Vision with One Camera, URL=http://neu.isravision.com/likecms/index.php?site=site.html&dir=isra&nav=162, download date April 12, 2005.

EXAMINER	DATE CONSIDERED

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

Express Mail No.
EV335546775US

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 911 603 B1

(12) **EUROPÄISCHE PATENTSCHRIFT**

(45) Veröffentlichungstag und Bekanntmachung des Hinweises auf die Patenterteilung:
27.06.2001 Patentblatt 2001/26

(51) Int Cl.[7]: **G01B 11/00**, G05B 19/401

(21) Anmeldenummer: **97118334.8**

(22) Anmeldetag: **22.10.1997**

(54) **Verfahren zur optischen Bestimmung der Lage eines räumlichen Körpers**

Method for the determination of the position of a three-dimensional body

Procédé pour la détermination de la position d'un object tridimensionel

(84) Benannte Vertragsstaaten:
BE DE DK ES FR GB IT PT SE

(43) Veröffentlichungstag der Anmeldung:
28.04.1999 Patentblatt 1999/17

(73) Patentinhaber: **ISRA Vision Systems AG**
64297 Darmstadt (DE)

(72) Erfinder: **Ersü, Enis**
64297 Darmstadt (DE)

(74) Vertreter: **KEIL & SCHAAFHAUSEN**
Patentanwälte,
Cronstettenstrasse 66
60322 Frankfurt am Main (DE)

(56) Entgegenhaltungen:
US-A- 4 942 539 **US-A- 5 160 977**

- **PATENT ABSTRACTS OF JAPAN vol. 017, no. 445 (P-1593), 16. August 1993 & JP 05 099622 A (A T R SHICHIYOUKAKU KIKO KENKYUSHO:KK), 23. April 1993**

Anmerkung: Innerhalb von neun Monaten nach der Bekanntmachung des Hinweises auf die Erteilung des europäischen Patents kann jedermann beim Europäischen Patentamt gegen das erteilte europäische Patent Einspruch einlegen. Der Einspruch ist schriftlich einzureichen und zu begründen. Er gilt erst als eingelegt, wenn die Einspruchsgebühr entrichtet worden ist. (Art. 99(1) Europäisches Patentübereinkommen).

Printed by Jouve, 75001 PARIS (FR)

EP 0 911 603 B1

Beschreibung

[0001] Die Erfindung betrifft ein Verfahren zur optischen Bestimmung der Lage eines endlichen starren Körpers in einem räumlichen Koordinatensystem.

[0002] Bei der Serienherstellung mehrteiliger Körper ist es beim Einsatz von Robotern erforderlich, die einzelnen Bauteile in richtiger Lage und an der richtigen Stelle für den fertigzustellenden dreidimensionalen Körper bereit zu halten. Darüberhinaus ist es auch üblich, derartige Roboter für das Schweißen oder für das Einfügen von Bauteilen in das Gesamtgerät einzusetzen.

[0003] Hierbei ist es wichtig, die Lage des zu bestükkenden Bauteils und die Lage des tätigwerdenden Roboters mit dem einzufügenden Bauteil zur Vermeidung von Ausschuß aufeinander abzustimmen.

[0004] Ein derartiges Aufeinanderabstimmen wird gemäß der europäischen Veröffentlichung 0489919 mittels Kalibriertafel mit Punkten erreicht. Ebenso wird in der US-Patentschrift 4639878 eine Abstimmung dergestalt erreicht, daß letztlich einzelne Punkte auf dem zu bearbeitenden Körper mit dem Roboter in Übereinstimmung gebracht werden. Gemäß US-Patentschrift 4 942 539, "Verfahren und Vorrichtung zur automatischen Bestimmung der Position und Orientierung eines Objektes im 3D-Raum" ist bekannt, daß anhand der perspektivischen Information in einem Bild die Lage eines Objektes in einem Raum unter Einbeziehung einer Kombination von Punkten und Linien bestimmt werden kann. Im Hinblick auf die Verwendung von Punkten, sei es an dem zu bearbeitenden Bauteil und/oder in Verbindung mit einer Kalibriertafel, welche ebenfalls über Punkte abgetastet wird, treten Schwierigkeiten deshalb auf, weil am zu bearbeitenden Bauteil angeordnete Punkte durch Verschmutzung oder Überdekkung durch andere Bauteile nicht immer sicher erkannt werden können, bzw. derartige Punkte gar nicht vorliegen.

[0005] Ausgehend hiervon liegt der vorliegenden Erfindung die Aufgabe zugrunde, ohne Kenntnis der gegenseitigen Lage von Werkzeug und Werkstück bei Verwendung eines Roboters ein zielsicheres Arbeiten am Werkstück zu ermöglichen. Diese Aufgabe wird durch ein Verfahren gemäß Anspruch 1 gelöst. Vorteilhafte Ausgestaltungen des Verfahrens sind Gegenstand der Ansprüche 2 und 3. Dabei wird auf eine Zuordnung ausgezeichneter Punkte völlig verzichtet, so daß die Beschränkung auf solche am Körper identifizierbaren Punkte völlig entfällt; es können darüberhinaus sogar gekrümmte Linien verwendet werden.

[0006] Durch diese Ausgestaltung wird trotz Minimierung im Aufwand eine eindeutige Zuordnung zwischen Werkstück und Werkzeuglage erreicht. Darüberhinaus wird der Einfluß vorhandener Ungenauigkeiten minimiert.

[0007] Eine Vorrichtung zur Durchführung des Verfahrens mit in einem Raum angeordneten Kameras und einem in diesem befindlichen Körper mit eigenem Koordinatensystem zeichnet sich dadurch aus, daß mindestens drei Kanten und/oder Linien auf dem Körper mit einer oder mehreren Kameras erkannt wird, daß jede Kamera auf eine andere Kante und/oder Linie ausgerichtet ist und daß die gegenseitige Lage der Kameras kalibriert wird. Hierdurch wird in einfacher und schneller Weise ohne vorheriges Aufnehmen von Punkten eine gegenseitige Lagebestimmung der zusammenzusetzenden Körper erreicht. Zufolge der kontrollierten Bewegbarkeit der im Raum befindlichen Kamera gemäß Anspruch 3, welche in bezug zum räumlichen Koordinatensystem steht, kann diese Kamera dazu herangezogen werden, die Lage eines größeren Bauteils im Raum zu bestimmen.

[0008] In der nachfolgenden Zeichnung wird die Erfindung an einem Ausführungsbeispiel näher erläutert. Es wird jedoch darauf hingewiesen, daß es sich nicht nur zum Deckel in konvexe Behälter, wie im Ausführungsbeispiel dargestellt handelt, sondern daß auch andere Bauteilzusammenfügungen unter den Schutzumfang der vorliegenden Erfindung fallen, beispielsweise das Einfügen von Bauteilen in ein Fahrzeug, wie Türen, Fenster, das Auftragen von Klebe- oder Dichtraupen oder das Zusammenfügen und Verschweißen räumlich gekrümmter Bauteile im Reaktorbau oder in der Feinwerktechnik das Zusammenfügen in no-man-Betrieben von optischen Bauteilen, ganz allgemein zur Lagebestimmung von Transportmitteln und deren Bauteilen beim Zusammenbau, beim Auseinandernehmen oder einer Reparatur.

[0009] In einem Ausführungsbeispiel wird gemäß der Figur ein Transportmittel 1 dargestellt, welches über eine Fördersystem 5 einer Bearbeitungsstelle 6 zugeführt wird.

[0010] Unter Transportmittel sind Transportmittel aller Art zu verstehen, wie Flugzeug, Satelit, Schiff, Fahrzeug usw.; der Ausdruck Fördersystem steht stellvertretend für alle Arten derartiger Systeme wie Rollbahnen, Förderbänder, Schrägaufzüge, Senktrechtförderer usw.

[0011] Die Bearbeitungsstelle 6 besteht aus einem Roboter 7, welcher heb- und senkbar sowie drehbar und neigbar ist. Vom Roboter wird im Ausführungsbeispiel eine Deckel 8 für das Transportmittel 1 bereit gehalten. Dieser Deckel 8 soll in die hierzu vorbereitete Öffnung 9 des Transportmittel 1 an der Bearbeitungsstelle 6 eingefügt werden.

[0012] Um ein derartiges Einfügen auch bei nachfolgenden Transportmittel derselben Gattung fehlerfrei im Serienbetrieb durchzuführen, wird gemäß der Erfindung die Öffnung 9 des Transportmittel 1, welche über ein körpereigenes Koordinatensystem 2 beschreibbar ist, von drei Kameras 10, welche ein ebenes Koordinatensystem 3 besitzen und welche zu einem räumlichen Koordinatensystem 4 ausgerichtet sind, aufgenommen. Hierdurch ist sichergestellt, daß beim gleichen Transportmitteltyp das körpereigene Koordinatensystem 2 gleich bleibt und daß somit ein sicheres Einsetzen von Deckeln durchgeführt werden kann.

[0013] Auf den über Linsen 11 aufgenommenen Bil-

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dern auf den ebenen Koordinatensystemen 3 jeder Kamera 10 ist die Zuordnung der Bilder zu der jeweiligen Kante zwischen Öffnung und Deckel sichergestellt. So wird eine linke Kante 12 der Öffnung 9 zu einer Bildkante 12a. Eine obere Kante 13 zu einer Bildkante 13a, unabhängig davon, welcher Teil der Kanten über die jeweilige Kamera 10 aufgenommen wird. Dieser Wert ist dann eindeutig den entsprechenden Kanten des Deckels 8 zuzuordnen.

[0014] Der Verlauf aller abgebildeten Linien muß der bekannten Geometrie des Körpers entsprechen wenn die räumlichen Verläufe aller Linien entsprechend der Geometrie des starren Körpers, in diesem Falle des Deckels 8, welche eingefügt werden soll, der Abbildung der Kameras und der Kalibrierung der Kameras in bezug auf das räumliche Koordinatensystem 4 zur Bestimmung der Lage des Transportmittels 1 zur Übereinstimmung gebracht worden sind.

Patentansprüche

1. Verfahren zur optischen Bestimmung der Lage eines endlichen starren Körpers in einem räumlichen Koordinatensystem (4) dadurch gekennzeichnet, daß aus einer Auswahl von mehreren, mindestens drei auf dem starren Körper vorhandenen Linien oder Kanten, deren Bezug zum körpereigenen Koordinatensystem (2) bekannt ist, jede der genannten mindestens drei Linien oder Kanten für sich in einem ihr zugeordneten ebenen Koordinatensystem (3) abgebildet wird und daß die Lage jedes ebenen Koordinatensystems (3) auf das räumliche Koordinatensystem(4) bezogen ist, wobei auf eine Zuordnung ausgezeichneter Punkte verzichtet wird.

2. Verfahren nach Anspruch 1 dadurch gekennzeichnet,daß diese optisch bestimmte Lage dieses Körpers mit einer entsprechenden Lage eines anderen Körpers verglichen wird.

3. Verfahren nach Anspruch 1 und/oder 2 dadurch gekennzeichnet, daß zur Abbildung der Linien oder Kanten eine räumlich kontrolliert bewegbare Kamera herangezogen wird.

Claims

1. Method for the optical determination of the position of a finite rigid body in a spatial coordinate system (4), characterized in that from a selection of several, at least three lines or edges provided on the rigid body, the relation of which to the coordinate system (2) of the body being known, each of the said at least three lines or edges are depicted in a plane coordinate system (3) assigned to them and that the position of each plane coordinate system (3) refers to the spatial coordinate system (4), where no marked points have been assigned.

2. Method according to claim 1, characterized in that this optically determined position of this body is compared with a corresponding position of another body.

3. Method according to claim 1 and/or 2, characterized in that for the depiction of the lines or edges a spatially controlled movable camera is used.

Revendications

1. Procédé de détermination optique de la position d'un corps rigide fini dans un système de coordonnées spatiales (4) caractérisé en ce que, à partir d'un choix de plusieurs lignes ou bords, au moins trois, présents sur le corps rigide et dont la relation avec le système de coordonnées propre du corps (2) est connue, chacun des au moins trois lignes ou bords est représenté dans un système de coordonnées plan (3) qui lui est attribué, et en ce que la position de chaque système de coordonnées plan (3) est rapportée au système de coordonnées spatiale (4) en renonçant à une attribution de points particuliers.

2. Procédé selon la revendication 1, caractérisé en ce que cette position déterminée optiquement de ce corps est comparée à une position correspondante d'un autre corps.

3. Procédé selon la revendication 1 et / ou 2, caractérisé en ce qu'une caméra mobile contrôlée dans l'espace est utilisée pour la représentation des lignes ou bords.

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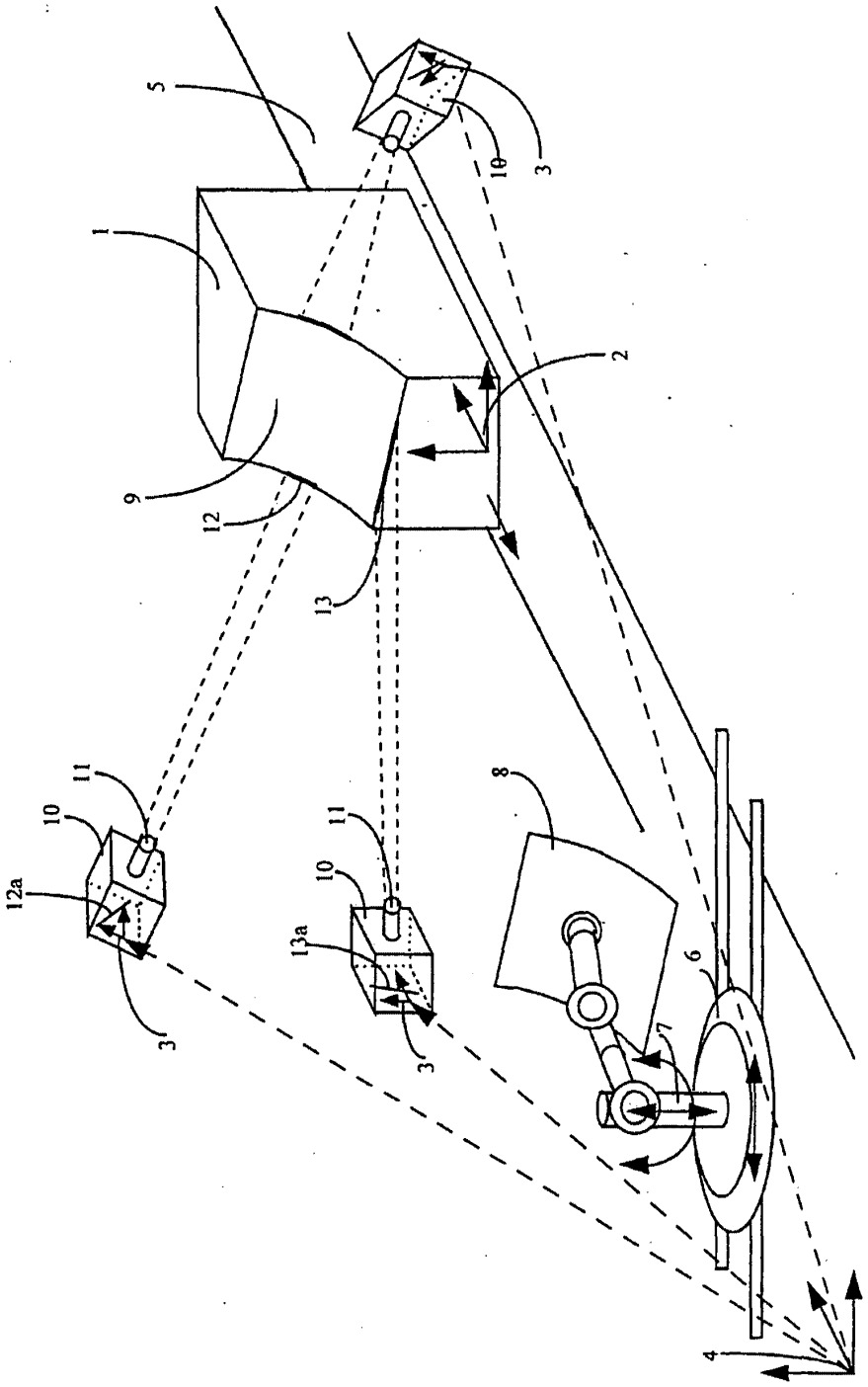


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Description

[0001] the invention concerns a procedure to the optical regulation of the position of a limited stiff body in a spatial coordinate system.

[0002] bodies mehrteiliger with the Serienhersteilung it is necessary with the application of robots to hold ready the single components in right position and at the right place for the three-dimensional body to be finished. Beyond it, it is also usual to use such robots for the welding or for the insertion of components in the whole device.

[0003], on this occasion, it is important to tune the position of the component to be equipped and the position of the active-growing robot with the component to be inserted to the avoidance of committee on each other.

[0004] a such Aufeinanderabstimmen is reached according to the European publication **0489919** by means of Kalibriertafel with points. Also a vote is reached in the US-clever writing **4639878** in such a way that, in the end, single points on the body to be worked on with the robot are brought in correspondence. It is

[0005] in view of the use of points, in the component to be worked on and/or in conjunction with a Kalibriertafel which is likewise felt about points, difficulties appear because arranged points by soiling or Überdeckung by other components not always can be certainly recognized by the component to be worked on, or such points are not at all.

[0006] outgoing the task forms the basis from this of the present invention. without allowing unerring works on the work piece knowledge of the reciprocal position of tools and work piece by use of a robot. This task is solved according to the invention by the fact, that from a choice of several lines available on the stiff body or edges which stand in bezug to the coordinate system belonging to body, every line or edge for themselves in one her assigned. to level ones

Claims

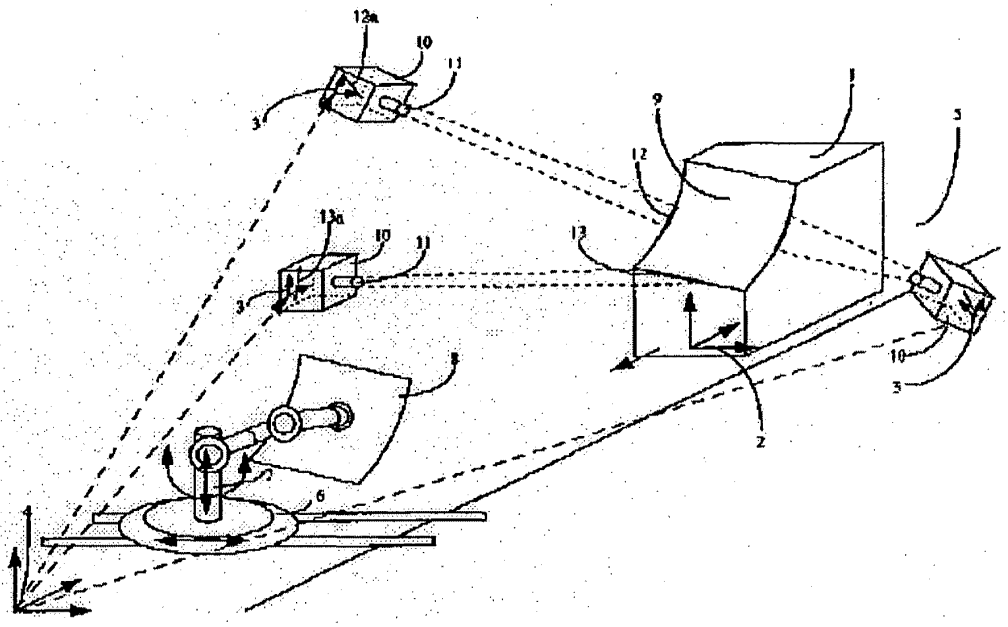
1. procedures to the optical regulation of the position of a limited stiff body in a spatial coordinate system (4) thereby marked that from a choice of several, on the stiff body before handenen lines or edges which stand in bezug to the coordinate system belonging to body (2), every line or edge is illustrated for itself in her assigned level coordinate system (3) and that the position of every level coordinate system (3) is covered to the spatial coordinate system (4).

2. Procedures after claim 1 thereby marked, that several lines available on the stiff body or edges on a level coordinate system (3) whose position is covered to the spatial coordinate system (4) are illustrated and that afterwards according to the regulation of every single line or edge after her position a relation is produced

between spatial (4) and the (2) coordinate systems belonging to body, and that this position of this body is compared to a suitable position in another body.

3. Device for the realization of the procedure after claim 1 and/or 2 with arranged an in a space cameras and to one in this located body with the own coordinate system (2) thereby marked that at least three edges and/or lines on the body with one or several cameras (10) are recognized that every camera (10) on another edge or line is aimed and that the reciprocal position of the cameras is calibrated.

4. Device after claim 3 thereby marked that a self-possessed moveable camera (10) is planned in the space.



Patents Cited by this patent

06-27-05

EXPRESS MAIL NO. EV335546775US

OIPE JC26 JUN 23 2005 PATENT & TRADEMARK OFFICE

TRANSMITTAL FORM

(To be used for all correspondence after initial filing)

Application Number	10/634,874
Filing Date	August 6, 2003
First Named Inventor	Babak Habibi
Art Unit	3661
Examiner Name	McDieunel Marc
Attorney Docket No.	170154.401C1

ENCLOSURES (*check all that apply*)

- [X] Fee Transmittal Form
  - [X] Fee Attached
- [X] Amendment/Response
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [X] Extension of Time Request
- [ ] Express Abandonment Request
- [X] Information Disclosure Statement; Form PTO-1449
- [X] Cited References
- [ ] Certified Copy of Priority Document(s)
- [ ] Response to Missing Parts under 37 C.F.R. 1.52 or 1.53
- [ ] Response to Missing Parts/Incomplete Application
- [ ] Drawing(s)
- [ ] Request for Corrected Filing Receipt
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation, Change of Correspondence Address
- [ ] Declaration
- [ ] Statement under 37 CFR 3.73(b)
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) _____
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC *(Appeal Notice, Brief, Reply Brief)*
- [ ] Proprietary Information
- [ ] Status Letter
- [X] Return Receipt Postcard
- [ ] Other Enclosure(s) (*please identify below*):

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	Seed Intellectual Property Law Group PLLC	Customer Number	00500
Signature			
Printed Name	Frank Abramonte		
Date	June 23, 2005	Reg. No.	38,066

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Typed or printed name		Date:

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PATENT & TRADEMARK OFFICE JUN 23 2005 OIPE

Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act. 2005 (H.R. 4818).

FEE TRANSMITTAL for FY 2005

Complete if Known	
Application Number	10/634,874
Filing Date	August 6, 2003
First Named Inventor	Babak Habibi
Examiner Name	McDieunel Marc
Art Unit	3661
Attorney Docket No.	170154.401C1

☒ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($)**240**

METHOD OF PAYMENT (check all that apply)

☒ **Check** ☐ Credit Card ☐ Money Order ☐ Other (please identify): ____

☒ Deposit Account Deposit Account Number: 19-1090 Deposit Account Name: Seed IP Law Group PLLC

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☐ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☐ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☒ Charge any underpayments or credit any overpayments

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FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

	FILING FEES		SEARCH FEES		EXAMINATION FEES		
		Small Entity		Small Entity		Small Entity	
Application Type	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fee ($)	Fees Paid ($)
Utility	300	150	500	250	200	100	____
Design	200	100	100	50	130	65	____
Provisional	200	100	0	0	0	0	____

2. EXCESS CLAIM FEES

Fee Description	Fee ($)	Small Entity Fee ($)
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	200	100
Multiple dependent claims	360	180

Total Claims		Extra Claims		Fee ($)		Fee Paid ($)
29	-20 or HP =	0	X	____	=	____

HP = highest number of total claims paid for, if greater than 20

Multiple Dependent Claims	
Fee ($)	Fee Paid ($)
____	____

Indep. Claims		Extra Claims		Fee ($)		Fee Paid ($)
3	-3 or HP =	0	X	____	=	____

HP = highest number of independent claims paid for, if greater than 3

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)) the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets		Extra Sheets		Number of each additional 50 or fraction thereof		Fee ($)	Fee Paid ($)
____	-100 =	____	/50 =	____ (round **up** to a whole number)	x	____	____

4. OTHER FEE(S)

	Fees Paid ($)
Non-English Specification, $130 fee (no small entity discount)	____
Other (e.g., late filing surcharge): Fee for Information Disclosure Statement	180
Fee for one-month extension of time	60
____	____

SUBMITTED BY

Signature		Registration No. (Attorney/Agent)	38,066	Telephone	206-622-4900
Name (Print/Type)	**Frank Abramonte**			Date	June 23, 2005

604237_1

Best Available Copy

PATENT APPLICATION FEE DETERMINATION RECORD

Effective December 8, 2004

10/634,874

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS		
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	minus 20=	*
INDEPENDENT CLAIMS	minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	150.00	OR	BASIC FEE	300.00
X$ 25=		OR	X$50=	
X100=		OR	X200=	
+180=		OR	+360=	
TOTAL		OR	TOTAL	

Amdt 6/23/05

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 29	Minus	** 32	= /
Independent	* 3	Minus	*** 2	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 25=		OR	X$50=	
X100=		OR	X200=	
+180=		OR	+360=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 25=		OR	X$50=	
X100=		OR	X200=	
+180=		OR	+360=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 25=		OR	X$50=	
X100=		OR	X200=	
+180=		OR	+360=	

Key: **IEEE JNL** = IEEE Journal or Magazine, **IEE JNL** = IEE Journal or Magazine, **IEEE CNF** = IEEE Conference, **IEE CNF** = IEE Conference, **IEEE STD** = IEEE Standard

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Key: **IEEE JNL** = IEEE Journal or Magazine, **IEE JNL** = IEE Journal or Magazine, **IEEE CNF** = IEEE Conference, **IEE CNF** = IEE Conference, **IEEE STD** = IEEE Standard

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IEEE CNF

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/634,874	08/06/2003	Babak Habibi	B4450014	7619

720 7590 09/14/2005

OYEN, WIGGS, GREEN & MUTALA LLP
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601 WEST CORDOVA STREET
VANCOUVER, BC V6B 1G1
CANADA

EXAMINER	
MARC, MCDIEUNEL	

ART UNIT	PAPER NUMBER
3661	

DATE MAILED: 09/14/2005

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

PTO-90C (Rev. 10/03)

Office Action Summary	Application No.	Applicant(s)	
	10/634,874	HABIBI ET AL.	
	Examiner	Art Unit	
	McDieunel Marc	3661	

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

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *23 June 2005*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *33-61* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *all* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

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

a)☐ All b)☐ Some * c)☐ None of:

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)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

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DETAILED ACTION

1. Claims 33-61 are pending.

Claim Rejections - 35 USC § 102

2. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

3. Claims 33-61 are rejected under 35 U.S.C. 102(b) as being anticipated by **Wei et al.** (***Multisensory Visual servoing by a Neural Network*, 1999**).

As per claims 33-61, **Wei et al.**, teaches a multisensory visual servoing by a neural network, including a system and an associated method that is useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of a robot (see fig. 1), the method comprising:

capturing a number of images of a calibration object by the camera (see figs. 2-3);

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera (see fig. 2); and

determining a set of extrinsic parameters of the camera from at least one of the

number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation design a transformation between a camera space reference frame and a training space reference frame (see fig. 2). With respect to claim 53, an apparatus useful in robotics as described above, the apparatus comprising:

a single camera operable to capture at a number of images of a calibration object by the camera (see fig. 2);

means for calibrating the camera, by determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera (see fig. 4, wherein tracking being considered as calibrating); and

determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame (see fig. 2); and

means for estimating a pose of a target object, by capturing a two-dimensional image of an volume containing a target object (see fig. 4); and

locating at least six features in the captured image of the target object (see page 276, col. 2, section II., wherein features being considered as input dimention); and

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using an algorithm that employs a known or determinable physical relationship between at least some of the

located features (see fig. 2). With respect to claim 58, an apparatus useful in robotics as described above, the apparatus comprising:

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using an algorithm that employs a known or determinable physical relationship between at least some of the located features (see entire document).

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to McDieunel Marc whose telephone number is (571) 272-6964. The examiner can normally be reached on 6:30-5:00 Mon-Thu.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black can be reached on (571) 272-6956. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

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).

McDieunel Marc
Saturday, September 10, 2005

FORM PTO-1449 (REV. 7-80)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTY. DOCKET NO. 170154.401C1	APPLICATION NO. 10/634,874
	INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	APPLICANTS Babak Habibi et al.	
		FILING DATE August 6, 2003	GROUP ART UNIT 3661

OIPE JC26 JUN 2 3 2005 PATENT & TRADEMARK OFFICE

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	AA	4,578,561	03/25/86	Corby, Jr. et al.	219	124.34	
	AB	4,835,450	05/30/89	Suzuki	318	568.13	
	AC	5,083,073	01/21/92	Kato	318	577	
	AD	5,350,269	09/27/94	Azuma et al.	414	416	
	AE	5,454,775	10/03/95	Cullen et al.	483	16	
	AF	6,341,246	01/22/02	Gerstenberger et al.	700	245	
	AG	6,466,843	10/15/02	Bonanni et al.	700	245	
	AH	6,804,416	10/12/04	Bachelder et al.	382	294	
	AI	2004/0114033	06/17/04	Eian et al.	348	42	
	AJ	60/413,180		Eian et al.			09/23/02

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	TRANSLATION YES	TRANSLATION NO
	AK	0151417	08/14/85	EP		
	AL	0493612	07/08/92	EP		
	AM	0951968	10/27/99	EP		
	AN	401124072	05/89	JP		
	AO	0911603 B1	04/28/99	EP (with machine translation)	X	

OTHER PRIOR ART *(Including Author, Title, Date, Pertinent Pages, Etc.)*

	AP		Denzler, J., et al., "Learning, Tracking and Recognition of 3D Objects," *Proceedings of the IEEE/RSJ/GI International Conference on Intelligent Robots and Systems*. (No date available.)
	AQ		"Advanced Robotic Systems and the Real World," *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, XP000512662, Vol. 1, Munich, September 12, 1994, pp. 89-96.

EXAMINER	DATE CONSIDERED
McDieunel Marc	9-10-2005

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

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FORM PTO-1449 (REV.7-80)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTY. DOCKET NO. 170154.401C1	APPLICATION NO. 10/634,874
INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)		APPLICANTS Babak Habibi et al.	
		FILING DATE August 6, 2003	GROUP ART UNIT 3661

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
m.m	BA	60/587,488		Boca et al.			07/14/04
	BB						
	BC						
	BD						
	BE						
	BF						
	BG						
	BH						
	BI						
	BJ						

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	TRANSLATION YES	TRANSLATION NO
	BK					
	BL					
	BM					
	BN					
	BO					

OTHER PRIOR ART *(Including Author, Title, Date, Pertinent Pages, Etc.)*

m.m	BP		W. Meyer, "One-Eyed Robots With 3D Vision," ISRA Vision Systems AG, Press News, Release No. 16, June 15, 2004, pp 1-7.
m.m	BQ		"3D Robot Guidance with a Single Camera," ISRA Vision Systems AG. (No date available.)
m.m	BR		3D Vision with One Camera, URL=http://neu.isravision.com/likecms/index.php?site=site.html&dir=isra&nav=162, download date April 12, 2005.

EXAMINER	DATE CONSIDERED
/Marc Diruno/ Marc	9-9-2005

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

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Notice of References Cited	Application/Control No. 10/634,874	Applicant(s)/Patent Under Reexamination HABIBI ET AL.	
	Examiner McDieunel Marc	Art Unit 3661	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-2003/0004694	01-2003	Aliaga et al.	703/2
	B	US-6,594,600	07-2003	Arnoul et al.	702/94
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

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

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	Wei et al., Multisensory visual servoing by a neural network, 1999, IEEE, pg. 276-280
	V	Kim, Computer vision assisted virtual reality calibration, 1999, Internet, pg. 450-464
	W	Bejczy, Challenges of human-robot communication in telerobotics, 1996, IEEE, pg. 1-8
	X	Sharma, Visual servoing with independently controlled cameras using a learned invariant representation, 1998, IEEE, pg. 3263-3268

*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.

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Search Notes	Application No.	Applicant(s)	
	10/634,874	HABIBI ET AL.	
	Examiner	Art Unit	
	McDieunel Marc	3661	1

SEARCHED			
Class	Subclass	Date	Examiner
700	245	9/10/2005	MM

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
Palm inventors search	9/10/2005	MM
NPL search see attached listing	9/10/2005	MM

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JUN 07 2006
PATENT AND TRADEMARK OFFICE

EXPRESS MAIL NO. EV529788248US

PETITION FOR REVIVAL OF AN APPLICATION FOR PATENT ABANDONED UNINTENTIONALLY UNDER 37 CFR 1.137(b)	Docket Number (Optional) 170154.401C1

First named inventor: **Babak Habibi et al.**

Application No.: **10/634,874** Art Unit: **3661**

Filed: **August 6, 2003** Examiner: **McDieunel Marc**

Title: **METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS**

Attention: Office of Petitions
Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450
Fax: (571) 273-8300

NOTE: If information or assistance is needed in completing this form, please contact Petitions Information at (571) 272-3282.

The above-identified application became abandoned for failure to file a timely and proper reply to a notice or action by the United States Patent and Trademark Office. The date of abandonment is the day after the expiration date of the period set for reply in the office notice or action plus any extensions of time actually obtained.

APPLICANT HEREBY PETITIONS FOR REVIVAL OF THIS APPLICATION

NOTE: A grantable petition requires the following items:

(1) Petition fee;
(2) Reply and/or issue fee;
(3) Terminal disclaimer with disclaimer fee - required for all utility and plant applications filed before June 8, 1995; and for all design applications; and
(4) Statement that the entire delay was unintentional.

1. Petition fee

☒ Small entity - fee $**750** (37 CFR 1.17(m)). Applicant claims small entity status. See 37 CFR 1.27.

☐ Other than small entity - fee $_____ (37 CFR 1.17(m))

2. Reply and/or fee

A. The reply and/or fee to the above-noted Office action in the form of **a Response** (identify type of reply):

☐ has been filed previously on _____ .

☒ is enclosed herewith.

B. The issue fee and publication fee (if applicable) of $

☐ has been paid previously on _____ .

☐ is enclosed herewith.

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IPR2023-01426

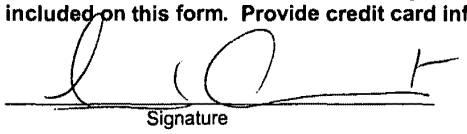
3. Terminal disclaimer with disclaimer fee

☒ Since this utility/plant application was filed on or after June 8, 1995, no terminal disclaimer is required.

☐ A terminal disclaimer (and disclaimer fee (37 CFR 1.20(d)) of $_____ for a small entity or $_____ for other than a small entity) disclaiming the required period of time is enclosed herewith (see PTO/SB/63).

4. STATEMENT: The entire delay in filing the required reply from the due date for the required reply until the filing of a grantable petition under 37 CFR 1.137(b) was unintentional. [NOTE: The United States Patent and Trademark Office may require additional information if there is a question as to whether either the abandonment or the delay in filing a petition under 37 CFR 1.137(b) was unintentional (MPEP 711.03(c), subsections (III)(C) and (D)).]

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.



Signature

June 7, 2006
Date

Frank Abramonte
Typed or printed name

38,066
Registration Number, if applicable

701 Fifth Avenue, Suite 6300
Address

(206) 622-4900
Telephone Number

Seattle, WA 98104
Address

Enclosures: ☒ Fee Payment

☒ Reply

☐ Terminal Disclaimer Form

☐ Additional sheets containing statements establishing unintentional delay

☐ Other: _____

CERTIFICATE OF MAILING OR TRANSMISSION [37 CFR 1.8(a)]

I hereby certify that this correspondence is being:

☐ Deposited with the United States Postal Service on the date shown below with sufficient postage as first class mail in an envelope addressed to: **Mail Stop Petition**, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

☐ Transmitted by facsimile on the date shown below to the United States Patent and Trademark Office at (571) 273-8300.

Date

Signature

Typed or printed name
of person signing certificate

SEND TO: Mail Stop Petition, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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IPR2023-01426

OIPE IAP79
JUN 07 2006
PATENT & TRADEMARK OFFICE

Express Mail No. EV529788248US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Examiner	:	McDieunel Marc
Art Unit	:	3661
Docket No.	:	170154.401C1
Date	:	June 7, 2006

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

RESPONSE

Commissioner for Patents:

This is a Response to the Office Action mailed September 14, 2005, in which a three (3) month Shortened Statutory Period for Response was set, due to expire December 14, 2005. Thirty-two (32) claims, including three (3) independent claims, have been paid for in the application. Claims 1-32 have been canceled. Claims 33-61 are pending. The Director is authorized to charge any additional fees due by way of this Response, or credit any overpayment, to our Deposit Account No. 19-1090.

Rejections Under 35 U.S.C. § 102(b)

Claims 33-61 were rejected under 35 U.S.C. § 102(b) as being anticipated by Wei et al., Multisensory Visual Servoing by a Neural Network, IEEE Transactions on Systems, Man, and Cybernetics-PartB: Cybernetics, Vol. 29, No. 2, April 1999 (hereinafter "Wei publication").

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The Wei publication is generally directed to multisensory visual servoing via a neural network. The system taught by the Wei publication employs two types of sensory data, camera images and laser range data.

Importantly, the Wei publication is directed to the use of a stereo *pair of cameras*, along with at least four laser range finders. Wei publication, page 279, final partial paragraph of left column through first partial paragraph of right column, and page 276, final full paragraph of right column. Thus, the Wei publication teaches that it is necessary to image at least two points by each of at least *two distinct cameras* with a defined spatial relationship to one another (*i.e.*, stereo pair), in addition to the information derived from the four laser range finders.

In contrast, Applicants' claims are directed to methods and apparatus that employ *single camera* three-dimensional (3-D) vision for robotic guidance.

For example, claim 33 is directed to "[a] method useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of a robot." Claim 33 recites "capturing a number of images of a calibration object by the camera; determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame."

Also for example, claim 53 is directed to an apparatus useful in robotics, and recites, *inter alia*, "a *single camera* operable to capture at a number of images of a calibration object by the camera." (Emphasis added.) Similarly, claim 58 is directed to an apparatus useful in robotics, and recites, inter alia, "a *single camera* operable to capture a number of images of a calibration object by the camera." (Emphasis added.)

It is the problems associated with *stereo vision* based systems and other *multi-camera* systems which are addressed by the various single camera embodiments described in Applicants' specification and claims. The removal of one or more cameras typically reduces the number of known quantities, and thus reduces the number of unknowns or dimensions that can

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be solved. Consequently, the Wei publication teachings with regard to stereo camera vision are not directly applicable to Applicants' *single camera* vision based methods and apparatus.

Also the Wei publication teaches an approach to *avoid* calibration. Wei publication, page 276, first full paragraph under heading I, left column ("On the contary, a neural network approach for doing the same job can avoid all such calibrations. . ."); page 279, first partial paragraph of right column ("If we use analytic computer vision methods to solve the same problem, a lot of calibrations have to be involved [15]. The use of a neural network method avoids these computations").

In contrast to those teachings, claim 33 recites "capturing a number of images of a calibration object by the camera; determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame."

Likewise, in contrast to the teachings of the Wei publication, claims 53 and 58 recite, *inter alia*, "a single camera operable to capture at a number of images of a calibration object by the camera and means for calibrating the camera."

Further, the dependent claims recite many limitations which are not taught or suggested by the Wei publication. For example, a number of the dependent claims recite specific acts and structures to calibrate the single camera, none of which are addressed in the Wei publication or present Office Action. Also for example, a number of the dependent claims recite specific acts and structures to determine transformations. Such acts or structures do not appear to be disclosed or suggested by the Wei publication.

Conclusion

Overall, the cited reference does not teach or suggest the claimed features of the embodiments recited in the independent claims, and thus such claims are allowable. Because the remaining claims depend from the allowable independent claims, and also because they include

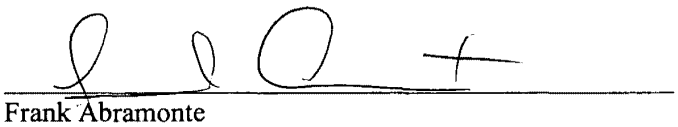
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additional limitations, such claims are likewise allowable. If the undersigned attorney has overlooked a relevant teaching in any of the references, the Examiner is requested to point out specifically where such teaching may be found.

In light of the above remarks, Applicants respectfully submit that all pending claims are allowable. Applicants, therefore, respectfully request that the Examiner reconsider this application and timely allow all pending claims. Examiner Marc is encouraged to contact Mr. Abramonte by telephone to discuss the above and any other distinctions between the claims and the applied reference, if desired. If the Examiner notes any informalities in the claims, the Examiner is encouraged to contact Mr. Abramonte by telephone to expediently correct such informalities.

Respectfully submitted,

Seed Intellectual Property Law Group PLLC



Frank Abramonte
Registration No. 38,066

FA:lrw

701 Fifth Avenue, Suite 6300
Seattle, Washington 98104-7092
(206) 622-4900
Fax: (206) 682-6031

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OIPE WP79 JUN 07 2006 PATENT & TRADEMARK OFFICE

Best Available Copy

EXPRESS MAIL NO: EV529788248US

REVOCATION OF POWER OF ATTORNEY WITH NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS		
	Application Number	10/634,874
	Filing Date	August 6, 2003
	First Named Inventor	Babak Habibi
	Art Unit	3661
	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

I hereby revoke all previous powers of attorney given in the above-identified application.

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint the practitioners at Seed IP Law Group PLLC, Customer Number: **00500**

☒ Please change the correspondence address for the above-identified application to:

☒ The address associated with Customer Number **00500**

OR

☐ Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the:

☐ Applicant/Inventor.

☒ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

☒ As assignee of record of the entire interest I/we hereby elect, under 37 CFR 3.71, to prosecute the application to the exclusion of the inventor(s).

SIGNATURE of Applicant or Assignee of Record

Signature		Date	June 7, 2006
Name	Edward White, C.A.		
Title and Company (Assignee)	Secretary		
	Braintech Canada, Inc.		

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☒ *Total of 1 forms are submitted.

JUN 07 2006 PATENT & TRADEMARK OFFICE

EXPRESS MAIL NO. EV529788248US

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Babak Habibi et al.

Application No./Patent No.: 10/634,874 Filed/Issue Date: August 6, 2003

Entitled: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Braintech Canada, Inc. (Name of Assignee) a corporation (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. [X] the assignee of the entire right, title, and interest; or
2. [ ] an assignee of less than the entire right, title and interest. The extent (by percentage) of its ownership interest is _____%

in the patent application/patent identified above by virtue of either:

A. [X] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or a true copy of the original assignment is attached.

OR

B. [ ] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From:_____ To:_____
   The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.
2. From:_____ To:_____
   The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.
3. From:_____ To:_____
   The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

[ ] Additional documents in the chain of title are listed on a supplemental sheet.

[X] As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (*i.e.*, a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

Signature — June 7, 2006 (Date)

Edward White, C.A. (Typed or printed name) — Secretary (Title)

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

Docket No. 170154.401C1 792086_1

ASSIGNMENT

WHEREAS, we, Babak Habibi, Simona Pescaru, Mohammad Sameti and Remus Florinel Boca (hereinafter referred to as ASSIGNORS), having mailing addresses of 3308 Manning Crescent, North Vancouver, British Columbia, Canada V7H 2R6; 113 – 980 West 1st Street, North Vancouver, British Columbia, Canada V7P 3N4; 2608 Sandstone Court, Coquitlam, British Columbia, Canada V3E 2T9; and 2009 - 2024 Fullerton Avenue, North Vancouver, British Columbia, Canada V7P 3G4, respectively, are the joint inventors of an invention entitled "METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS," as described and claimed in the specification for which an application for United States letters patent was filed on August 6, 2003, and assigned Application No. 10/634,874;

WHEREAS, Braintech Canada, Inc. (hereinafter referred to as ASSIGNEE), a Canadian corporation having a place of business at 102 – 930 West 1st Street, North Vancouver, British Columbia, Canada V7P 3N4, is desirous of acquiring the entire right, title and interest in and to the invention and in and to any letters patent that may be granted therefor in the United States and in any and all foreign countries;

NOW, THEREFORE, in exchange for good and valuable consideration, the receipt of which is hereby acknowledged, ASSIGNORS hereby sell, assign and transfer unto said ASSIGNEE the entire right, title and interest in and to said invention, said application and any and all letters patent which may be granted for said invention in the United States of America and its territorial possessions and in any and all foreign countries, and in any and all divisions, reissues and continuations thereof, including the right to file foreign applications directly in the name of ASSIGNEE and to claim priority rights deriving from said United States application to which said foreign applications are entitled by virtue of international convention, treaty or otherwise, said invention, application and all letters patent on said invention to be held and enjoyed by ASSIGNEE and its successors and assigns as fully and entirely as the same would have been held and enjoyed by ASSIGNORS had this assignment, transfer and sale not been made. ASSIGNORS hereby authorize and request the Commissioner of Patents and Trademarks to issue all letters patent on said invention to ASSIGNEE. ASSIGNORS agree to execute all instruments and documents required for the making and prosecution of applications for United

States and foreign letters patent on said invention, for litigation regarding letters patent, or for the purpose of protecting title to said invention or letters patent therefor.

May 12, 2005
Date

Babak Habibi

State of _____)
)
County of _____)

ss.

I certify that I know or have satisfactory evidence that Babak Habibi is the person who appeared before me, and said person acknowledged that he signed this instrument and acknowledged it to be his free and voluntary act for the uses and purposes mentioned in the instrument.

Dated _____

Signature of
Notary Public _____

Printed Name _____

My appointment expires _____

May 12, 2005
Date

Simona Pescaru

State of _____)
)
County of _____)

ss.

I certify that I know or have satisfactory evidence that Simona Pescaru is the person who appeared before me, and said person acknowledged that she signed this instrument and acknowledged it to be her free and voluntary act for the uses and purposes mentioned in the instrument.

Dated _____

Signature of
Notary Public _____

Printed Name _____

My appointment expires _____

ABB Inc. Exhibit 1002, Page 135 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

May 12, 2005
Date

Mohammad Sameti

State of _____)
)
County of _____)

ss.

I certify that I know or have satisfactory evidence that Mohammad Sameti is the person who appeared before me, and said person acknowledged that he signed this instrument and acknowledged it to be his free and voluntary act for the uses and purposes mentioned in the instrument.

Dated _____

Signature of
Notary Public _____

Printed Name _____

My appointment expires _____

May 12, 2005
Date

Remus Florinel Boca

State of _____)
)
County of _____)

ss.

I certify that I know or have satisfactory evidence that Remus Florinel Boca is the person who appeared before me, and said person acknowledged that he signed this instrument and acknowledged it to be his free and voluntary act for the uses and purposes mentioned in the instrument.

Dated _____

Signature of
Notary Public _____

Printed Name _____

My appointment expires _____

569383_1 (170154.401C1)

ABB Inc. Exhibit 1002, Page 136 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

JUN 0 7 2006
PATENT & TRADEMARK OFFICE

6-7-06

EXPRESS MAIL NO. EV529788248US

TRANSMITTAL FORM

(To be used for all correspondence after initial filing)

Application Number	10/634,874
Filing Date	August 6, 2003
First Named Inventor	Babak Habibi
Art Unit	3661
Examiner Name	McDieunel Marc
Attorney Docket No.	170154.401C1

ENCLOSURES (*check all that apply*)

- [X] Fee Transmittal Form
  - [X] Fee Attached
- [X] Amendment/Response
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement and Transmittal
- [ ] Cited References
- [ ] Certified Copy of Priority Document(s)
- [ ] Response to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Response to Missing Parts/Incomplete Application
- [ ] Drawing(s)
- [ ] Request for Corrected Filing Receipt
- [ ] Licensing-related Papers
- [X] Petition
- [ ] Petition to Convert to a Provisional Application
- [X] Power of Attorney, Revocation, Change of Correspondence Address
- [ ] Declaration
- [X] Statement under 37 CFR 3.73(b)
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) _____
  - [ ] Landscape Table on CD
- [ ] After Allowance Communication to TC
- [ ] Appeal Communication to Board of Appeals and Interferences
- [ ] Appeal Communication to TC *(Appeal Notice, Brief, Reply Brief)*
- [ ] Proprietary Information
- [ ] Status Letter
- [X] Return Receipt Postcard
- [ ] Other Enclosure(s) (*please identify below*):

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	Seed Intellectual Property Law Group PLLC	Customer Number	00500
Signature			
Printed Name	Frank Abramonte		
Date	June 7, 2006	Reg. No.	38,066

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below.

Signature		
Typed or printed name		Date:

SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.
792101_1

EXPRESS MAIL NO. EV529788248US

Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL
For FY 2006

JUN 07 2006

Complete if Known	
Application Number	10/634,874
Filing Date	August 6, 2003
First Named Inventor	Babak Habibi
Examiner Name	McDieunel Marc
Art Unit	3661
Attorney Docket No.	170154.401C1

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) **750**

METHOD OF PAYMENT (check all that apply)

☒ **Check** ☐ Credit Card ☐ Money Order ☐ Other (please identify): _____

☒ Deposit Account Deposit Account Number: 19-1090 Deposit Account Name: Seed IP Law Group PLLC

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☐ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, **except for the filing fee**

☐ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☒ Charge any underpayments or credit any overpayments

Warning: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION (All the fees below are due upon filing or may be subject to a surcharge.)

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

	FILING FEES		SEARCH FEES		EXAMINATION FEES		
		Small Entity		Small Entity		Small Entity	
Application Type	**Fee ($)**	**Fee ($)**	**Fee ($)**	**Fee ($)**	**Fee ($)**	**Fee ($)**	**Fees Paid ($)**
Utility	300	150	500	250	200	100	_____
Design	200	100	100	50	130	65	_____
Provisional	200	100	0	0	0	0	_____

2. EXCESS CLAIM FEES

Fee Description	**Fee ($)**	**Small Entity Fee ($)**
Each claim over 20 (including Reissues)	50	25
Each independent claim over 3 (including Reissues)	200	100
Multiple dependent claims	360	180

Total Claims		**Extra Claims**		**Fee ($)**		**Fee Paid ($)**
_____	-20 or HP =	_____	X	_____	=	_____

HP = highest number of total claims paid for, if greater than 20.

Multiple Dependent Claims

Fee ($)	**Fee Paid ($)**
_____	_____

Indep. Claims		**Extra Claims**		**Fee ($)**		**Fee Paid ($)**
_____	-3 or HP =	_____	X	_____	=	_____

HP = highest number of independent claims paid for, if greater than 3.

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)) the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets		**Extra Sheets**		**Number of each additional 50 or fraction thereof**		**Fee ($)**	**Fee Paid ($)**
_____	-100 =	_____	/50 =	_____ (round up to a whole number)	x	_____	_____

4. OTHER FEE(S)

	Fees Paid ($)
Non-English Specification, $130 fee (no small entity discount)	_____
Other (e.g., late filing surcharge): Fee for Petition to Revive under 37 CFR 1.137(b)	**750**
_____	_____
_____	_____

SUBMITTED BY

Signature		Registration No. (Attorney/Agent)	38,066	Telephone	206-622-4900
Name (Print/Type)	**Frank Abramonte**			Date	June 7, 2006

792100_1

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

JJGJR.: 07-06

Paper No: __

COPY MAILED

AUG 0 2 2006

OFFICE OF PETITIONS

SEED INTELLECTUAL
PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 6300
SEATTLE WA 98104-7092

In re Application of	:	
Habibi, et al.	:	DECISION
Application No.: 10/634,874	:	
Filing Date: 6 August, 2003	:	
Attorney Docket No. B4450014//	:	

This is a decision on the petition filed on 7 JUne, 2006, to revive the instant application under 37 C.F.R. §1.137(b) as having as abandoned due to unintentional delay.

For the reasons set forth below the petition as considered under 37 C.F.R. §1.137(b) is **DISMISSED**.

NOTES:

(1) Any petition (and fee) for reconsideration of this decision must be submitted within two (2) months from the mail date of this decision. Extensions of time under 37 C.F.R. §1.136(a) are permitted. The reconsideration request should include a cover letter entitled "Renewed Petition under 37 C.F.R. §1.137(b)."

(2) Thereafter, there will be no further reconsideration of this matter.

BACKGROUND

The record reflects that:

- Petitioner failed to reply timely and properly to a non-final Office action mailed on14 September, 2005, with reply due absent extension of time on or before 14 December, 2005;
-
- the application went abandoned by operation of law after midnight 14 December, 2005;
- it does not appear that the Office mailed the Notice of Abandonment before the instant petition was filed;
- with the instant petition (with fee), Petitioner filed as a reply an amendment, and made the statement of unintentional delay;
- Petitioner was not Counsel of record at the time the application went abandoned, Petitioner is not in a position to make such a statement as to the nature of the delay;
- Petitioner is aware that such representations are, as are all representations by practitioners and applicants before the Office, susceptible to review for compliance with the duty of candor.

Out of an abundance of caution, Petitioners always are reminded that those registered to practice *and* all others who make representations before the Office are reminded to inquire into the underlying facts of representations made to the Office and support averments with the appropriate documentation–since all owe to the Office the continuing duty to disclose.[1]

---

[1] See supplement of 17 June, 1999. The Patent and Trademark Office is relying on petitioner's duty of candor and good faith and accepting a statement made by Petitioner. See Changes to Patent Practice and Procedure, 62 Fed. Reg. at 53160 and 53178, 1203 Off. Gaz. Pat. Office at 88 and 103 (responses to comments 64 and 109)(applicant obligated under 37 C.F.R. §10.18 to inquire into the underlying facts and circumstances when providing statements to the Patent and Trademark Office).

Specifically, the regulations at 37 C.F.R. §10.18 provide:

§ 10.18 Signature and certificate for correspondence filed in the Patent and Trademark Office.
(a) For all documents filed in the Office in patent, trademark, and other non-patent matters, except for correspondence that is required to be signed by the applicant or party, each piece of correspondence filed by a practitioner in the Patent and Trademark Office must bear a signature by such practitioner complying with the provisions of §1.4(d), §1.4(e), or § 2.193(c)(1) of this chapter.
(b) By presenting to the Office (whether by signing, filing, submitting, or later advocating) any paper, the party presenting such paper, whether a practitioner or non-practitioner, is certifying that—

(1) All statements made therein of the party's own knowledge are true, all statements made therein on information and belief are believed to be true, and all statements made therein are made with the knowledge that whoever, in any matter within the jurisdiction of the Patent and Trademark Office, knowingly and willfully falsifies, conceals, or covers up by any trick, scheme, or device a material fact, or makes any false, fictitious or fraudulent statements or representations, or makes or uses any false writing or document knowing the same to contain any false, fictitious or fraudulent statement or entry, shall be subject to the penalties set forth under 18 U.S.C. 1001, and that violations of this

STATUTES, REGULATIONS AND ANALYSIS

Congress has authorized the Commissioner to "revive an application if the delay is shown to the satisfaction of the Commissioner to have been "unavoidable." 35 U.S.C. §133 (1994).[2]

The regulations at 37 C.F.R. §1.137(a) and (b) set forth the requirements for a petitioner to revive a previously unavoidably or unintentionally, respectively, abandoned application under this congressional grant of authority. The language of 35 U.S.C. §133 and 37 C.F.R. §1.137(a) is clear, unambiguous, and without qualification: the delay in tendering the reply to the outstanding Office action, as well as filing the first petition seeking revival, must have been unavoidable for the reply now to be accepted on petition.[3]

Delays in responding properly raise the question whether delays are unavoidable.[4] Where there is a question whether the delay was unavoidable, Petitioners must meet the burden of establishing

---

paragraph may jeopardize the validity of the application or document, or the validity or enforceability of any patent, trademark registration, or certificate resulting therefrom; and

(2) To the best of the party's knowledge, information and belief, formed after an inquiry reasonable under the circumstances, that —

(i) The paper is not being presented for any improper purpose, such as to harass someone or to cause unnecessary delay or needless increase in the cost of prosecution before the Office;

(ii) The claims and other legal contentions therein are warranted by existing law or by a nonfrivolous argument for the extension, modification, or reversal of existing law or the establishment of new law;

(iii) The allegations and other factual contentions have evidentiary support or, if specifically so identified, are likely to have evidentiary support after a reasonable opportunity for further investigation or discovery; and

(iv) The denials of factual contentions are warranted on the evidence, or if specifically so identified, are reasonably based on a lack of information or belief.

(c) Violations of paragraph (b)(1) of this section by a practitioner or non-practitioner may jeopardize the validity of the application or document, or the validity or enforceability of any patent, trademark registration, or certificate resulting therefrom. Violations of any of paragraphs (b)(2)(i) through (iv) of this section are, after notice and reasonable opportunity to respond, subject to such sanctions as deemed appropriate by the Commissioner, or the Commissioner's designee, which may include, but are not limited to, any combination of —

(1) Holding certain facts to have been established;

(2) Returning papers;

(3) Precluding a party from filing a paper, or presenting or contesting an issue;

(4) Imposing a monetary sanction;

(5) Requiring a terminal disclaimer for the period of the delay; or

(6) Terminating the proceedings in the Patent and Trademark Office.

(d) Any practitioner violating the provisions of this section may also be subject to disciplinary action. See § 10.23(c)(15).

[Added 50 FR 5175, Feb. 6, 1985, effective Mar. 8, 1985; para. (a) revised, 58 FR 54494, Oct. 22, 1993, effective Nov. 22, 1993; paras. (a) & (b) revised, paras. (c) & (d) added, 62 FR 53131, Oct. 10, 1997, effective Dec. 1, 1997; para. (a) revised, 69 FR 56481, Sept. 21, 2004, effective Oct. 21, 2004]

[2] 35 U.S.C. §133 provides:

35 U.S.C. §133 Time for prosecuting application.

Upon failure of the applicant to prosecute the application within six months after any action therein, of which notice has been given or mailed to the applicant, or within such shorter time, not less than thirty days, as fixed by the Commissioner in such action, the application shall be regarded as abandoned by the parties thereto, unless it be shown to the satisfaction of the Commissioner that such delay was unavoidable.

[3] Therefore, by example, an unavoidable delay in the payment of the Filing Fee might occur if a reply is shipped by the US Postal Service, but due to catastrophic accident, the delivery is not made.

[4] See: *Changes to Patent Practice and Procedure*; *Final Rule Notice*, 62 *Fed. Reg.* at 53158-59 (October 10, 1997), 1203 *Off. Gaz. Pat. Office* at 86-87 (October 21, 1997).

that the delay was unavoidable within the meaning of 35 U.S.C. §133 and 37 C.F.R. §1.137(a).[5] And the Petitioner must be diligent in attending to the matter.[6] Failure to do so does not constitute the care required under Pratt, and so cannot satisfy the test for diligence and due care.

(By contrast, unintentional delays are those that do not satisfy the very strict statutory and regulatory requirements of unavoidable delay, and also, by definition, are not intentional.[7]))

Allegations as to
Unintentional Delay

The requirements for a grantable petition under 37 C.F.R. §1.137(b) are the petition and fee, a statement/showing of unintentional delay, a proper reply, and–where appropriate--a terminal disclaimer and fee.

It appears as of this writing that Petitioner has yet to satisfy the "statement/showing" requirement under the regulation, and will require a statement from the applicant(s) or assignee(s) (with certificate under 37 C.F.R. §3.73(b)) in support of the petition .

CONCLUSION

The petition as considered under 37 C.F.R. §1.137(b) is **dismissed**.

Further correspondence with respect to this matter should be addressed as follows:[8]

By mail: Commissioner for Patents[9]
P.O. Box 1450
Alexandria, VA 22313-1450

---

[5] See: In re Application of G, 11 USPQ2d 1378, 1380 (Comm'r Pats. 1989).

[6] See: Diligence in Filing Petitions to Revive and Petitions to Withdraw the Holding of Abandonment, 1124 Off. Gaz. Pat. Office 33 (March 19, 1991). It was and is Petitioner's burden to exercise diligence in seeking either to have the holding of abandonment withdrawn or the application revived. See 1124 Off. Gaz. Pat. Office supra.

[7] Therefore, by example, an unintentional delay in the reply might occur if the reply and transmittal form are to be prepared for shipment by the US Postal Service, but other pressing matters distract one's attention and the mail is not timely deposited for shipment.

[8] On July 15, 2005, the Central Facsimile (FAX) Number changed to (571) 273-8300. The number (571) 273-8300 is be the only facsimile number recognized for centralized delivery. (For further information. see: http://www.uspto.gov/web/offices/pac/dapp/opla/preognotice/cfax062005.pdf .)

[9] To determine the appropriate addresses for other subject-specific correspondence, refer to the USPTO Web site at www.uspto.gov.

By FAX: IFW Formal Filings
(571) 273-8300
ATTN.: Office of Petitions

By hand: Mail Stop: Petition
Customer Service Window
Randolph Building
401 Dulany Street
Alexandria, VA 22314

While telephone inquiries regarding this decision may be directed to the undersigned at (571) 272-3214, it is noted that all practice before the Office is in writing (see: 37 C.F.R. §1.2[10]) and the proper authority for action on any matter in this regard are the statutes (35 U.S.C.), regulations (37 C.F.R.) and the commentary on policy (MPEP). Therefore, no telephone discussion may be controlling or considered authority for Petitioner's action(s).

John J. Gillon, Jr.
Senior Attorney
Office of Petitions

[10] The regulations at 37 C.F.R. §1.2 provide:

§1.2 Business to be transacted in writing.

All business with the Patent and Trademark Office should be transacted in writing.The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation,or understanding in relation to which there is disagreement or doubt.

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filing Date	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Docket No.	:	170154.401C1
Date	:	August 24, 2006

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

RENEWED PETITION UNDER 37 CFR 1.137(b)

This Renewed Petition is filed in response to the Decision mailed August 2, 2006, dismissing Applicants' Petition Under 37 CFR 1.137(b).

The petition was dismissed because the Petitions Attorney asserts that the Petitioner has yet to satisfy the "statement/showing" requirement under 37 CFR 1.137(b). In the Petition for Revival dated June 7, 2006, Petitioner did provide the required statement that the entire delay in filing the required reply, from the due date for the required reply until the filing of a grantable petition under 37 CFR 1.137(b), was unintentional. However, because the Petitioner was not counsel of record at the time the application went abandoned, the Petitions Attorney has dismissed the petition, stating that "Petitioner is not in a position to make such a statement as to the nature of the delay."

Petitioner respectfully disagrees. Although Petitioner was not counsel of record when the application went abandoned on December 14, 2005, Petitioner had been acting in a representative capacity since February 24, 2005, as substantiated by the attached Declaration of Frank Abramonte. Consequently, Petitioner did have sufficient personal knowledge of the circumstances to make a statement as to the nature of the delay. Further, Petitioner based such statement on the underlying facts and circumstances as related to Petitioner by Babak Habibi, president of the assignee company Braintech Canada Inc., who has first hand personal knowledge of same.

Further, Petitioner signed the Amendment dated June 23, 2005. Under 37 CFR 1.34, such signature constitutes a representation to the United States Patent and Trademark Office that Petitioner is authorized to represent the Assignee in the instant application. Thus, under 37 CFR 1.33(b), Petitioner was authorized to sign the Petition for Revival of an Application for Patent Abandoned Unintentionally Under 37 CFR 1.137(B), based on Form PTO/SB/62, which contains a statement as to the unintentional nature of the delay.

Petitioner understands that the Petitions Attorney requires additional information as set out in 37 CFR 1.137(b)(3) because there is a question as to whether the delay was unintentional. In support of the Petition Under 37 CFR 1.137(b), Petitioner has provided herewith: 1) a Declaration from Babak Habibi, president of the assignee who has first hand personal knowledge of the facts and circumstances, along with supporting Exhibits; and 2) a Declaration from Petitioner, who has first hand personal knowledge of the facts and circumstances, along with supporting Exhibits.

In view of the foregoing, and in view of the attached Declarations and Exhibits, Petitioner respectfully requests revival of the instant application.

ABB Inc. Exhibit 1002, Page 145 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Because the petition fee as set forth in 37 CFR 1.17(m) was paid with the original filing of the Petition Under 37 CFR 1.137(b), Petitioner believes no additional fee is due by way of this Renewed Petition. However, the Director is authorized to charge any additional fees due by way of this Renewed Petition, or credit any overpayment, to our Deposit Account No. 19-1090.

Because a response to the outstanding Office Action was filed along with the original filing of the Petition Under 37 CFR 1.137(b), Petitioner believes a second copy of that response is not necessary in light of the Patent Office's clear direction not to file duplicate papers.

STATEMENT: The entire delay in filing the required reply from the due date for the required reply until the filing of this renewed petition under 37 CFR 1.137(b) was unintentional.

Respectfully submitted,
Seed Intellectual Property Law Group PLLC



Frank Abramonte
Registration No. 38,066

Enclosures:
Declaration of Babak Habibi in Support of Petition for Revival Under 1.137(b), with Exhibits A through F
Declaration of Frank Abramonte in Support of Petition for Revival Under 1.137(b) , with Exhibits A through G

701 Fifth Avenue, Suite 6300
Seattle, Washington 98104-7092
Phone: (206) 622-4900
Fax: (206) 682-6031

(FXA:lrw) 824547_1

ABB Inc. Exhibit 1002, Page 146 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Examiner	:	McDieunel Marc
Art Unit	:	3661
Docket No.	:	170154.401C1

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

DECLARATION OF FRANK ABRAMONTE IN SUPPORT OF PETITION FOR REVIVAL UNDER 1.137(b)

Commissioner for Patents:

1. I am a patent attorney (Registration number 38,066) with the firm of Seed Intellectual Property Law Group PLLC, having a principal place of business at:
   701 Fifth Avenue
   Suite 6300
   Seattle, Washington 98104

2. I am personally aware of the facts recited in this declaration.

3. Braintech Canada Inc. (hereinafter Braintech) is assignee of U.S. patent application Serial No. 10/634,874, filed on August 6, 2003 (hereinafter the subject application).

4. On February 24, 2005, I received files transferred from Bruce M. Green (Registration No. 30,524) of Oyen Wiggs Green and Mutala, Intellectual Property Lawyers, including a file related to the subject application. Correspondence is attached as Exhibit A.

5. On March 14, 2005, I forwarded papers to Mr. Babak Habibi, president of Braintech related to the subject application, including papers entitled 1) Assignment, 2) Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, and 3) Statement Under 37 CFR 3.73(b). Correspondence is attached as Exhibit B.

ABB Inc. Exhibit 1002, Page 147 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

6. On April 21, 2005, I received from Mr. Habibi a first Office Action on the subject application, which had been mailed on February 24, 2005 to Mr. Green. Correspondence is attached as Exhibit C.

7. On May 6, 2005, I received an email from Mr. Green forwarding a copy of the first Office Action mailed February 24, 2005.

8. On May 12, 2005, while I was visiting the Braintech facilities in North Vancouver, B.C., Canada, I brought papers related to the subject application for execution. Later that day, Mr. Habibi returned the papers to me.

9. On May 20, 2005, I sent an email to Mr. Habibi, informing him that three (3) of the papers he had handed me had not been executed. The email had the three (3) papers attached, entitled: 1) Assignment, 2) Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, and 3) Statement Under 37 CFR 3.73(b). The email requested that he execute the papers and return them in time for filing the Response to the first Office Action mailed February 24, 2005. Correspondence is attached as Exhibit D.

10. On June 23, 2005, I filed a Response to the first Office Action (mailed February 24, 2005) along with a supplemental Information Disclosure Statement and reported the filing to Mr. Habibi. Correspondence is attached as Exhibit E. At that time I did not have an executed copy of the Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, or Statement Under 37 CFR 3.73(b).

11. On June 6, 2006, I checked the status of the subject application, and noted that the subject application had gone abandoned on December 14, 2005, for failure to timely reply to a second Office Action that was mailed September 14, 2005, to Mr. Green, prior counsel for Braintech. I immediately informed Mr. Habibi of the abandonment and discussed the events that lead to the abandonment. Mr. Habibi assured me that the abandonment was unintentional. Mr. Habibi instructed me to take appropriate action to revive the subject application.

12. To date, I have not received any correspondence or telephone calls from Mr. Green or his firm regarding the second Office Action mailed September 14, 2005.

13. On June 6, 2006, I began preparing a Response to the second Office Action mailed September 14, 2005, and a petition to revive the subject application.

ABB Inc. Exhibit 1002, Page 148 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

14. On June 7, 2006, I forwarded to Edward White of Braintech for signature another copy of the Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address and Statement Under 37 CFR 3.73(b) and requested immediate execution and return of the same. Correspondence is attached as Exhibit F.

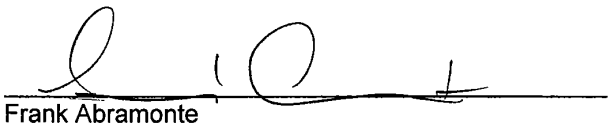
15. On June 7, 2006, I received the executed Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address and Statement Under 37 CFR 3.73(b) from Braintech.

16. On June 7, 2006, I filed the Petition to Revive in the U.S. Patent Office along with the appropriate fee, the executed Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, the executed Statement Under 37 CFR 3.73(b), and a Response to the second Office Action mailed September 14, 2005.

17. On June 7, 2006, I reported to Mr. Habibi the filing of the Petition to Revive for Unintentional Abandonment along with the executed Revocation of Power of Attorney with New Power of Attorney and Change of Correspondence Address form, the Statement Under 37 CFR 3.73(b), and the Response to the second Office Action mailed on September 14, 2005. Correspondence is attached as Exhibit G.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that the making of willfully false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

EXECUTED this 24th day of August, 2006.



Frank Abramonte
Registration No. 38,066

701 Fifth Avenue, Suite 6300
Seattle, Washington 98104-7092
Phone: (206) 622-4900
Fax: (206) 682-6031
(FXA:lrw) 821948_1

ABB Inc. Exhibit 1002, Page 149 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Exhibit A.

OYEN WIGGS GREEN & MUTALA LLP

INTELLECTUAL PROPERTY LAWYERS
REGISTERED PATENT AND TRADEMARK AGENTS

Gerald O.S. Oyen* Blake R. Wiggs*
Bruce M. Green* Catherine D. Mutala*
David J. McGruder* Thomas W. Bailey*
Gavin N. Manning* George F. Kondor
Hilton W. C. Sue Craig A. Ash
Richard A. Johnson Todd A. Rattray
Grace S. Law Mark A. Hopkinson
David H. Takagawa
* Law Corporation

480 - THE STATION
601 WEST CORDOVA STREET
VANCOUVER, B.C., CANADA
V6B 1G1

PHONE: (604) 669-3432
FAX: (604) 681-4081
bgreen@patentable.com
www.patentable.com

22 February, 2005

By Courier

Frank Abramonte, Esq.
Seed IP Law Group PLLC
701 Fifth Avenue, Suite 6300
Seattle WA 98104
U.S.A.

RECEIVED
FEB 2 4 2005
SEED INTELLECTUAL PROPERTY
LAW GROUP PLLC

Dear Mr. Abramonte:

Re: BrainTech Canada, Inc.
Our File: B445

As requested by Babak Habibi, enclosed are copies of all Patent and Trademark files which we have been handling for BrainTech Canada, Inc. Also attached is a report of active files, their current status, and the corresponding deadlines.

Yours truly,

Bruce M. Green
BMG/cnr
Enclosures

cc: Mr. Babak Habibi
BrainTech Canada, Inc.

Exhibit B

Laura Workman

From: Laura Workman
Sent: Monday, March 14, 2005 3:26 PM
To: 'dtodd@braintech.com'
Subject: FW: Assignments and Power of Attorney Documents for Signature

Dear Mr. Todd,

Attached for signature are the documents necessary to change the correspondence address in the U.S. Patent and Trademark Office. Please execute the documents and return them to us for filing.

PLEASE NOTE: The Power of Attorney and Statement documents should be executed *after* the latest date on the assignment documents.


401 Statement and Fee Address ...


401C1 Assignment, Revocation a...


402P1 Assignment, Revocation a...

Best regards,

Laura Rae Workman
Legal Assistant to Frank Abramonte
SEED Intellectual Property Law Group PLLC
701 Fifth Avenue, Suite 6300
Seattle, Washington 98104-7092 USA
Facsimile: (206) 682-6031
Telephone: (206) 622-4900 ext. 248
LauraW@SeedIP.com

ABB Inc. Exhibit 1002, Page 151 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Exhibit C

Frank Abramonte

From: Babak Habibi [bhabibi@braintech.com]
Sent: Thursday, April 21, 2005 12:07 PM
To: Frank Abramonte
Subject: FW: Braintech
Importance: High

Frank, this seems like a very important piece of correspondence from the PTO on the CIP application. At this point I am unsure whether Oyen Wiggs has responded to this letter. Please examine and let me know what actions we should take.

Best Regards,

Babak Habibi
Braintech Inc.
www.braintech.com
604-988-6440 (t)

From: Owen Jones
Sent: Thursday, April 21, 2005 11:51 AM
To: Babak Habibi
Subject: FW: Braintech

From: Vince Taylor
Sent: Thursday, April 21, 2005 10:08 AM
To: Owen Jones
Subject: FW: Braintech

Hi....any thoughts on an answer?

From: Gunderson, Mark H NAVSEA [mailto:mark.gunderson@navy.mil]
Sent: Tuesday, April 19, 2005 10:50 AM
To: vince taylor
Subject: Braintech

Hey Vince,

How are things going at Braintech? I noticed there is a non-final rejection on the extension of the first patent. Is this a concern? Thanks.

Regards,

Mark Gunderson

8/15/2006

Crane Division, Naval Surface Warfare Center (NSWC Crane)

Harnessing the Power of Technology for the Warfighter

Code 80221, Bldg. 3330C

Crane, IN 47522-5001

Ph: 812-854-6335

Fax: 812-854-4687

Email: Mark.Gunderson@navy.mil

<<Reject.pdf>>

8/15/2006

Exhibit D

Laura Workman

From: Frank Abramonte
Sent: Friday, May 20, 2005 3:43 PM
To: 'bhabibi@braintech.com'
Subject: FW: Formal Docs to Client

Babak,

(5/12/06)

You must have missed signing these in the pile of papers I gave you last Thursday. Please execute and return the attached by Tuesday morning, if possible.

I have new claims for the continuation-in-part, but am reconsidering the strategy in light of my detail review of the application.

-Frank


Assignment.DOC


Revocation.DOC


Statement Under 3.73(b).DOC

ABB Inc. Exhibit 1002, Page 154 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Exhibit E

Seed IP

June 23, 2005

Frank Abramonte
FrankA@SeedIP.com

Mr. Babak Habibi, President
Braintech Canada Inc.
102 & 104b – 930 West 1st Street
North Vancouver, BC V7P 3N4
CANADA

Re: U.S. Patent Application No. 10/634,874
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Seed IP Ref: 170154.401C1

Dear Mr. Habibi:

Enclosed for your records, please find the Amendment and Supplemental Information Disclosure Statement that were filed today in the U.S. Patent and Trademark Office.

We will continue to keep you informed of the progress of this application.

Very truly yours,
Seed IP Law Group PLLC

Frank Abramonte

Enclosures:
Amendment, with transmittal documents
Supplemental Information Disclosure Statement

604264_1

Seed Intellectual Property Law Group PLLC
address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
phone 206.622.4900
fax 206.682.6031
website SeedIP.com

****
*** TX REPORT ***
****

Exhibit F

TRANSMISSION OK

TX/RX NO	2991
CONNECTION TEL	#53916049866131
CONNECTION ID	
ST. TIME	06/07 12:43
USAGE T	00'26
PGS. SENT	2
RESULT	OK

-CL

Seed IP

June 7, 2006

Laura Workman
LauraW@SeedIP.com

Facsimile Transmission

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 2 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Thank you for the signed Revocation of Power of Attorney. As you noted, I previously attached a Fee Transmittal rather than the Statement Under 37 CFR 3.73(b). I apologize for the inconvenience.

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

Seed IP

June 7, 2006

Laura Workman
LauraW@SeedIP.com

Facsimile Transmission

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 2 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Thank you for the signed Revocation of Power of Attorney. As you noted, I previously attached a Fee Transmittal rather than the Statement Under 37 CFR 3.73(b). I apologize for the inconvenience.

Attached please find the Statement Under 37 CFR 3.73(b) for signature. Please sign and return it to us by facsimile without delay.

Transmission Information:

Date: 6/7/06 Time: 12:43 By: Crystal L.

CONFIDENTIALITY NOTICE:
The information contained in this facsimile message is legally privileged and/or confidential information intended only for the use of the addressee named above. If you are not the intended recipient, you are hereby notified that any use, dissemination, distribution, or copying of this facsimile or its content is strictly prohibited. If you have received this facsimile in error, please immediately notify us by telephone and return the original facsimile message to us by mail or destroy it without making a copy. Thank you.
792115_1

****
*** TX REPORT ***
****

TRANSMISSION OK

TX/RX NO	3112
CONNECTION TEL	#93416049866131
CONNECTION ID	
ST. TIME	06/07 12:03
USAGE T	00'52
PGS. SENT	3
RESULT	OK

Seed IP

June 7, 2006

Frank Abramonte
FrankA@SeedIP.com

Facsimile Transmission

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 3 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Please sign the attached Revocation of Power of Attorney and Statement Under 37 CFR 3.73(b), and return them to us by facsimile without delay.

Seed IP

June 7, 2006

Frank Abramonte
FrankA@SeedIP.com

Facsimile Transmission

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 3 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Please sign the attached Revocation of Power of Attorney and Statement Under 37 CFR 3.73(b), and return them to us by facsimile without delay.

Please let us know if you have any questions.

Transmission Information:

Date: Time: By:

CONFIDENTIALITY NOTICE:
The information contained in this facsimile message is legally privileged and/or confidential information intended only for the use of the addressee named above. If you are not the intended recipient, you are hereby notified that any use, dissemination, distribution, or copying of this facsimile or its content is strictly prohibited. If you have received this facsimile in error, please immediately notify us by telephone and return the original facsimile message to us by mail or destroy it without making a copy. Thank you.
792115_1

EXPRESS MAIL NO. EV529788248US

REVOCATION OF POWER OF ATTORNEY WITH NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS		
	Application Number	10/634,874
	Filing Date	August 6, 2003
	First Named Inventor	Babak Habibi
	Art Unit	3661
	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

I hereby revoke all previous powers of attorney given in the above-identified application.

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint the practitioners at Seed IP Law Group PLLC, Customer Number: **00500**

☒ Please change the correspondence address for the above-identified application to:

☒ The address associated with Customer Number **00500**

OR

☐ Firm *or* Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the:

☐ Applicant/Inventor.

☒ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

☒ As assignee of record of the entire interest I/we hereby elect, under 37 CFR 3.71, to prosecute the application to the exclusion of the inventor(s).

SIGNATURE of Applicant or Assignee of Record

Signature		Date	
Name	Edward White, C.A.		
Title and Company (Assignee)	Secretary		
	Braintech Canada, Inc.		

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☒ *Total of 1 forms are submitted.

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

792097_1

jas

EXPRESS MAIL NO. EV529788248US

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: **Babak Habibi et al.**

Application No./Patent No.: **10/634,874** Filed/Issue Date: **August 6, 2003**

Entitled: **METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS**

Braintech Canada, Inc. (Name of Assignee) a **corporation** (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. [X] the assignee of the entire right, title, and interest; or

2. [ ] an assignee of less than the entire right, title and interest.
The extent (by percentage) of its ownership interest is _____%

in the patent application/patent identified above by virtue of either:

A. [X] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or a true copy of the original assignment is attached.

OR

B. [ ] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From:_____ To:_____
The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

2. From:_____ To:_____
The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

3. From:_____ To:_____
The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

[ ] Additional documents in the chain of title are listed on a supplemental sheet.

[X] As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (*i.e.*, a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

_____ Signature

_____ Date

Edward White, C.A. Typed or printed name

Secretary Title

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

Docket No. 170154.401C1

792096_1

jaa

Exhibit G

Laura Workman

From: Frank Abramonte
Sent: Wednesday, June 07, 2006 5:31 PM
To: 'bhabibi@braintech.com'
Cc: Laura Workman
Subject: Petition to Revive and Response to Office Action

U.S. Application No. 10/634,874
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Seed IP Ref: 170154.401C1

Dear Babak:

Attached for your records is a copy of the Petition to Revive and Response to Office Action that were filed today in the USPTO with regard to the application identified above. Please note that we also submitted a Revocation of Power of Attorney With New Power of Attorney and Change of Correspondence Address with this filing. Please let me know if you have any questions.

Best regards,

-Frank



Petition to Revive_ Response t...

ABB Inc. Exhibit 1002, Page 162 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Examiner	:	McDieunel Marc
Art Unit	:	3661
Docket No.	:	170154.401C1

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

DECLARATION OF BABAK HABIBI IN SUPPORT OF PETITION FOR REVIVAL UNDER 1.137(b)

Commissioner for Patents:

1. I am president of Braintech Canada Inc. (hereinafter Braintech) having a principal place of business at:
   102 - 930 West 1st Street
   North Vancouver, British Columbia, Canada
   V7P 3N4

2. Braintech is assignee of U.S. patent application Serial No. 10/634,874 filed on August 6, 2003 (hereinafter the subject application).

3. I am personally aware of the facts recited herein.

4. Our counsel at the time of filing the subject application was Bruce M. Green (Registration No. 30,524) of Oyen Wiggs Green and Mutala, Intellectual Property Lawyers, with an address of:

ABB Inc. Exhibit 1002, Page 163 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

480 The Station
601 West Cordova Street
Vancouver, British Columbia, Canada
V6B1G1

5. On February 17, 2005, I instructed Mr. Green to transfer all our files to Frank Abramonte (Registration number 38,066).

6. On March 14, 2005, I received papers from Mr. Abramonte related to the subject application, including papers entitled1) Assignment,2) Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, and 3) Statement Under 37 CFR 3.73(b). Correspondence attached as Exhibit A.

7. I unintentionally failed to return the Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address to Mr. Abramonte.

8. On April 21, 2005, I forwarded to Mr. Abramonte a first Office Action, which I received from Mr. Gunderson, an acquaintance, via Owen Jones of Braintech. Correspondence is attached as Exhibit B.

9. On May 12, 2005, Mr. Abramonte was visiting the Braintech facilities in North Vancouver, Canada. Mr. Abramonte handed me a number of documents for execution. Before Mr. Abramonte and I parted, I handed to Mr. Abramonte the papers I had previously received related to the subject application.

10. On May 20, 2005, I received an email from Mr. Abramonte, informing me that three (3) of the papers I had handed Mr. Abramonte on May 12, 2005, had not been executed. The email had the three (3) papers attached, entitled: 1) Assignment, 2) Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, and 3) Statement Under 37 CFR 3.73(b). The email requested that I return the executed papers. Correspondence is attached as Exhibit C.

11. On June 1, 2005, I returned to the office after a business trip and an illness.

12. I inadvertently failed to return the Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address and Statement Under 37 CFR 3.73(b) to Mr. Abramonte.

13. On June 23, 2005, Mr. Abramonte reported to me that a Response to the first Office Action had been filed that day. Correspondence is attached as Exhibit D.

14. The application went abandoned on December 14, 2005 for failure to respond to a second Office Action dated September 14, 2005.

15. On June 6, 2006, Mr. Abramonte informed me by telephone of the abandonment of the subject application. Mr. Abramonte was the first to inform Braintech of the abandonment. Mr. Abramonte explained that according to the U.S. Patent Office records, a second Office Action on the subject application issued and was sent on September 14, 2005, to Mr. Green, our prior counsel. To this date, we have not received any correspondence from Mr. Green or his firm indicating that the second Office Action had issued or that there was any outstanding action or associated deadline with respect to the subject application.

16. On June 6, 2006, I explained to Mr. Abramonte that we had not received any indication of the outstanding Office Action or deadline from prior counsel, and had no intention of allowing the subject application to go abandoned. I instructed Mr. Abramonte to take appropriate action.

17. On June 7, 2006, Mr. Abramonte forwarded another copy of the Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address and Statement Under 37 CFR 3.73(b) to Edward White of Braintech, and requested that the documents be executed and returned immediately. Correspondence is attached as Exhibit E.

18. On June 7, 2006, we returned executed copies of the Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address and Statement Under 37 CFR 3.73(b) to Mr. Abramonte.

19. On June 7, 2006, Mr. Abramonte reported to me the filing of papers entitled: 1) Petition to Revive for Unintentional Abandonment, 2) Revocation Of Power Of Attorney With New Power Of Attorney And Change Of Correspondence Address, and 3) Response to the Office Action mailed on September 14, 2005. Correspondence attached as Exhibit F.

ABB Inc. Exhibit 1002, Page 165 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

20. On August 15, 2006, Mr. Abramonte reported to me the Decision dated August 2, 2006, dismissing our Petition to Revive.

21. At no time did we ever intend to allow the subject application to go abandoned.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that the making of willfully false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

EXECUTED this 18th day of August, 2006.

Babak Habibi

701 Fifth Avenue, Suite 6300
Seattle, Washington 98104-7092
Phone: (206) 622-4900
Fax: (206) 682-6031

(FXA:lnw) 821102_2

ABB Inc. Exhibit 1002, Page 166 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Exhibit A

Laura Workman

From: Laura Workman
Sent: Monday, March 14, 2005 3:26 PM
To: 'dtodd@braintech.com'
Subject: FW: Assignments and Power of Attorney Documents for Signature

Dear Mr. Todd,

Attached for signature are the documents necessary to change the correspondence address in the U.S. Patent and Trademark Office. Please execute the documents and return them to us for filing.

PLEASE NOTE: The Power of Attorney and Statement documents should be executed *after* the latest date on the assignment documents.


401 Statement and Fee Address ...


401C1 Assignment, Revocation a...


402P1 Assignment, Revocation a...

Best regards,

Laura Rae Workman
Legal Assistant to Frank Abramonte
SEED Intellectual Property Law Group PLLC
701 Fifth Avenue, Suite 6300
Seattle, Washington 98104-7092 USA
Facsimile: (206) 682-6031
Telephone: (206) 622-4900 ext. 248
LauraW@SeedIP.com

ABB Inc. Exhibit 1002, Page 167 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Exhibit B

Frank Abramonte

From: Babak Habibi [bhabibi@braintech.com]
Sent: Thursday, April 21, 2005 12:07 PM
To: Frank Abramonte
Subject: FW: Braintech
Importance: High

Frank, this seems like a very important piece of correspondence from the PTO on the CIP application. At this point I am unsure whether Oyen Wiggs has responded to this letter. Please examine and let me know what actions we should take.

Best Regards,

Babak Habibi
Braintech Inc.
www.braintech.com
604-988-6440 (t)

From: Owen Jones
Sent: Thursday, April 21, 2005 11:51 AM
To: Babak Habibi
Subject: FW: Braintech

From: Vince Taylor
Sent: Thursday, April 21, 2005 10:08 AM
To: Owen Jones
Subject: FW: Braintech

Hi....any thoughts on an answer?

From: Gunderson, Mark H NAVSEA [mailto:mark.gunderson@navy.mil]
Sent: Tuesday, April 19, 2005 10:50 AM
To: vince taylor
Subject: Braintech

Hey Vince,

How are things going at Braintech? I noticed there is a non-final rejection on the extension of the first patent. Is this a concern? Thanks.

Regards,

Mark Gunderson

8/15/2006

Crane Division, Naval Surface Warfare Center (NSWC Crane)

Harnessing the Power of Technology for the Warfighter

Code 80221, Bldg. 3330C

Crane, IN 47522-5001

Ph: 812-854-6335

Fax: 812-854-4687

Email: Mark.Gunderson@navy.mil

<<Reject.pdf>>

8/15/2006

Exhibit C

Laura Workman

From: Frank Abramonte
Sent: Friday, May 20, 2005 3:43 PM
To: 'bhabibi@braintech.com'
Subject: FW: Formal Docs to Client

Babak,

(5/12/06)

You must have missed signing these in the pile of papers I gave you last Thursday. Please execute and return the attached by Tuesday morning, if possible.

I have new claims for the continuation-in-part, but am reconsidering the strategy in light of my detail review of the application.

-Frank


Assignment.DOC


Revocation.DOC


Statement Under 3.73(b).DOC

ABB Inc. Exhibit 1002, Page 170 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Exhibit D

Seed IP

June 23, 2005

Frank Abramonte
FrankA@SeedIP.com

Mr. Babak Habibi, President
Braintech Canada Inc.
102 & 104b – 930 West 1st Street
North Vancouver, BC V7P 3N4
CANADA

Re: U.S. Patent Application No. 10/634,874
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Seed IP Ref: 170154.401C1

Dear Mr. Habibi:

Enclosed for your records, please find the Amendment and Supplemental Information Disclosure Statement that were filed today in the U.S. Patent and Trademark Office.

We will continue to keep you informed of the progress of this application.

Very truly yours,
Seed IP Law Group PLLC

Frank Abramonte

Enclosures:
Amendment, with transmittal documents
Supplemental Information Disclosure Statement

604264_1

Seed Intellectual Property Law Group PLLC
address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
phone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

****
*** TX REPORT ***
****

Exhibit E

TRANSMISSION OK

TX/RX NO	2991
CONNECTION TEL	#53916049866131
CONNECTION ID	
ST. TIME	06/07 12:43
USAGE T	00'26
PGS. SENT	2
RESULT	OK

-CL

Seed IP

June 7, 2006

Laura Workman
LauraW@SeedIP.com

Facsimile Transmission

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 2 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Thank you for the signed Revocation of Power of Attorney. As you noted, I previously attached a Fee Transmittal rather than the Statement Under 37 CFR 3.73(b). I apologize for the inconvenience.

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

Seed IP

June 7, 2006

Laura Workman
LauraW@SeedIP.com

Facsimile Transmission

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 2 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Thank you for the signed Revocation of Power of Attorney. As you noted, I previously attached a Fee Transmittal rather than the Statement Under 37 CFR 3.73(b). I apologize for the inconvenience.

Attached please find the Statement Under 37 CFR 3.73(b) for signature. Please sign and return it to us by facsimile without delay.

Transmission Information:

Date: 6/7/06 Time: 12:43 By: Crystal L.

CONFIDENTIALITY NOTICE:
The information contained in this facsimile message is legally privileged and/or confidential information intended only for the use of the addressee named above. If you are not the intended recipient, you are hereby notified that any use, dissemination, distribution, or copying of this facsimile or its content is strictly prohibited. If you have received this facsimile in error, please immediately notify us by telephone and return the original facsimile message to us by mail or destroy it without making a copy. Thank you.
792115_1

****
*** TX REPORT ***
****

TRANSMISSION OK

TX/RX NO	3112
CONNECTION TEL	#93416049866131
CONNECTION ID	
ST. TIME	06/07 12:03
USAGE T	00'52
PGS. SENT	3
RESULT	OK

Seed IP

June 7, 2006

Frank Abramonte
FrankA@SeedIP.com

Facsimile Transmission

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 3 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Please sign the attached Revocation of Power of Attorney and Statement Under 37 CFR 3.73(b), and return them to us by facsimile without delay.

Seed IP

June 7, 2006

Frank Abramonte
FrankA@SeedIP.com

Facsimile Transmission

Seed Intellectual Property Law Group PLLC

address 701 Fifth Avenue
Suite 6300
Seattle, WA 98104
telephone 206.622.4900
facsimile 206.682.6031
website SeedIP.com

To: Edward White, C.A.

Fax No.: 604.986.6131

Phone No.: 604.988.6441 ext. 205

Re: **U.S. Patent Application No. 10/634,874**
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Your Ref.:

Seed IP Ref.: 170154.401c1

No. of Pages: 3 (including this page)

If you do not receive all pages, please call Laura Workman at (206) 622-4900 or fax our office.

[X] Urgent [ ] For Review [ ] Please Confirm Receipt [X] Please Reply ASAP

Comments:

Dear Mr. White;

Please sign the attached Revocation of Power of Attorney and Statement Under 37 CFR 3.73(b), and return them to us by facsimile without delay.

Please let us know if you have any questions.

Transmission Information:

Date: Time: By:

CONFIDENTIALITY NOTICE:
The information contained in this facsimile message is legally privileged and/or confidential information intended only for the use of the addressee named above. If you are not the intended recipient, you are hereby notified that any use, dissemination, distribution, or copying of this facsimile or its content is strictly prohibited. If you have received this facsimile in error, please immediately notify us by telephone and return the original facsimile message to us by mail or destroy it without making a copy. Thank you.
792115_1

EXPRESS MAIL NO. EV529788248US

REVOCATION OF POWER OF ATTORNEY WITH NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS		
	Application Number	10/634,874
	Filing Date	August 6, 2003
	First Named Inventor	Babak Habibi
	Art Unit	3661
	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

I hereby revoke all previous powers of attorney given in the above-identified application.

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint the practitioners at Seed IP Law Group PLLC, Customer Number: **00500**

☒ Please change the correspondence address for the above-identified application to:

☒ The address associated with Customer Number **00500**

OR

☐ Firm *or* Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the:

☐ Applicant/Inventor.

☒ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)

☒ As assignee of record of the entire interest I/we hereby elect, under 37 CFR 3.71, to prosecute the application to the exclusion of the inventor(s).

SIGNATURE of Applicant or Assignee of Record

Signature		Date	
Name	Edward White, C.A.		
Title and Company (Assignee)	Secretary		
	Braintech Canada, Inc.		

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☒ *Total of 1 forms are submitted.

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

792097_1

EXPRESS MAIL NO. EV529788248US

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: **Babak Habibi et al.**

Application No./Patent No.: **10/634,874** Filed/Issue Date: **August 6, 2003**

Entitled: **METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS**

Braintech Canada, Inc. a **corporation**
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. [X] the assignee of the entire right, title, and interest; or

2. [ ] an assignee of less than the entire right, title and interest.
The extent (by percentage) of its ownership interest is _____%

in the patent application/patent identified above by virtue of either:

A. [X] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or a true copy of the original assignment is attached.

OR

B. [ ] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From:_____ To:_____
The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

2. From:_____ To:_____
The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

3. From:_____ To:_____
The document was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

[ ] Additional documents in the chain of title are listed on a supplemental sheet.

[X] As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[**NOTE**: A separate copy (*i.e.*, a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

_____ _____
Signature Date

Edward White, C.A. **Secretary**
Typed or printed name Title

SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.
Docket No. 170154.401C1 792096_1

jaa

Exhibit F

Laura Workman

From: Frank Abramonte
Sent: Wednesday, June 07, 2006 5:31 PM
To: 'bhabibi@braintech.com'
Cc: Laura Workman
Subject: Petition to Revive and Response to Office Action

U.S. Application No. 10/634,874
METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Seed IP Ref: 170154.401C1

Dear Babak:

Attached for your records is a copy of the Petition to Revive and Response to Office Action that were filed today in the USPTO with regard to the application identified above. Please note that we also submitted a Revocation of Power of Attorney With New Power of Attorney and Change of Correspondence Address with this filing. Please let me know if you have any questions.

Best regards,

-Frank



Petition to Revive_ Response t...

ABB Inc. Exhibit 1002, Page 178 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Electronic Acknowledgement Receipt

EFS ID:	1171205
Application Number:	10634874
Confirmation Number:	7619
Title of Invention:	Method and apparatus for single image 3D vision guided robotics
First Named Inventor:	Babak Habibi
Customer Number:	500
Filer:	Frank Abramonte/Laura Workman
Filer Authorized By:	Frank Abramonte
Attorney Docket Number:	B4450014
Receipt Date:	24-AUG-2006
Filing Date:	06-AUG-2003
Time Stamp:	20:04:57
Application Type:	Utility
International Application Number:	

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)	Multi Part	Pages
1	Petition for review by the Office of Petitions.	170154_401C1_Renewed_Petition.pdf	1002563	no	35

Warnings:	
Information:	
Total Files Size (in bytes):	1002563

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.

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

JJGJR.: 08-07

Paper No: __

COPY MAILED

AUG 27 2007

OFFICE OF PETITIONS

SEED INTELLECTUAL
PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 6300
SEATTLE WA 98104-7092

In re Application of	:	
Habibi, et al.	:	DECISION
Application No.: 10/634,874	:	
Filing Date: 6 August, 2003	:	
Attorney Docket No. B4450014//	:	

This is a decision on the petition filed on 24 August, 2006, to revive the instant application under 37 C.F.R. §1.137(b) as having as abandoned due to unintentional delay.

The Office regrets the delay in addressing this matter, however, the instant petition was presented to the attorneys in the Office of Petitions only at this writing.[1]

For the reasons set forth below the petition under 37 C.F.R. §1.137(b) is **GRANTED**.

[1] NOTE: **Monitoring of the status of applications on PAIR can inform one's management of application responses and provide an indication when mailings of Office actions should be expected. Status Inquiries filed at three (3) or four (4) month intervals provide a demonstration of diligence and attention in supporting a petition seeking relief under 37 C.F.R. §1.181.**

BACKGROUND

The record reflects that:

- Petitioner failed to reply timely and properly to a non-final Office action mailed on14 September, 2005, with reply due absent extension of time on or before 14 December, 2005;
-
- the application went abandoned by operation of law after midnight 14 December, 2005;
- it does not appear that the Office mailed the Notice of Abandonment before the instant petition was filed;
- with the original petition (with fee), Petitioner filed as a reply an amendment, and made the statement of unintentional delay, however, Petitioner was not Counsel of record at the time the application went abandoned, Petitioner was not in a position to make such a statement as to the nature of the delay–as a result the petition was dismissed on 2 August, 2006;
- the instant petition seeks to overcome this deficiency, and, while the certificate under 37 C.F.R. §3.73(b) is unsigned–a deficiency that Petitioner should correct immediately–the Office record reflects the assignment to referenced in the unsigned certificate and the statement of the assignee's officer, Baibak Habibi, is considered as is the transmittal letter of former Counsel forwarding files to present Counsel several months before the date of abandonment–thus making valid present Counsel's statement of unintentional delay.

Out of an abundance of caution, Petitioners always are reminded that those registered to practice *and* all others who make representations before the Office are reminded to inquire into the underlying facts of representations made to the Office and support averments with the appropriate documentation–since all owe to the Office the continuing duty to disclose.[2]

---

[2] See supplement of 17 June, 1999. The Patent and Trademark Office is relying on petitioner's duty of candor and good faith and accepting a statement made by Petitioner. See Changes to Patent Practice and Procedure, 62 Fed. Reg. at 53160 and 53178, 1203 Off. Gaz. Pat. Office at 88 and 103 (responses to comments 64 and 109)(applicant obligated under 37 C.F.R. §10.18 to inquire into the underlying facts and circumstances when providing statements to the Patent and Trademark Office).

Specifically, the regulations at 37 C.F.R. §10.18 provide:

§ 10.18 Signature and certificate for correspondence filed in the Patent and Trademark Office.
(a) For all documents filed in the Office in patent, trademark, and other non-patent matters, except for correspondence that is required to be signed by the applicant or party, each piece of correspondence filed by a practitioner in the Patent and Trademark Office must bear a signature by such practitioner complying with the provisions of §1.4(d), §1.4(e), or § 2.193(c)(1) of this chapter.
(b) By presenting to the Office (whether by signing, filing, submitting, or later advocating) any paper, the party presenting such paper, whether a practitioner or non-practitioner, is certifying that—
(1) All statements made therein of the party's own knowledge are true, all statements made therein on information and belief are believed to be true, and all statements made therein are made with the knowledge that whoever, in any matter within the jurisdiction of the Patent

STATUTES, REGULATIONS AND ANALYSIS

Congress has authorized the Commissioner to "revive an application if the delay is shown to the satisfaction of the Commissioner to have been "unavoidable." 35 U.S.C. §133 (1994).[3]

The regulations at 37 C.F.R. §1.137(a) and (b) set forth the requirements for a petitioner to revive a previously unavoidably or unintentionally, respectively, abandoned application under this congressional grant of authority. The language of 35 U.S.C. §133 and 37 C.F.R. §1.137(a) is clear, unambiguous, and without qualification: the delay in tendering the reply to the outstanding Office action, as well as filing the first petition seeking revival, must have been unavoidable for the reply now to be accepted on petition.[4]

Delays in responding properly raise the question whether delays are unavoidable.[5] Where there is

---

and Trademark Office, knowingly and willfully falsifies, conceals, or covers up by any trick, scheme, or device a material fact, or makes any false, fictitious or fraudulent statements or representations, or makes or uses any false writing or document knowing the same to contain any false, fictitious or fraudulent statement or entry, shall be subject to the penalties set forth under 18 U.S.C. 1001, and that violations of this paragraph may jeopardize the validity of the application or document, or the validity or enforceability of any patent, trademark registration, or certificate resulting therefrom; and

(2) To the best of the party's knowledge, information and belief, formed after an inquiry reasonable under the circumstances, that —

(i) The paper is not being presented for any improper purpose, such as to harass someone or to cause unnecessary delay or needless increase in the cost of prosecution before the Office;

(ii) The claims and other legal contentions therein are warranted by existing law or by a nonfrivolous argument for the extension, modification, or reversal of existing law or the establishment of new law;

(iii) The allegations and other factual contentions have evidentiary support or, if specifically so identified, are likely to have evidentiary support after a reasonable opportunity for further investigation or discovery; and

(iv) The denials of factual contentions are warranted on the evidence, or if specifically so identified, are reasonably based on a lack of information or belief.

(c) Violations of paragraph (b)(1) of this section by a practitioner or non-practitioner may jeopardize the validity of the application or document, or the validity or enforceability of any patent, trademark registration, or certificate resulting therefrom. Violations of any of paragraphs (b)(2)(i) through (iv) of this section are, after notice and reasonable opportunity to respond, subject to such sanctions as deemed appropriate by the Commissioner, or the Commissioner's designee, which may include, but are not limited to, any combination of —

(1) Holding certain facts to have been established;

(2) Returning papers;

(3) Precluding a party from filing a paper, or presenting or contesting an issue;

(4) Imposing a monetary sanction;

(5) Requiring a terminal disclaimer for the period of the delay; or

(6) Terminating the proceedings in the Patent and Trademark Office.

(d) Any practitioner violating the provisions of this section may also be subject to disciplinary action. See § 10.23(c)(15).

[Added 50 FR 5175, Feb. 6, 1985, effective Mar. 8, 1985; para. (a) revised, 58 FR 54494, Oct. 22, 1993, effective Nov. 22, 1993; paras. (a) & (b) revised, paras. (c) & (d) added, 62 FR 53131, Oct. 10, 1997, effective Dec. 1, 1997; para. (a) revised, 69 FR 56481, Sept. 21, 2004, effective Oct. 21, 2004]

[3] 35 U.S.C. §133 provides:

35 U.S.C. §133 Time for prosecuting application.

Upon failure of the applicant to prosecute the application within six months after any action therein, of which notice has been given or mailed to the applicant, or within such shorter time, not less than thirty days, as fixed by the Commissioner in such action, the application shall be regarded as abandoned by the parties thereto, unless it be shown to the satisfaction of the Commissioner that such delay was unavoidable.

[4] Therefore, by example, an unavoidable delay in the payment of the Filing Fee might occur if a reply is shipped by the US Postal Service, but due to catastrophic accident, the delivery is not made.

[5] See: *Changes to Patent Practice and Procedure*; *Final Rule Notice*, 62 *Fed. Reg.* at 53158-59 (October 10, 1997), 1203 *Off. Gaz. Pat. Office* at 86-87 (October 21, 1997).

a question whether the delay was unavoidable, Petitioners must meet the burden of establishing that the delay was unavoidable within the meaning of 35 U.S.C. §133 and 37 C.F.R. §1.137(a).[6] And the Petitioner must be diligent in attending to the matter.[7] Failure to do so does not constitute the care required under Pratt, and so cannot satisfy the test for diligence and due care.

(By contrast, unintentional delays are those that do not satisfy the very strict statutory and regulatory requirements of unavoidable delay, and also, by definition, are not intentional.[8]))

Allegations as to
Unintentional Delay

The requirements for a grantable petition under 37 C.F.R. §1.137(b) are the petition and fee, a statement/showing of unintentional delay, a proper reply, and–where appropriate--a terminal disclaimer and fee.

It appears that Petitioner has satisfied the requirements of the regulation.

CONCLUSION

The petition as considered under 37 C.F.R. §1.137(b) is **granted**.

The instant application is released to Technology Center 3600 for further processing in due course.

While telephone inquiries regarding this decision may be directed to the undersigned at (571) 272-3214, it is noted that all practice before the Office is in writing (see: 37 C.F.R. §1.2[9]) and the proper authority for action on any matter in this regard are the statutes (35 U.S.C.), regulations

---

[6] See: In re Application of G, 11 USPQ2d 1378, 1380 (Comm'r Pats. 1989).

[7] See: Diligence in Filing Petitions to Revive and Petitions to Withdraw the Holding of Abandonment, 1124 Off. Gaz. Pat. Office 33 (March 19, 1991). It was and is Petitioner's burden to exercise diligence in seeking either to have the holding of abandonment withdrawn or the application revived. See 1124 Off. Gaz. Pat. Office supra.

[8] Therefore, by example, an unintentional delay in the reply might occur if the reply and transmittal form are to be prepared for shipment by the US Postal Service, but other pressing matters distract one's attention and the mail is not timely deposited for shipment.

[9] The regulations at 37 C.F.R. §1.2 provide:
§1.2 Business to be transacted in writing.
All business with the Patent and Trademark Office should be transacted in writing.The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation,or understanding in relation to which there is disagreement or doubt.

(37 C.F.R.) and the commentary on policy (MPEP). Therefore, no telephone discussion may be controlling or considered authority for Petitioner's action(s).

John J. Gillon, Jr.
Senior Attorney
Office of Petitions

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 NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/634,874	08/06/2003	Babak Habibi	B4450014

CONFIRMATION NO. 7619

OC000000025713045

500
SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

Date Mailed: 09/06/2007

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 06/07/2006.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Office of Initial Patent Examination (571) 272-4000, or 1-800-PTO-9199
OFFICE COPY

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 NUMBER	FILING OR 371 (c) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/634,874	08/06/2003	Babak Habibi	B4450014

CONFIRMATION NO. 7619

OC000000025713027

500
SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

Date Mailed: 09/06/2007

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 06/07/2006.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Office of Initial Patent Examination (571) 272-4000, or 1-800-PTO-9199
OFFICE COPY

WEST Search History

Hide Items | Restore | Clear | Cancel

DATE: Saturday, September 22, 2007

Hide?	Set Name	Query	Hit Count
		DB=PGPB,USPT,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=ADJ	
☐	L9	calibrat$6 and L8	130
☐	L8	reference frame and L7	252
☐	L7	(700/245,246,253,257,258,259,279 or 29/218,702,714,720,407.1,407.04 or 318/568.13,568.15,568.16,640 or 348/42,94,154,190,291,287552 or 901/6,14,17,46,47 or 414/730,737 or 382/154).ccls.	11432
☐	L6	('20050233770' |'20050190957' |'20050142293' |'20050045214' |'20040258514' |'20040243320')!.ABPN1,NRPN,PN,TBAN,WKU.	12
☐	L5	wafer and computer and L4	2168
☐	L4	camera and L3	6541
☐	L3	(robot$6 or articulat$3 or automat$6 or autonomous$2 or CNC or machine$2 or mechanical device or mechan$6 or servomechan$4) and L2	27944
☐	L2	calibrat$$ and semiconductor and (correct$3 or fix$3)	32746
☐	L1	10/126493	7

END OF SEARCH HISTORY

ABB Inc. Exhibit 1002, Page 188 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

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

NOTICE OF ALLOWANCE AND FEE(S) DUE

500 7590 10/10/2007

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	PAPER NUMBER
3661	

DATE MAILED: 10/10/2007

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

TITLE OF INVENTION: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$720	$300	$0	$1020	01/10/2008

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 SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

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 and an extra copy of the form should be submitted. 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: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

ABB Inc. Exhibit 1002, Page 189 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (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)

500 7590 10/10/2007

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

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 facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

TITLE OF INVENTION: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$720	$300	$0	$1020	01/10/2008

EXAMINER	ART UNIT	CLASS-SUBCLASS
MARC, MCDIEUNEL	3661	700-245000

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/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form 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 has been filed for recordation as set forth in 37 CFR 3.11. 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. The following fee(s) are submitted:

☐ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

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

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

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

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information 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 12 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.

ABB Inc. Exhibit 1002, Page 190 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

500 7590 10/10/2007

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	PAPER NUMBER
3661	

DATE MAILED: 10/10/2007

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

The Patent Term Adjustment to date is 215 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 215 day(s).

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 Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

ABB Inc. Exhibit 1002, Page 191 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Notice of Allowability	Application No.	Applicant(s)	
	10/634,874	HABIBI ET AL.	
	Examiner	Art Unit	
	McDieunel Marc	3661	

-- 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 *8/24/2006*.

2. ☒ The allowed claim(s) is/are *33-61*.

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

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ 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. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

ABB Inc. Exhibit 1002, Page 192 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Allowable Subject Matter

1. Claims 33-61 are allowed in light of the remark on pages 2-3, filed 6/7/2006.

2. Any inquiry concerning this communication or earlier communications from the examiner should be directed to McDieunel Marc whose telephone number is (571) 272-6964. The examiner can normally be reached on 6:30-5:00 Mon-Thu.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black can be reached on (571) 272-6956. 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.

McDieunel Marc
Examiner
Art Unit 3661

Saturday, September 22, 2007
MM/

THOMAS BLACK
SUPERVISORY PATENT EXAMINER

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	Art Unit
	Marc, McDieunel	3661

ORIGINAL		INTERNATIONAL CLASSIFICATION	
CLASS	SUBCLASS	CLAIMED	NON-CLAIMED
700	245	G 0 6 F 19/00 (2006.01.01)	

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
700	246	253	257	258	259
318	568.13	568.15	568.16	640	
29	702	714	720		
901	6	14	17	46	47

M.Marc Marc, McDieunel (Assistant Examiner)	9/22/2007 (Date)	THOMAS BLACK SUPERVISORY PATENT EXAMINER (Primary Examiner) (Date) 9/28/07	Total Claims Allowed: 29
(Legal Instruments Examiner)	(Date)		O.G. Print Claim(s): 1 / O.G. Print Figure: 1

ABB Inc. Exhibit 1002, Page 194 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	Art Unit
	Marc, McDieunel	3661

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

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

CLAIM		DATE								
Final	Original	09/22/2007								
	1	-								
	2	-								
	3	-								
	4	-								
	5	-								
	6	-								
	7	-								
	8	-								
	9	-								
	10	-								
	11	-								
	12	-								
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	24	-								
	25	-								
	26	-								
	27	-								
	28	-								
	29	-								
	30	-								
	31	-								
	32	-								
1	33	=								
2	34	=								
3	35	=								
4	36	=								

ABB Inc. Exhibit 1002, Page 195 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	Art Unit
	Marc, McDieunel	3661

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

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

CLAIM		DATE								
Final	Original	09/22/2007								
5	37	=								
6	38	=								
7	39	=								
8	40	=								
9	41	=								
10	42	=								
11	43	=								
12	44	=								
13	45	=								
14	46	=								
15	47	=								
16	48	=								
17	49	=								
18	50	=								
19	51	=								
20	52	=								
21	53	=								
22	54	=								
23	55	=								
24	56	=								
25	57	=								
26	58	=								
27	59	=								
28	60	=								
29	61	=								

ABB Inc. Exhibit 1002, Page 196 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PATENT APPLICATION FEE DETERMINATION RECORD
Effective January 1, 2003

Application or Docket Number: 10634874

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	37	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	32 minus 20=	* 12
INDEPENDENT CLAIMS	2 minus 3 =	* 0
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	375.00	OR	BASIC FEE	750.00
X$ 9=	108	OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL	483	OR	TOTAL	

6/25/5

CLAIMS AS AMENDED - PART II

AMENDMENT A	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	* 29	Minus	** 32	0
Independent	* 3	Minus	*** 3	0
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

ABB Inc. Exhibit 1002, Page 197 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	Art Unit
	Marc, McDieunel	3661

SEARCHED

Class	Subclass	Date	Examiner
700	245,246,253,257,258,259,279	9/22/07	MM
318	568.13,568.15.568.16,640	9/22/07	MM
901	6,14,17,46,47	9/22/07	MM
29	218,407.1,702,714,720	10/3/07	MM
348	42,94,154,190,,191,287,291,552	9/22/07	MM
382	154	9/22/07	MM

SEARCH NOTES

Search Notes	Date	Examiner
Palm inventor search	9/22/07	MM
West search see attached listings	9/22/07	MM

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
PGPub search has been conducted		9/22/07	MM

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
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500 7590 12/11/2007

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	**PAPER NUMBER**
3664	

MAIL DATE	DELIVERY MODE
12/11/2007	PAPER

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.

ABB Inc. Exhibit 1002, Page 199 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Supplemental Notice of Allowability	Application No. 10/634,874	Applicant(s) HABIBI ET AL.	
	Examiner McDieunel Marc	Art Unit 3664	

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

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2. ☒ The allowed claim(s) is/are *33-61*.

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

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ 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. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☒ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

KHOI H. TRAN
SUPERVISORY PATENT EXAMINER

ABB Inc. Exhibit 1002, Page 200 of 996
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IPR2023-01426

EXAMINER'S AMENDMENT

1. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Frank Abramonte, Reg., No.: 38,066 on Thursday, December 06, 2007.

The application has been amended as follows:

In claim 43, added below line 6, -- determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame. --.

Allowable Subject Matter

2. Claims 33-61 are allowed in light of the remark on pages 2-3, filed 6/7/2006.

3. Any inquiry concerning this communication or earlier communications from the examiner should be directed to McDieunel Marc whose telephone number is (571) 272-6964. The examiner can normally be reached on 6:30-5:00 Mon-Thu.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thomas Black can be reached on (571) 272-6956. 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.

McDieunel Marc
Examiner
Art Unit 3664

Thursday, December 06, 2007
MM/

KHOI H. TRAN
SUPERVISORY PATENT EXAMINER

Interview Summary	Application No.	Applicant(s)	
	10/634,874	HABIBI ET AL.	
	Examiner	Art Unit	
	McDieunel Marc	3664	

All participants (applicant, applicant's representative, PTO personnel):

(1) *McDieunel Marc*. (3)_____.

(2) *Frank Abramonte, Reg., No.: 38,066*. (4)_____.

Date of Interview: *06 December 2007*.

Type: a)☒ Telephonic b)☐ Video Conference
c)☐ Personal [copy given to: 1)☐ applicant 2)☒ applicant's representative]

Exhibit shown or demonstration conducted: d)☐ Yes e)☒ No.
If Yes, brief description: _____.

Claim(s) discussed: *43*.

Identification of prior art discussed: *None*.

Agreement with respect to the claims f)☒ was reached. g)☐ was not reached. h)☐ N/A.

Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: *Authorization for this examiner's amendment was given in a telephone interview with Frank Abramonte, Reg., No.: 38,066 on Thursday, December 06, 2007. See supplemental office action*.

(A fuller description, if necessary, and a copy of the amendments which the examiner agreed would render the claims allowable, if available, must be attached. Also, where no copy of the amendments that would render the claims allowable is available, a summary thereof must be attached.)

THE FORMAL WRITTEN REPLY TO THE LAST OFFICE ACTION MUST INCLUDE THE SUBSTANCE OF THE INTERVIEW. (See MPEP Section 713.04). If a reply to the last Office action has already been filed, APPLICANT IS GIVEN A NON-EXTENDABLE PERIOD OF THE LONGER OF ONE MONTH OR THIRTY DAYS FROM THIS INTERVIEW DATE, OR THE MAILING DATE OF THIS INTERVIEW SUMMARY FORM, WHICHEVER IS LATER, TO FILE A STATEMENT OF THE SUBSTANCE OF THE INTERVIEW. See Summary of Record of Interview requirements on reverse side or on attached sheet.

KHOI H. TRAN
SUPERVISORY PATENT EXAMINER

Examiner Note: You must sign this form unless it is an Attachment to a signed Office action.

Examiner's signature, if required

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Summary of Record of Interview Requirements

Manual of Patent Examining Procedure (MPEP), Section 713.04, Substance of Interview Must be Made of Record
A complete written statement as to the substance of any face-to-face, video conference, or telephone interview with regard to an application must be made of record in the application whether or not an agreement with the examiner was reached at the interview.

Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews
Paragraph (b)
In every instance where reconsideration is requested in view of an interview with an examiner, a complete written statement of the reasons presented at the interview as warranting favorable action must be filed by the applicant. An interview does not remove the necessity for reply to Office action as specified in §§ 1.111, 1.135. (35 U.S.C. 132)

37 CFR §1.2 Business to be transacted in writing.
All business with the Patent or Trademark Office should be transacted in writing. The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt.

The action of the Patent and Trademark Office cannot be based exclusively on the written record in the Office if that record is itself incomplete through the failure to record the substance of interviews.

It is the responsibility of the applicant or the attorney or agent to make the substance of an interview of record in the application file, unless the examiner indicates he or she will do so. It is the examiner's responsibility to see that such a record is made and to correct material inaccuracies which bear directly on the question of patentability.

Examiners must complete an Interview Summary Form for each interview held where a matter of substance has been discussed during the interview by checking the appropriate boxes and filling in the blanks. Discussions regarding only procedural matters, directed solely to restriction requirements for which interview recordation is otherwise provided for in Section 812.01 of the Manual of Patent Examining Procedure, or pointing out typographical errors or unreadable script in Office actions or the like, are excluded from the interview recordation procedures below. Where the substance of an interview is completely recorded in an Examiners Amendment, no separate Interview Summary Record is required.

The Interview Summary Form shall be given an appropriate Paper No., placed in the right hand portion of the file, and listed on the "Contents" section of the file wrapper. In a personal interview, a duplicate of the Form is given to the applicant (or attorney or agent) at the conclusion of the interview. In the case of a telephone or video-conference interview, the copy is mailed to the applicant's correspondence address either with or prior to the next official communication. If additional correspondence from the examiner is not likely before an allowance or if other circumstances dictate, the Form should be mailed promptly after the interview rather than with the next official communication.

The Form provides for recordation of the following information:

- Application Number (Series Code and Serial Number)
- Name of applicant
- Name of examiner
- Date of interview
- Type of interview (telephonic, video-conference, or personal)
- Name of participant(s) (applicant, attorney or agent, examiner, other PTO personnel, etc.)
- An indication whether or not an exhibit was shown or a demonstration conducted
- An identification of the specific prior art discussed
- An indication whether an agreement was reached and if so, a description of the general nature of the agreement (may be by attachment of a copy of amendments or claims agreed as being allowable). Note: Agreement as to allowability is tentative and does not restrict further action by the examiner to the contrary.
- The signature of the examiner who conducted the interview (if Form is not an attachment to a signed Office action)

It is desirable that the examiner orally remind the applicant of his or her obligation to record the substance of the interview of each case. It should be noted, however, that the Interview Summary Form will not normally be considered a complete and proper recordation of the interview unless it includes, or is supplemented by the applicant or the examiner to include, all of the applicable items required below concerning the substance of the interview.

A complete and proper recordation of the substance of any interview should include at least the following applicable items:

1) A brief description of the nature of any exhibit shown or any demonstration conducted,
2) an identification of the claims discussed,
3) an identification of the specific prior art discussed,
4) an identification of the principal proposed amendments of a substantive nature discussed, unless these are already described on the Interview Summary Form completed by the Examiner,
5) a brief identification of the general thrust of the principal arguments presented to the examiner,
   (The identification of arguments need not be lengthy or elaborate. A verbatim or highly detailed description of the arguments is not required. The identification of the arguments is sufficient if the general nature or thrust of the principal arguments made to the examiner can be understood in the context of the application file. Of course, the applicant may desire to emphasize and fully describe those arguments which he or she feels were or might be persuasive to the examiner.)
6) a general indication of any other pertinent matters discussed, and
7) if appropriate, the general results or outcome of the interview unless already described in the Interview Summary Form completed by the examiner.

Examiners are expected to carefully review the applicant's record of the substance of an interview. If the record is not complete and accurate, the examiner will give the applicant an extendable one month time period to correct the record.

Examiner to Check for Accuracy

If the claims are allowable for other reasons of record, the examiner should send a letter setting forth the examiner's version of the statement attributed to him or her. If the record is complete and accurate, the examiner should place the indication, "Interview Record OK" on the paper recording the substance of the interview along with the date and the examiner's initials.

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IPR2023-01426

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.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

500 7590 12/21/2007

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	PAPER NUMBER
3664	

DATE MAILED: 12/21/2007

PRIORITY ACKNOWLEDGMENT

☐ 1. Receipt is acknowledged of priority papers submitted under 35 U.S.C. 119. The papers have been placed of record in the file.

☑ 2. Applicant's claim for priority, based on papers filed in parent Application Number 10 153 680 submitted under 35 U.S.C. 119, is acknowledged.

☐ 3. The priority papers, submitted _____, after payment of the issue fee are
- ☐ acknowledged
  While the priority claim or certified copy filed will be placed in the file record, neither will be reviewed and the patent when published will not include the priority claim.
  See 37 CFR 1.55(a)(2).
- ☐ not acknowledged since the processing fee in 37 CFR 1.17(i) has not been received.

☐ 4. For utility and plant applications filed on or after November 29, 2000, the priority claim is not entered because the claim was not presented within the time limit required by 37 CFR 1.55(a)(1). A petition to accept a delayed claim for priority under 35 U.S.C. 119(a) - (d) or (f), or 365(a) may be filed. See 37 CFR 1.55(c) and MPEP 201.14(a).

Midel Geronimo
For:
Manager, Publishing Division
Office of Patent Publication
(703) 305-8388

PTOL-147 (Rev. 10/03)

PTO/SB/30EFS (05/07)
Approved for use through 11/30/2007. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL
(Submitted Only via EFS-Web)

Application Number	10634874	Filing Date	2003-08-06	Docket Number (if applicable)	170154.401C1	Art Unit	3664
First Named Inventor	Babak Habibi			Examiner Name	Marc McDieuenel		

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

SUBMISSION REQUIRED UNDER 37 CFR 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

- ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ☐ Other _____

☒ Enclosed

- ☒ Amendment/Reply
- ☒ Information Disclosure Statement (IDS)
- ☐ Affidavit(s)/ Declaration(s)
- ☒ Other
  Information Disclosure Statement Transmittal; Twelve cited references

MISCELLANEOUS

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months _____
(Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☒ Other
Fee Deficiency Authorization Form

FEES

☒ **The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**
The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to Deposit Account No 191090

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

☒ Patent Practitioner Signature

☐ Applicant Signature

Signature of Registered U.S. Patent Practitioner			
Signature	/Frank Abramonte/	Date (YYYY-MM-DD)	2008-01-10
Name	Frank Abramonte	Registration Number	38066

This collection of information is required by 37 CFR 1.114. 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 1.11 and 1.14. This collection is estimated to take 12 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, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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 the Freedom of Information Act requires disclosure of these record s.

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 inspections 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.

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Examiner	:	Marc McDieunel
Art Unit	:	3664
Docket No.	:	170154.401C1
Date	:	January 10, 2008

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

PRELIMINARY AMENDMENT

Commissioner for Patents:

Please amend the above-identified application as follows:

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks begin on page 9 of this paper.

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IPR2023-01426

Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1.-32. (Canceled)

33. (Currently Amended) ~~A~~The method of claim 50~~useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of a robot~~, ~~the method~~ further comprising:

capturing a number of images of a calibration object by the camera;

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and

determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame.

34. (Previously Presented) The method of claim 33, further comprising:

positioning the camera with respect to the calibration object.

35. (Previously Presented) The method of claim 34 wherein positioning the camera with respect to the calibration object comprises positioning the camera orthogonally with respect to a ruled template with a number of features, where a known or determinable physical relationship exists between at least some of the features.

36. (Previously Presented) The method of claim 34 wherein positioning the camera with respect to the calibration object comprises positioning the camera with respect to a sample of a type of object the robot will manipulate, the sample having a number of features,

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where a known or determinable physical relationship exists between at least some of the features.

37. (Previously Presented) The method of claim 34 wherein capturing a number of images of a calibration object by the camera comprises capturing at least one image at each of a plurality of positions spaced perpendicularly from the calibration object.

38. (Previously Presented) The method of claim 34 wherein capturing a number of images of a calibration object by the camera comprises capturing at least one image at each of a plurality of different orientations with respect to the calibration object.

39. (Previously Presented) The method of claim 33 wherein determining a set of intrinsic parameters of the camera from the at least one of the number of images of the calibration object captured by the camera comprises determining at least one of a focal length, a first order radial lens distortion coefficient, a set of coordinates of a center of a radial lens distortion, or a scale factor indicative of a framegrabber scanline resampling uncertainty.

40. (Previously Presented) The method of claim 33 wherein determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame comprises determining a respective translation component along three orthogonal axes, and a respective rotation component about the three orthogonal axes.

41. (Previously Presented) The method of claim 33, further comprising:

determining a camera space-to-tool space transformation based at least in part on at least two of the number of images captured by the camera of the calibration object.

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IPR2023-01426

42. (Previously Presented) The method of claim 33, further comprising:

determining a camera space-to-tool space transformation based on single one of the number of images captured by the camera of the calibration object and on a number of physical coordinates of at least one feature of the calibration object.

43. (Currently Amended) The method of claim 50~~33~~, further comprising:

capturing an image of a teaching object of a type of object that will be manipulated by the robot;

selecting a number of features from the captured image of the teaching object;

determining a set of object space coordinates for each of the selected features from the captured image of the teaching object; and

44. (Previously Presented) The method of claim 43 wherein selecting a number of features from the captured image of the teaching object comprises selecting six features from the captured image of the teaching object.

45. (Previously Presented) The method of claim 43, further comprising:

determining an object space-to-camera space transformation defining a transformation between an object space reference frame and the camera space reference frame.

46. (Previously Presented) The method of claim 45, further comprising:

determining a position and an orientation of an object frame in the tool frame reference frame based at least in part on the object frame-to-camera space and camera space-to-tool space transformations.

47. (Previously Presented) The method of claim 46, further comprising:

providing the position and orientation of the object frame to the robot; and

training an intended operation path inside the object frame.

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48. (Canceled)

49. (Currently Amended) The method of claim 5048, further comprising:

adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features; and

capturing another two-dimensional image of the volume containing the target object before determinint the object space-to-camera space transformation for the target object.

50. (Currently Amended) A The method useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of a robotof claim 48, the method further comprising:

capturing a two-dimensional image of a volume containing a target object; and

locating a number of features in the captured image of the target object; and

determining an object space-to-camera space transformation for the target object based at least in part on a position of at least some of the located features using only the signal captured image and an algorithm that employs a known or determinable physical relationship between at least some of the located features.

51. (Previously Presented) The method of claim 50, further comprising:

determining at least one movement of the robot that orients the camera orthogonally with respect to the target object based at least on part on the object space-to-camera space transformation.

52. (Previously Presented) The method of claim 51, further comprising:

determining a position of the object frame in the tool space reference frame; and

providing an object frame to the robot.

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53. (Currently Amended) An apparatus useful in robotics, the apparatus comprising:

a single camera operable to capture at a number of images of a calibration object by the camera;

means for calibrating the camera, by:

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and

determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame; and

means for estimating a pose of a target object, by:

capturing a two-dimensional image of ~~an~~ a volume containing a target object; and

locating at least six features in the captured image of the target object; and

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features in solely the captured image using an algorithm that employs a known or determinable physical relationship between at least some of the located features.

54. (Previously Presented) The apparatus of claim 53, further comprising:

means for training, comprising:

capturing an image of a teaching object of a type of object that will be manipulated by the robot;

selecting a number of features from the captured image of the teaching object;

determining a set of object space coordinates for each of the selected features from the captured image of the teaching object; and

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determining an object space-to-camera space transformation defining a transformation between an object space reference frame and the camera space reference frame.

55. (Previously Presented) The apparatus of claim 54 wherein the means for calibrating, the means for estimating a pose, and the means for training comprises at least one programmed computer.

56. (Previously Presented) The apparatus of claim 54 wherein the means for calibrating, the means for estimating a pose, and the means for training comprises at least one computer-readable medium storing instructions operating at least one computer.

57. (Previously Presented) The apparatus of claim 53 wherein the pose estimating means estimates the pose of the target object further by:

adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features.

58. (Currently Amended) An apparatus useful in robotics, the apparatus comprising:

a single camera operable to capture a number of images of a calibration object by the camera;

means for calibrating the camera, by:

determining a set of intrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera; and

determining a set of extrinsic parameters of the camera from at least one of the number of images of the calibration object captured by the camera, the set of extrinsic parameters comprising a camera space-to-training space transformation defining a transformation between a camera space reference frame and a training space reference frame; and

means for estimating a pose of a target object, by:

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capturing a two-dimensional image of ~~an~~ a volume containing a target object; ~~and~~

locating at least five features in the captured image of the target object; and

determining an object space-to-camera space transformation based at least in part on a position of at least some of the located features using the captured image without any additional captured images and an algorithm that employs a known or determinable physical relationship between at least some of the located features.

59. (Previously Presented) The apparatus of claim 58 wherein the means for calibrating and the means for estimating a pose comprises at least one programmed computer.

60. (Previously Presented) The apparatus of claim 58 wherein the means for calibrating and the means for estimating a pose comprises at least one computer-readable medium storing instructions operating at least one computer.

61. (Previously Presented) The apparatus of claim 58 wherein the pose estimating means estimates the pose of the target object further by:

adjusting a position of the movable portion of the robot if the number of features located in the captured image of the target object is determined to be an insufficient number of features.

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REMARKS

In this Amendment, claims 33, 43, 49, 50, 53, and 58 have been amended. Claim 48 has been canceled. No new matter has been added by way of this Amendment.

The Director is authorized to charge any additional fees due by way of this Amendment, or credit any overpayment, to our Deposit Account No. 19-1090.

All of the claims remaining in the application are now clearly allowable. Favorable consideration and a Notice of Allowance are earnestly solicited.

Respectfully submitted,

SEED Intellectual Property Law Group PLLC

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Confirmation No.	:	7619
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
Examiner	:	Marc McDieunel
Art Unit	:	3664
Docket No.	:	170154.401C1
Date	:	January 10, 2008

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

FEE DEFICIENCY AUTHORIZATION FORM

Commissioner for Patents:

Applicants hereby authorize the Director to charge any deficiencies in fees due by way of the enclosed papers only under 37 CFR 1.16 and 1.17 to Deposit Account No. 19-1090.

Respectfully submitted,

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ABB Inc. Exhibit 1002, Page 218 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Babak Habibi et al.
Application No.	:	10/634,874
Filed	:	August 6, 2003
For	:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Examiner	:	Marc McDieunel
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Date	:	January 10, 2008

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Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT TRANSMITTAL

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In accordance with 37 CFR 1.56 and 1.97 through 1.98, applicants wish to make known to the U.S. Patent and Trademark Office the references set forth on the attached Information Disclosure Statement. Copies of cited U.S. patents and published patent applications are not required and accordingly have not been provided. Copies of any other cited references are enclosed. As to any reference cited, applicants do not admit that it is "prior art" under 35 U.S.C. §§ 102 or 103, and specifically reserve the right to traverse or antedate any such reference, as by a showing under 37 CFR 1.131 or other method. Although the aforesaid references are made known to the Patent and Trademark Office in compliance with applicants' duty to disclose all information they are aware of which is believed relevant to the examination of the above-identified application, applicants believe that their invention is patentable.

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Please acknowledge receipt of this Information Disclosure Statement and kindly make the cited references of record in the above-identified application.

Applicants believe this Information Disclosure Statement has been timely filed, however, the Director is authorized to charge any fee due by way of this Information Disclosure Statement to our Deposit Account No. 19-1090.

Respectfully submitted,

SEED Intellectual Property Law Group PLLC

/Frank Abramonte/
Frank Abramonte
Registration No. 38,066

FXA:sc

Enclosures:
Information Disclosure Statement
Cited References (12)

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PTO/SB/08a (05-07)
Approved for use through 11/30/2007. OMB 0651-0031
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	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

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	1	4402053		1983-08-30	Kelley et al.	
	2	5212738		1993-05-18	Chande et al.	
	3	5978521		1999-11-02	Wallack et al.	
	4	6115480		2000-09-05	Washizawa	
	5	6628819	B1	2003-09-30	Huang et al.	
	6	7061628	B2	2006-06-13	Franke et al.	
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	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

	1	20030007159	A1	2003-01-09	Franke et al.	
	2	20040172164	A1	2004-09-02	Habibi et al.	

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	1	01124072	JP		1989-05-16	Masanobu	(+ abstract)	☐
	2	0763406	EP		1997-03-19	Ersue Enis		☐

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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]
	1	Borotschnig, H., et al., "Appearance-Based Active Object Recognition," Image and Vision Computing, 18:715-727, 2000.	☐
	2	Chen, L., et al., "An investigation on the accuracy of three-dimensional space reconstruction using the Direct Linear Transformation Technique," J. Biomechanics 27(4):493-500, 1994.	☐
	3	Denzler J., et al., "Learning, Tracking and Recognition of 3D Objects," Proceedings of the IEEE/RSJ/GI, International Conference on Intelligent Robots and Systems (IROS) 1:89-96, 1994.	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

	4	Ji, Q., et al., "An Integrated Linear Technique for Pose Estimation from different Geometric Features," International Journal of Pattern Recognition and Artificial Intelligence, 13(5):705-733, August 1999.	☐
	5	Jia, Y-B., et al., "Sensing Polygon Poses by Inscription," Proc. of 1994 IEEE International Conference on Robotics and Automation, pp. 1642-1649, May 1994.	☐
	6	Kim, W.S., "Computer vision assisted virtual reality calibration," URL=http://www.robotics.jpl.nasa.gov/publications/Won_Kim/ra98_vrc.pdf., pp. 1-14, 1999.	☐
	7	Kovacic, S., et al., "Planning Sequences of Views for 3-D Object Recognition and Pose Determination," Pattern Recognition 31(10):1407-1417, 1998.	☐
	8	Sanchez, A., et al., "Robot-arm Pick and Place Behavior Programming System Using Visual Perception," in Proceedings of the 15th International Conference on Pattern Recognition 4:507-510, September 2000.	☐
	9	Tsai, R. et al., "An Efficient and Accurate Camera Calibration Technique for 3D Machine Vision," Proceedings of IEEE, Conference on Computer Vision and Pattern Recognition, pp. 364-374, 1986.	☐
	10	Tsai, R., "A Versatile Camera Calibration Technique for High-Accuracy 3D Machine Vision Metrology Using Off-the-Shelf TV Cameras and Lenses," IEEE Journal of Robotics and Automation, RA-3(4):323-344, August 1987.	☐

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Frank Abramonte/	Date (YYYY-MM-DD)	2008-01-10
Name/Print	Frank Abramonte	Registration Number	38066

This collection of information is required by 37 CFR 1.97 and 1.98. 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 1 hour 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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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:

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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.

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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 inspections 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.

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 01-124072

(43)Date of publication of application : 16.05.1989

(51)Int.Cl. G06F 15/70
G06F 15/62

(21)Application number : 62-282594

(22)Date of filing : 09.11.1987

(71)Applicant : SEIKO INSTR & ELECTRON LTD

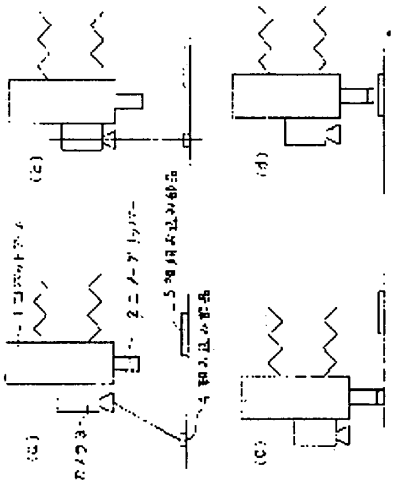
(72)Inventor : TAKADA MASANOBU

(54) PICK AND PLACE

(57)Abstract:

PURPOSE: To highly accurately incorporate built-in parts in a camera by allowing a vision to execute silhouette processing under a state that a TV camera is arranged just above the built-in parts.

CONSTITUTION: The camera 3 is moved to the upper part of the built-in parts 4 to detect the silhouette of the parts 4, the vision calculates the centroid position and inclined angle of the silhouette and a robot arm 1 is moved so that the XY coordinates of the center of the camera 3 are positioned just above the centroid of the parts 4. Then, the TV camera 3 picks up the silhouette of the parts 4 again as a silhouette image and the vision calculates the centroid position and inclined angle of the silhouette from the silhouette image and transmits the calculated results to the robot. Consequently, the centroid coordinates and the inclined angle of the silhouette of the built-in parts 4 can be obtained without generating an error and highly accurate incorporation can be attained.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of

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IPR2023-01426

⑲日本国特許庁（JP）　⑪特許出願公開

⑫公開特許公報（A）　平1－124072

⑤1Int.Cl.⁴	識別記号	庁内整理番号	⑬公開　平成1年(1989)5月16日
G 06 F 15/70	350	B－7368－5B	
15/62	400	8419－5B	

審査請求　未請求　発明の数 1　（全3頁）

⑤4発明の名称　ピックアンドプレイス

⑳特　願　昭62－282594

㉒出　願　昭62(1987)11月9日

⑦2発明者　高田　正信　東京都江東区亀戸6丁目31番1号　セイコー電子工業株式会社内

⑦1出願人　セイコー電子工業株式会社　東京都江東区亀戸6丁目31番1号

明　細　書

1．発明の名称

ピックアンドプレイス

2．特許請求の範囲

組み込み部品の下から光源で照明し、組み込み部品の上でカメラによりシルエット像をとらえて画像処理し、かつ、あらかじめ決められたＸ軸Ｙ軸を基準にして、組み込み部品の置かれている座標とＸ軸からみた傾き角度を算出し、ロボットに伝送するビジョンシステムを具備するロボットの動作において、最初にビジョンシステムが組み込み部品の重心座標を読み取り、次にその読み取られたＸＹ座標の上にビジョンシステムのカメラが移動し、再度組み込み部品の置かれているＸＹ座標とＸ軸からみた傾き角度を算出することで、組み込み部品の位置を認識することを特徴とするピックアンドプレイス。

3．発明の詳細な説明

〔産業上の利用分野〕

本発明は、厚みをもった部品を被組み込み部品に組み込むロボットに関する。

〔発明の概要〕

透過照明とテレビカメラにより、厚みをもつ部品（組み込み部品と称す）のシルエットをシルエット画像として得て、そのシルエット画像からシルエットの重心位置と、シルエットの長軸とロボットが持つＸ軸との角度（傾き角度と称す）を算出し、ロボットに伝送するビジョンシステム（ビジョンと称す）を具備したロボットの動作を、組み込み部品のシルエットの重心位置をビジョンで算出し、算出したシルエットの重心位置をロボットに伝送し、ロボットがシルエットの重心位置からシルエットの重心のＸＹ座標を算出し、ロボットに装着されたテレビカメラの中心のＸＹ座標が算出されたＸＹ座標に移動する動作を第一の動作とし、組み込み部品のシルエットの重心位置をビジョンで算出し、算出したシルエットの重心位置をロボットに伝送し、ロボットがシルエットの重

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心位置からシルエットの重心のＸＹ座標を算出し、ロボットのグリッパーの中心のＸＹ座標がその算出したＸＹ座標に移動する動作を第二の動作とし、ロボットグリッパーがＺ軸方向に下がり組み込み部品をエアーグリッパーし、あらかじめティーチングした被組み込み座標に移動し組み込む動作を第三の動作とし、第一の動作、第二の動作、第三の動作を連続して行うことによって精度の高い組み込み動作を可能にした。

〔従来の技術〕

従来、透過照明とテレビカメラにより、組み込み部品のシルエットをシルエット画像として得て、そのシルエット画像からシルエットの重心位置と、シルエットの傾き角度を算出し、ロボットに伝送するビジョンを具備したロボットを利用して組み込み部品を被組み込み部品に組み込む場合、上記第二の動作と第三の動作を連続して行っていた。

〔発明が解決しようとする問題点〕

ところが、組み込み部品に厚みがあり、かつ、組み込み部品を斜め上方からビジョンがとらえると、例えば、第２図(b)に示すように円板のシルエットは楕円柱ととしてとらえられシルエットの重心位置が、組み込み部品の真上上方からビジョンがとらえて得られたシルエットの重心位置に対して偏り（誤差と称す）が生じる。

〔問題点を解決するための手段〕

上記誤差を無くするには、組み込み部品の真上にテレビカメラが位置した状態でビジョンがシルエット処理すれば良い。すなわち、従来の第二の動作、第三の動作の連続動作の前に、前記第一の動作を行うようにした。

〔作用〕

上記構成及び動作により、組み込み部品のシルエットの重心座標及び傾き角度を誤差なく得られるようになり、精度の高い組み込みができる。

〔実施例〕

以下に、本発明の実施例を図面に基づいて説明する。

第１図の(a)において、１はロボットアーム，２はロボットアームに装着されたエアーグリッパー，

３はロボットアームに装着されたカメラ，４は厚みをもち円板の形状をした組み込み部品，５は被組み込み部品である。

次に、第１図の(a)，(b)，(c)，(d)，および第２図の(a)，(b)を使って本発明の動作について説明する。

ロボットを利用して組み込み部品４を被組み込み部品５に組み込む動作において、まずカメラ３が組み込み部品４の上方に移動し、組み込み部品４のシルエットをとらえる。そのシルエットはビジョンに画像として入力され、ビジョンはシルエットの重心位置と傾き角度を算出し、ロボットへ出力する。ロボットはそのシルエットの重心位置と傾き角度から、組み込み部品４の重心のＸＹ座標と傾き角度を得る。そしてロボットアーム１はカメラ３の中心のＸＹ座標が組み込み部品４の重心の真上に位置するよう移動する。この状態が第１図(b)である。そこで再びテレビカメラ３により組み込み部品４のシルエットのシルエットをシルエット画像として得て、ビジョンはそのシルエット画像からシルエットの重心位置と傾き角度を算出し、ロボットに伝送する。ロボットがシルエットの重心位置からシルエットの重心のＸＹ座標と傾き角度を算出し、ロボットのグリッパー２の中心のＸＹ座標がその算出されたシルエットの重心のＸＹ座標に一致するように移動する。そして、ロボットアーム１がＺ軸方向に下がり組み込み部品をエアーグリップする。この状態が第１図(c)である。

ロボットアームはあらかじめティーチングされた被組み込み座標に移動し、さらにＺ軸方向に下がり被組み込み部品５に組み込み部品４を組み込む。この状態が第１図(d)である。

〔発明の効果〕

従来の方法、すなわち前記第二の動作と第三の動作の連続動作において、第二の動作のシルエット処理の結果、第２図の(b)に示すように実際の組み込み部品４の重心座標とシルエット処理の結果算出される座標との間に誤差が生じる。そして、第三の動作を統行すると被組み込み部品５に組み込み部品４が組みにくくなる。

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本発明によれば、前記第一の動作を最初に行うことで、組み込み部品4の真上にテレビカメラ3が位置して、第二の動作のテレビカメラ3によるシルエット画像のビジョンへの取り込みが行えるので、第2図(b)に示す誤差はなくなる。この様子を第2図(a)に示す。従って、被組み込み部品5に組み込み部品4を精度良く組み込めるのである。

4．図面の簡単な説明

第1図(a)，(b)，(c)，(d)は本発明の動作を示す図、第2図(a)，(b)は本発明の実施例における組み込み部品の厚みに起因する位置認識誤差に関する説明図である。

1・・・ロボットアーム

2・・・グリッパー

3・・・テレビカメラ

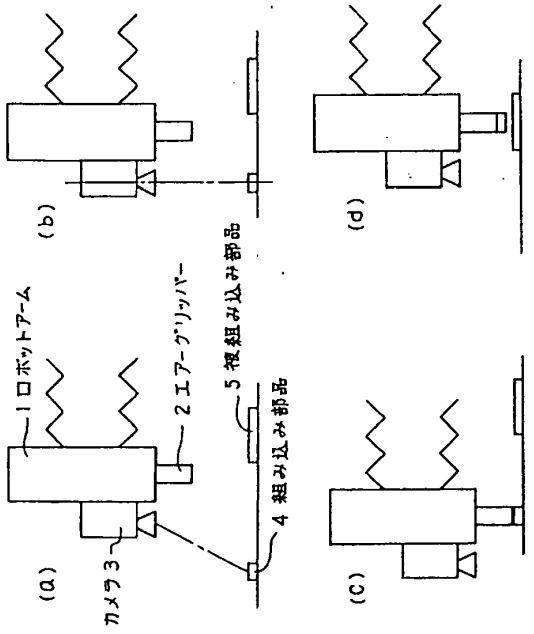
4・・・組み込み部品

5・・・被組み込み部品

以　上

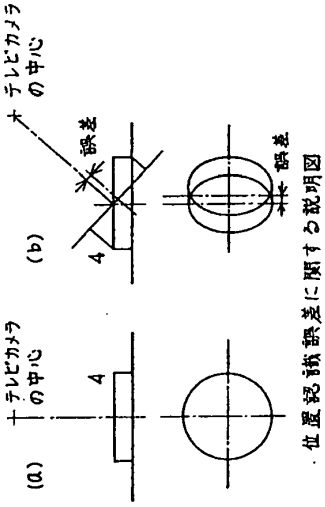
出願人　セイコー電子工業株式会社

－7－



本発明の動作を示す図

第 1 図



位置認識誤差に関する説明図

第 2 図

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(19) Europäisches Patentamt
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(54) **Verfahren zum Bestimmen der Lage eines Körpers im Raum**

Method of determination of the spatial position of an object

Méthode de détermination de la position d'un objet dans l'espace

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Anmerkung: Innerhalb von neun Monaten nach der Bekanntmachung des Hinweises auf die Erteilung des europäischen Patents kann jedermann beim Europäischen Patentamt gegen das erteilte europäische Patent Einspruch einlegen. Der Einspruch ist schriftlich einzureichen und zu begründen. Er gilt erst als eingelegt, wenn die Einspruchsgebühr entrichtet worden ist. (Art. 99(1) Europäisches Patentübereinkommen).

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Beschreibung

[0001] Die Erfindung betrifft ein Verfahren zum Bestimmen der Lage eines Körpers im Raum um mit mehreren mit diesem zusammenwirkenden räumlich getrennten elektronischen Kameras mit Bildverarbeitung um Manipulationen an diesem durchzuführen.

[0002] Derartige Verfahren zur Bestimmung der Lage eines Körpers in einem Raum sind insbesondere bei der Herstellung von Kraftfahrzeugen erforderlich, wenn es bei der Serienherstellung und Serienmanipulation darum geht, Körper gleichen Typs mit Zusatzteilen wie Türen, Kotflügeln, Radaufhängungen oder Kofferraumdeckeln zu versehen. Auch ist es einsetzbar, um erforderliche Manipulationen beim Schweißen, Lackieren oder Abdichten von Nähten raschestmöglich durchzuführen.

[0003] Jedoch nicht nur auf dem Gebiet der Fahrzeugtechnik, sondern auf allen anderen Gebieten, bei welchen ein Bauteil aus mehreren Bauteilen zusammengesetzt werden soll, ist zur raschen Herstellung eines derartigen Elements, insbesondere im Hinblick auf die Genauigkeit und die Schnelligkeit eine Lagebestimmung unumgänglich.

[0004] Um derartige Vermessungen durchzuführen, fehlt es nicht an Versuchen, dies zu bewerkstelligen. So ist es beispielsweise bekannt geworden, Kanten einer Fahrzeugkarosserie mit Hilfe einer Laserabtastung festzustellen, diese Werte zu speichern und entsprechend diesen Werten nachfolgende Bauteile auszurichten, um dann anschließend daran, beispielsweise mit Hilfe von Robotern, Türen anzuschweißen oder auch das Befestigen von Kofferraumdeckeln oder Motorhauben zu bewerkstelligen.

[0005] Es ist jedoch bekannt, daß durch Laserstahl eine Gesundheitsschädigung nicht auszuschließen ist. Für die Verbindung eines Bauteils mit einem Grundkörper, beispielsweise einer Autotür mit einem Grundrahmen, ist es erforderlich, Lagetoleranzen auszugleichen, weil sonst ein Verscheißen nicht sicher durchgeführt werden kann, wenn nicht die Stellen für die Scharniere der Tür am Rahmen genau erreicht werden oder wenn zwischen diesen Stellen und den Türscharnieren zu Beginn des Schweißvorgangs ein zu großer Abstand besteht. Die Folge derartiger Mißeinstellungen sind dann zwangsläufig Ausschußherstellungen, die erst mühselig entweder nachgearbeitet oder direkt verschrottet werden müssen.

[0006] Als Hilfsmittel verwendet man deshalb auch mechanische Arretierungen, welche auf den Förderbändern die zusammenzubauenden Bauteile, d. h. den Grundkörper sicher führen, damit von dieser Seite aus bereits eine grobe Voreinstellung gegeben ist. Derartige Hilfseinrichtungen sind jedoch nicht nur einem Verschleiß und einer Verschmutzung ausgesetzt, sondern es tritt wie oben ausgeführt auch die Toleranz bei der Herstellung des Grundkörpers sehr stark in Erscheinung. Dies und die zunehmende Forderung nach flexibler Fertigung bei einem Produktmix führen dazu, daß solche Einrichtungen praktisch nicht mehr einsetzbar sind. Unter Produktmix versteht man im vorliegenden Fall eine nicht sortenreine Fertigung auf einer Fertigungslinie.

[0007] Durch das Patent mit der Nr. US-A-4 639 878 ist eine Methode und eine Einrichtung zur automatischen Festlegung der Position eines dreidimensionalen Körpers in einer Arbeitsstation bekannt geworden, bei der drei Kameras verwendet werden, wobei jede Kamera verschiedene Werte eines Kalibrierkörpers aufnimmt und wobei zusätzlich ein dreidimensionaler Körper zu den Koordinaten der auf dem Körper angeordneten Koordinaten, welche ihren Nullpunkt in auf dem Körper vorgegebenen Öffnungen besitzenden Übereinstimmung gebracht wird.

[0008] Aus dem US Patent ist ein Verfahren zum Bestimmen der Lage eines Körpers im Raum um Manipulationen an diesem durchzuführen mit mehreren mit diesem zusammenwirkenden räumlich getrennten elektronischen Kameras mit Bildverarbeitung bekannt, wobei der Körper in den Raum zwischen den elektronischen Kameras verbracht wird, je ein charakteristischer Punkt auf dem in den Raum verbrachten Körper in je einer diesem zugeordneten elektronischen Kamera abgebildet wird, daß dessen Lage in Bild mit seiner konstruktiven vorgegebenen Position des charakteristischen Punktes auf den in den Raum verbrachten Körper zusammen mit gespeicherten Werten verarbeitet wird und alle verarbeiteten Werte die Lage des in dem Raum verbrachten Körpers in den sechs räumlichen Freiheitsgraden charakterisieren.

[0009] Ausgehend hiervon liegt der vorliegenden Erfindung die Aufgabe zugrunde, ein zu manipulierendes Element in Bezug zum Manipulator direkt zu bringen. Diese Aufgabe wird erfindungsgemäß dadurch gelöst,

a) daß jede von mindestens drei räumlich getrennten elektronischen Kameras mit Bildverarbeitung bei deren Einmessen eine ihr zugeordnete Kalibriertafel mit Punktmuster aufnimmt, deren Bilder, sowie das Punktmuster zur Bestimmung der Lage der einzelnen Kamera im Raum verarbeitet und deren Lage speichert,

b) daß eine Vermessung der Kalibriertafeln zueinander getrennt hiervon erfolgt, daß diese Werte ebenfalls gespeichert werden,

c) daß anschließend der Körper in den Raum zwischen den elektronischen Kameras verbracht wird,

d) daß je ein charakteristischer Punkt auf den in den Raum verbrachten Körper in je einer diesem zugeordneten elektronischen Kamera abgebildet wird, daß dessen Lage im Bild mit seiner konstruktiven vorgegebenen Position des charakteristischen Punkts auf den in den Raum verbrachten Körper zu-

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sammen mit den gespeicherten Werten verarbeitet wird und

e) daß alle derart verarbeiteten Werte die Lage des in den Raum verbrachten Körpers in den sechs räumlichen Freiheitsgraden charakterisieren.

[0010] Es wird als unter die Erfindung fallend angesehen, wenn die unter Kombinationen a und b gegeneinander ausgetauscht werden.

[0011] Hierdurch wird erreicht, daß unabhängig von der Genauigkeit der Herstellung des Grundkörpers jeweils an der richtigen Stelle, bezogen auf den Manipulator, Elemente an der richtigen Stelle am Grundkörper angebracht werden können, da die Ausrichtung des Körpers nunmehr zwangsläufig durch eine Koordinatentransformation zwischen dem die räumliche Lage des Körpers darstellenden Koordinatensystem und dem Koordinatensystem des Roboters oder Manipulators, der zwangsläufig zu den Fahrzeugkoordinaten ausgerichtet sein muß, um ein sicheres und ausschußfreies Bearbeiten des Körpers beispielsweise des Grundgestells einer Karosserie zu bewirken. Auch ist es hierdurch möglich, Lackierungen oder Abdichtungen oder Ummantellungen zielgenau am zu fertigenden Bauteil anzubringen.

[0012] Darüberhinaus ist auch eine mechanische Bearbeitung eines so in den Raum verbrachten Körpers möglich, wenn zusätzlich erfindungsgemäß die Führung eines Gegenhalters das Bauteil bzw. die Karosse abstützt, so daß mittels spanabhebender Bearbeitung beispielsweise eine Bearbeitung durchgeführt werden kann.

[0013] Eine Ausgestaltung des erfinderischen Gegenstandes besteht darin, daß die Position eines Nullkörpers des selben Typs bestimmt wird und daß die Messung aller folgenden Körper auf diesen bezogen werden. Damit wird erreicht, daß eventuelle Fehler bei der Einmessung sowie der Vermessung zufolge ungenauer Herstellung der Grundkarosse beispielsweise minimiert werden, da diese Fehler sich beim Bezug der weiteren Karossen auf die Nullkarosse als Fehler höherer Ordnung wesentlich verringern.

[0014] Im Nachfolgenden wird an einem Ausführungsbeispiel die erfinderische Verfahrensweise näher erläutert.

[0015] Es zeigen in schematischer Darstellung:

Figur 1 einen Einmeßvorgang für die Position einer Kamera bezüglich des Raums

Figur 2 eine Bestimmung der räumlichen Lage eines Körpers an welchem Manipulationen durchgeführt werden

Figur 3 Einfluß einer Positionierung eines Nullkörpers

[0016] In der Beschreibung werden in den einzelnen Figuren gleiche Bauteile mit denselben Bezugziffern bezeichnet.

[0017] Gemäß Figur 1 wird eine Kamera 1, bei der es sich um eine bekannte CCD-Kamera mit bekannter Bildverarbeitung handelt, optisch mit einer Kalibriertafel 2 in Verbindung gebracht. Auf der Kalibriertafel 2 sind Markierungen 3 angeordnet, deren gegenseitiger Abstand bekannt ist. Die Kamera 1 wird an den Rand des Raumes verbracht, beispielsweise bei einer Lackierkabine zum Lackieren von Fahrzeugkarossen hinter einer Wand der Lackierkabine, um die Kamera vor Beschädigung und Verschmutzen zu schützen, dergestalt, daß lediglich eine kleine Öffnung in der Wand verbleibt, durch welche die Kamera 1 eine optische Verbindung mit der ihr zugeordneten Kalibriertafel 2 aufnehmen kann.

[0018] Voraussetzung für eine richtige Einmessung ist lediglich, daß die Kamera 1 nicht senkrecht zur Kalibriertafel 2 steht.

[0019] Die nunmehr über die Kamera aufgenommenen Informationen dienen dazu, die räumliche Lage, bzw. das Koordinatensystem der Kamera 1, festzulegen. In den anderen Wänden 4 der Lackierkabine sind mindestens noch zwei weitere Kameras 1 in der selben Weise angeordnet und arbeiten ebenfalls mit weiteren Kalibriertafeln zusammen. Der Vorgang des Einmessens wurde der Einfachheit halber nur mit einer Kamera erläutert. Es ist jedoch verständlich, daß jede der beiden anderen Kameras in der selben Weise eingemessen werden kann.

[0020] Nach Einmessen der Kameras in der oben beschriebenen Weise wird in einem getrennten Vorgang wie ebenfalls auf Figur 1 dargestellt, nunmehr die Lage der Kalibriertafeln 2 bestimmt. Im Ausführungsbeispiel handelt es sich um drei Kalibriertafeln, die durch ein anderes Meßmittel, beispielsweise Theodoliten 5, vermessen und deren Ergebnis gespeichtert wird. Das in der Figur 1 dargestellte Koordinatensystem 17 stellt das Bezugskoordinatensystem für die gesamte Messung dar.

[0021] Aufgrund dieser Einmeßwerte, bestehend aus den in der Kamera mittels Bildverarbeitung gemessenen und gespeicherten Werten und den durch die theodolitische Vermessung der drei Kalibriertafeln erhaltenen Werte, ist die Position der Kamera bestimmt.

[0022] Wird nun, wie in Figur 2 dargestellt, ein Körper 6 in den Raum verbracht, beispielsweise über am Boden 7 verlegte Schienen 8, so kann, nachdem die Kameras 1 auf den Raum eingemessen wurden, nun ein beliebieger Punkt bzw. beliebige Punkte am Körper 6, bei dem es sich im Ausführungsbeispiel um eine Karosserie handelt, ausgewählt werden, an welchen Manipulationen am Körper 6 durchgeführt werden müssen, beispielsweise das Einsetzen von Türen oder das Anbringen von Deckeln oder das Einstellen von Spritzpistolen bei einer Lackieranlage zu der jeweiligen Oberfläche des Körpers mit Hilfe von Robotern 9. Mittels der Kameras wird die Postition je eines Merkmals, dessen Position in dem dem Objekt zugeordneten Koordinatensystem 18 gespeichert ist, im aufgenommenen Kamera-

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bild mittels Bildverarbeitung erkannt und mit dem bei der Einmessung gespeicherten Werten verarbeitet. Hieraus ist der Bezug des Koordinatensystems 18 zum Koordinatensystem 17 bestimmt. So tragen im Ausführungsbeispiel die beiden Roboter 9 Farbdüsen 10 und 11, welche eine fehlerfreie Lackierung des Fahrzeugs ermöglichen. Anstelle dieser Farbdüsen 10/11 können auch andere Hilfswerkzeuge treten, beispielsweise Versiegelungseinrichtungen, welche Schweißnähte versiegeln oder auch Schraubeinrichtungen, welche Blechteile mit oder ohne entsprechende Gegenhalterungen an den Karossen anbringen.

[0023] Hierzu ist, wie bereits in der Einleitung gesagt, erfindungsgemäß gleichartig eingestellt ein Gegenhalter verwendbar, um beispielsweise die Bohrkräfte, welche beim Bohrvorgang auftreten, aufnehmen zu können, ohne daß die Karosserie während der Manipulation in eine andere Lage verschoben wird.

[0024] In Figur 3 ist ein Ausführungsbeispiel dargestellt, mit welchem der Einfluß einer Positionierung eines Nullkörpers auf die hierdurch zu steigernde Bearbeitungsgenauigkeit erläutert wird. Ein Nullkörper 12 wird, wie zu Figur 1 und Figur 2 insbesondere beschrieben, vermessen. Hierbei handelt es sich bei dem Nullkörper um einen Körper des selben Typs der nachfolgend zu bearbeitenden Körper. Durch diese Vorgehensweise lassen sich Fehler, die beispielsweise durch Ungenauigkeiten in der Herstellung oder des Einmessens, oder Meßfehler, die bei der Vermessung des Nullkörpers aufgetreten sind, minimieren. Es bleiben nur noch Fehler höherer Ordnung übrig. Bei nachfolgenden Messungen wird aus einem bei der Nullmessung bestimmten Lagewert zufolge Verschiebung des nächsten zu manipulierenden Körpers 13 ein Verschiebevektor festgestellt, welcher dann bei der Einstellung des in Figur 9 dargestellten Roboters durch Vergleich zwischen Istposition des nächsten zu manipulierenden Körpers 13 mit der Sollposition bzw. Nullposition des Nullkörpers 12 verglichen wird und hiermit berücksichtigbar bleibt.

Patentansprüche

1. Verfahren zum Bestimmen der Lage eines Körpers (6) im Raum um Manipulationen an diesem durchzuführen mit mehreren mit diesem zusammenwirkenden räumlich getrennten elektronischen, Kameras (1) mit Bildverarbeitung wobei,

   a) jede von mindestens drei räumlich getrennten elektronischen Kameras (1) mit Bildverarbeitung bei deren Einmessen eine ihr zugeordnete Kalibriertafel (2) mit Punktmuster aufnimmt, deren Bilder sowie das Punktmuster zur Bestimmung der Lage der einzelnen Kamera (1) im Raum verarbeitet und deren Lage speichert,

   b) eine Vermessung (5) der Kalibriertafeln (2) zueinander getrennt hiervon erfolgt, daß diese Werte ebenfalls gespeichert werden,

   c) anschließend der Körper (6) in den Raum zwischen den elektronischen Kameras (1) verbracht wird,

   d) je ein charakteristischer Punkt auf dem in den Raum verbrachten Körper (6) in je einer diesem zugeordneten elektronischen Kamera (1) abgebildet wird, daß dessen Lage in Bild mit seiner konstruktiven vorgegebenen Position des charakteristischen Punktes auf den in den Raum verbrachten Körper (6) zusammen mit den gespeicherten Werten verarbeitet wird und

   e) alle derart verarbeiteten Werte die Lage des in dem Raum verbrachten Körpers (6) in den sechs räumlichen Freiheitsgraden charakterisieren.

2. Verfahren nach Anspruch 1 dadurch gekennzeichnet, daß die Position eines Nullkörpers desselben Typs bestimmt wird und daß die Messung aller folgenden Körper (6) auf diesen bezogen wird.

Claims

1. Procedure to determine the position of a body (6) in space in order to carry out manipulations thereof, with several spatially separated electronic cameras (1), interacting with body, with image processing, whereby

   a) each of at least three spatially separated electronic cameras (1) with image processing, where for calibration an associated calibration table (2) with dot patterns is taken, the image of which as well as the dot pattern are processed to determine the position of the indiviual cameras (1) and their positions are stored.

   b) measurement (5) of the calibration tables 2) against each other is done independent thereof, so that these values are also stored.

   c) subsequently the body (6) is positioned in the space between the electronic cameras (1)

   d) a characteristic point each on the body (6) positioned in the space, is imaged in one electronic camera (1) associated with it, so that the position thereof in the image with its constructively predetermined position of the characteristic point on the body (6) positioned in the space, is processed together with the stored

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values, and

e) all thus processed values characterize the position of the body (6) positioned in space, in the six spatial degrees of freedom.

2. Procedure according to claim 1, characterized such, that the position of a nullbody of same type is determined and that measurement off all subsequent bodys (6) takes reference to this.

Revendications

1. Procédé pour déterminer le positionnement d'un corps (6) dans l'espace afin d'effectuer des manipulation sur cclui-ci au moyen de plusieurs caméras électroniques (1) séparées dans l'espace et agissant sur ce corps au moyen de traitement d'images. Ce procédé se caractérise comme suit:

a) Lors de l'étalonnage, chacune des au minimum trois caméras électroniques (1) á traitment d'images séparées dans l'espace prend sur plan un tableau d'étalonnage (2) á réscau de points lui étant attribué et prenant les mesures des images et du réseau de points permettant la détermination et l'enregistement du positionnement de chaque caméra dans l'espace.

b) Idépendamment, un mesurage (5) des tableaux d'étalonnage (2) entre eux sera effectué at ces données également enregistrées

c) Le corps (6) sera ensuite placé dans l'espace se trouvant entre les caméras électroniques.

d) Par chacune des caméras électroniques (1), un point précis sur le corps (6) placé dans l'espace, attribué á l'une de ces caméras, sera photographié, Son positionnement dans l'image avec sa position contructive prédéfinie du point caractéristique par rapport au corps (6) placé dans l'espace sera traité en combinaison avec les données enregistrées.

e) Toutes les valeurs traitées de cette maniére caractérisent le positionnement du corps (6) placé dans l'espace dans les six degrés de liberté spaciaux.

2. Conformément á la spécification 1, ce peocédé se caractérise par la détermintion de la position d'und corps zéro du méme type et par le fait que la mesure de tous les corps suivants (6) se référe á ce dernier.

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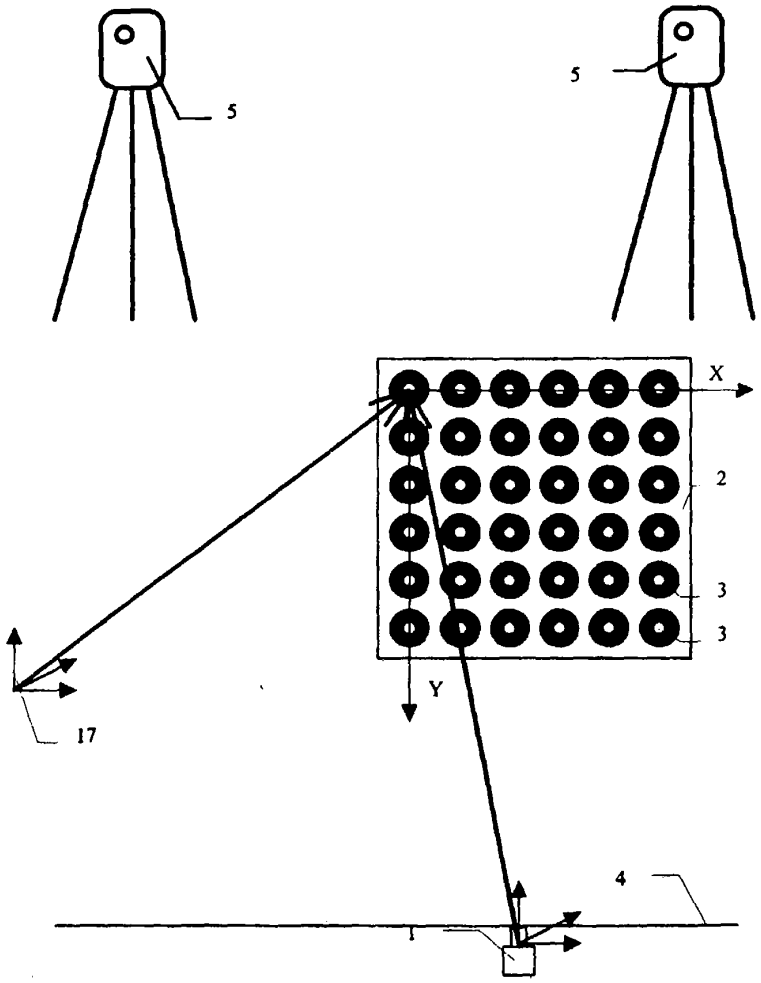


Fig. 1

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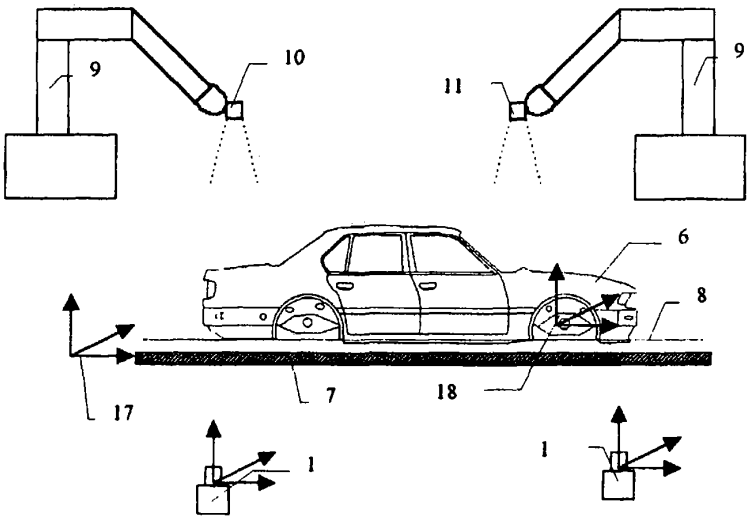


Fig. 2

ABB Inc. Exhibit 1002, Page 236 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

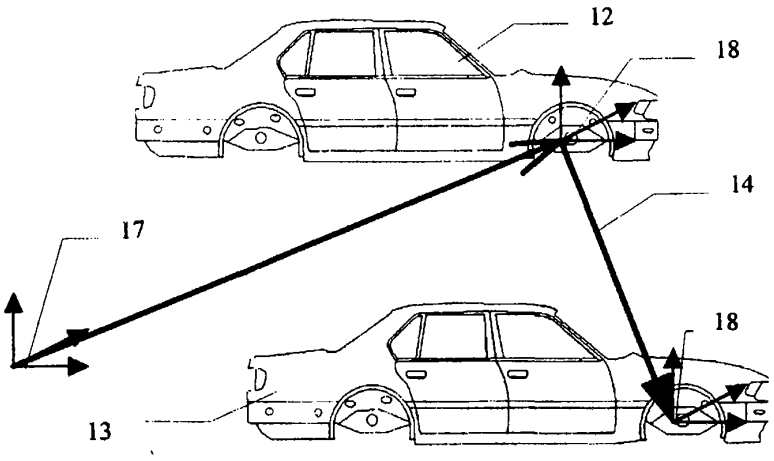


Fig. 3

ABB Inc. Exhibit 1002, Page 237 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Method of determination of the spatial position of an object

Patent number: EP0763406
Publication date: 1997-03-19
Inventor: ERSUE ENIS DIPL-ING (DE); WIENAND STEPHAN DIPL-ING (DE)
Applicant: ISRA SYSTEMTECHNIK GMBH (DE)
Classification:
- international: B25J9/16; G05B19/401
- european: B25J9/16
Application number: EP19950114588 19950915
Priority number(s): EP19950114588 19950915

Also published as:
EP0763406 (B1)

Cited documents:
US4639878
EP0489919
WO9429774
WO9305479
US4796200
more >>

Report a data error here

Abstract of **EP0763406**

The method involves using several spatially separated electronic cameras with image processing function which is calibrated by imaging a calibration board with a point pattern associated with each camera, and using the resulting images to determine the position of each camera w.r.t. the calibration board. The position of each camera is stored, the calibration board is independently measured and the resulting measurements are also stored. An object is entered into the space between the cameras and a determined point on the object is imaged on each camera. The relative position of that point in the image is processed together with the constructive, predetermined position of the characteristic point on the object and the stored data. All processed values describe the position of the object in the six spatial degrees of freedom.

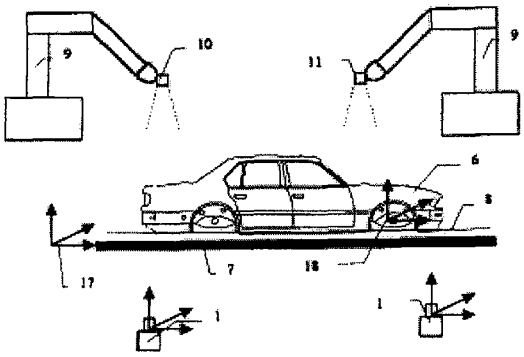


Fig. 2

Data supplied from the ***esp@cenet*** database - Worldwide

ABB Inc. Exhibit 1002, Page 238 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Electronic Patent Application Fee Transmittal

Application Number:	10634874
Filing Date:	06-Aug-2003
Title of Invention:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
First Named Inventor/Applicant Name:	Babak Habibi
Filer:	Frank Abramonte/Sandy Clayton
Attorney Docket Number:	170154.401C1

Filed as Small Entity

Utility Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Independent claims in excess of 3	2201	1	105	105
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Request for continued examination	2801	1	405	405
		Total in USD ($)		**510**

Electronic Acknowledgement Receipt

EFS ID:	2701520
Application Number:	10634874
International Application Number:	
Confirmation Number:	7619
Title of Invention:	METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS
First Named Inventor/Applicant Name:	Babak Habibi
Customer Number:	500
Filer:	Frank Abramonte/Sandy Clayton
Filer Authorized By:	Frank Abramonte
Attorney Docket Number:	170154.401C1
Receipt Date:	10-JAN-2008
Filing Date:	06-AUG-2003
Time Stamp:	19:43:49
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$510
RAM confirmation Number	3604
Deposit Account	191090
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)

1	Request for Continued Examination (RCE)	401C1_RCE.pdf	694857 f0f94a8bb7376030fe01efee9b0241b505477086	no	3
Warnings:					
Information:					
2		401C1_Prelim_Amend.pdf	87865 edc034b0677ba8bbffcd18003405f326986ce48c	yes	9
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Preliminary Amendment		1	1	
	Claims		2	8	
	Applicant Arguments/Remarks Made in an Amendment		9	9	
Warnings:					
Information:					
3	Miscellaneous Incoming Letter	401C1_Fee_Deficiency.pdf	51453 b14e66bdd360c6a1893f19f9080d59974eddb4cb	no	1
Warnings:					
Information:					
4	Information Disclosure Statement Letter	401C1_IDS.pdf	68718 09b45bb14bf419f928c705671a6cd02cd3640421	no	2
Warnings:					
Information:					
5	Information Disclosure Statement (IDS) Filed	401C1_IDS_SB08.pdf	833269 018b781106fceb4909a7b9dffe719cc8364c4bc8	no	5
Warnings:					
Information:					
6	Foreign Reference	JP1124072.pdf	148224 320ad7e3295024ceeed4f9e3ae8b46b17bbefe77	no	4
Warnings:					
Information:					
7	Foreign Reference	ep0763406.pdf	367652 0cc9efcda9fc30634c0dcb15acc0b8c473baa990	no	9
Warnings:					
Information:					

8	NPL Documents	Borotschnig.pdf	1048290 b5e4c735bf2c99424307db145812768c7db72e13	no	13
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Information:					
9	NPL Documents	Chen.pdf	602807 f9e0e5354d7bdf02c9435510b4e07cca11f9448d	no	8
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Information:					
10	NPL Documents	Denzler.pdf	596820 fd2681bcc4ecd19df286d25ee9e3d2b06a5a8815	no	9
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Information:					
11	NPL Documents	Ji.pdf	1995428 6f10c3c1504ef3c153cc94c4980d475e38ef0a13	no	29
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13	NPL Documents	Kim.pdf	1329749 9dc1d195d9c7524e1b68eecc1aa0b6391f02d8a0	no	14
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14	NPL Documents	Kovacic.pdf	574613 44b8e81833273f7887a69d4bb3cc1aae561b8d20	no	11
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15	NPL Documents	Sanchez.pdf	337482 47b9db0da114349fdf6773f73599297b863bc845	no	4
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Information:					
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Warnings:					
Information:					
			Total Files Size (in bytes):	13709125	

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.

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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.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
10/634,874	08/06/2003	

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☒		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	01/10/2008	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 28	Minus	** 32	= 0	X $25 =	0	OR	X $ =	
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $105 =	0	OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE	0	OR	TOTAL ADD'L FEE	

AMENDMENT		(Column 1)		(Column 2)	(Column 3)	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA					
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/ERIC V. BURNS/

This collection of information is required by 37 CFR 1.16. 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 12 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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United States Patent and Trademark Office
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NOTICE OF ALLOWANCE AND FEE(S) DUE

500 7590 02/25/2008

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	PAPER NUMBER
3664	

DATE MAILED: 02/25/2008

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

TITLE OF INVENTION: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$720	$300	$0	$1020	05/27/2008

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 SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

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 and an extra copy of the form should be submitted. 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: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

ABB Inc. Exhibit 1002, Page 246 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (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)

500 7590 02/25/2008

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

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 facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

TITLE OF INVENTION: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$720	$300	$0	$1020	05/27/2008

EXAMINER	ART UNIT	CLASS-SUBCLASS
MARC, MCDIEUNEL	3664	700-245000

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/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form 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 has been filed for recordation as set forth in 37 CFR 3.11. 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. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

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

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

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

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information 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 12 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.

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ABB Inc. Exhibit 1002, Page 247 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

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.
10/634,874	08/06/2003	Babak Habibi	170154.401C1	7619

500 7590 02/25/2008

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104

EXAMINER	
MARC, MCDIEUNEL	
ART UNIT	PAPER NUMBER
3664	

DATE MAILED: 02/25/2008

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

The Patent Term Adjustment to date is 215 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 215 day(s).

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 Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2010.

ABB Inc. Exhibit 1002, Page 248 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Notice of Allowability	Application No.	Applicant(s)	
	10/634,874	HABIBI ET AL.	
	Examiner	Art Unit	
	MCDIEUNEL MARC	3664	

-- 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 *01/10/2008*.

2. ☒ The allowed claim(s) is/are *33-47 and 49-61*.

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

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ 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. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

ABB Inc. Exhibit 1002, Page 249 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Allowable Subject Matter

1. Claims 50-47 and 49-61 are allowed in light of the amendment filed 10/10/2008.

2. The following is an examiner's statement of reasons for allowance:

The prior art of record fail to teach or fairly suggest a method useful in three-dimensional pose estimation for use with a single camera mounted to a movable portion of robot that further comprises the steps of determining an object space-to-camera space transformation for the target object based at least in part on a position of at least some of the located features using only the signal captured image and an algorithm that employs a known or determinable physical relationship between at least some of the located features in combination with the other elements of the claimed invention.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

3. Any inquiry concerning this communication or earlier communications from the examiner should be directed to MCDIEUNEL MARC whose telephone number is (571)272-6964. The examiner can normally be reached on 6:30-5:00 Mon-Thu.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Khoi Tran can be reached on (571) 272-6919. 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.

/McDieunel Marc/
Examiner, Art Unit 3664

MM/
/Khoi H Tran/
Supervisory Patent Examiner, Art Unit 3664

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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BIB DATA SHEET

CONFIRMATION NO. 7619

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/634,874	08/06/2003	700	3664	170154.401C1

APPLICANTS

Babak Habibi, North Vancouver, CANADA;
Simona Pescaru, North Vancouver, CANADA;
Mohammad Sameti, Coquitlam, CANADA;
Remus Florinel Boca, North Vancouver, CANADA;

**** CONTINUING DATA **************************** Yes

This application is a CIP of 10/153,680 05/24/2002 PAT 6,816,755

**** FOREIGN APPLICATIONS ************************** Yes

CANADA 2,369,845 01/31/2002

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** ** SMALL ENTITY **
11/12/2003

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /MCDIEUNEL MARC/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		CANADA	7	~~32~~ 28	~~2~~ 3

ADDRESS

SEED INTELLECTUAL PROPERTY LAW GROUP PLLC
701 FIFTH AVE
SUITE 5400
SEATTLE, WA 98104
UNITED STATES

TITLE

METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

FILING FEE RECEIVED		
653	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

ABB Inc. Exhibit 1002, Page 252 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PTO/SB/08a (05-07)
Approved for use through 11/30/2007. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

U.S.PATENTS						Remove
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	4402053		1983-08-30	Kelley et al.	
	2	5212738		1993-05-18	Chande et al.	
	3	5978521		1999-11-02	Wallack et al.	
	4	6115480		2000-09-05	Washizawa	
	5	6628819	B1	2003-09-30	Huang et al.	
	6	7061628	B2	2006-06-13	Franke et al.	
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U.S.PATENT APPLICATION PUBLICATIONS						Remove
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

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

	1	20030007159	A1	2003-01-09	Franke et al.	
	2	20040172164	A1	2004-09-02	Habibi et al.	

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

FOREIGN PATENT DOCUMENTS Remove

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] ¡	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	01124072	JP		1989-05-16	Masanobu	(+ abstract)	☐
	2	0763406	EP		1997-03-19	Ersue Enis		☐

If you wish to add additional Foreign Patent Document citation information please click the Add button Add

NON-PATENT LITERATURE DOCUMENTS Remove

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]
	1	Borotschnig, H., et al., "Appearance-Based Active Object Recognition," Image and Vision Computing, 18:715-727, 2000.	☐
	2	Chen, L., et al., "An investigation on the accuracy of three-dimensional space reconstruction using the Direct Linear Transformation Technique," J. Biomechanics 27(4):493-500, 1994.	☐
	3	Denzler J., et al., "Learning, Tracking and Recognition of 3D Objects," Proceedings of the IEEE/RSJ/GI, International Conference on Intelligent Robots and Systems (IROS) 1:89-96, 1994.	☐

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	Marc McDieunel
	Attorney Docket Number	170154.401C1

	4	Ji, Q., et al., "An Integrated Linear Technique for Pose Estimation from different Geometric Features," International Journal of Pattern Recognition and Artificial Intelligence, 13(5):705-733, August 1999.	☐
	5	Jia, Y-B., et al., "Sensing Polygon Poses by Inscription," Proc. of 1994 IEEE International Conference on Robotics and Automation, pp. 1642-1649, May 1994.	☐
	6	Kim, W.S., "Computer vision assisted virtual reality calibration," URL=http://www.robotics.jpl.nasa.gov/publications/Won_Kim/ra98_vrc.pdf., pp. 1-14, 1999.	☐
	7	Kovacic, S., et al., "Planning Sequences of Views for 3-D Object Recognition and Pose Determination," Pattern Recognition 31(10):1407-1417, 1998.	☐
	8	Sanchez, A., et al., "Robot-arm Pick and Place Behavior Programming System Using Visual Perception," in Proceedings of the 15th International Conference on Pattern Recognition 4:507-510, September 2000.	☐
	9	Tsai, R. et al., "An Efficient and Accurate Camera Calibration Technique for 3D Machine Vision," Proceedings of IEEE, Conference on Computer Vision and Pattern Recognition, pp. 364-374, 1986.	☐
	10	Tsai, R., "A Versatile Camera Calibration Technique for High-Accuracy 3D Machine Vision Metrology Using Off-the-Shelf TV Cameras and Lenses," IEEE Journal of Robotics and Automation, RA-3(4):323-344, August 1987.	☐

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

EXAMINER SIGNATURE

Examiner Signature	/McDieunel Marc/	Date Considered	02/09/2008

*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. /M.M./

FORM PTO-1449 (REV. 7-80)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTY. DOCKET NO. 170154.401C1	APPLICATION NO. 10/634,874
	INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	APPLICANTS Babak Habibi et al.	
		FILING DATE August 6, 2003	GROUP ART UNIT 3664 ~~3661~~

OIPE JUN 23 2005 JC26 PATENT & TRADEMARK OFFICE

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	AA	4,578,561	03/25/86	Corby, Jr. et al.	219	124.34	
	AB	4,835,450	05/30/89	Suzuki	318	568.13	
	AC	5,083,073	01/21/92	Kato	318	577	
	AD	5,350,269	09/27/94	Azuma et al.	414	416	
	AE	5,454,775	10/03/95	Cullen et al.	483	16	
	AF	6,341,246	01/22/02	Gerstenberger et al.	700	245	
	AG	6,466,843	10/15/02	Bonanni et al.	700	245	
	AH	6,804,416	10/12/04	Bachelder et al.	382	294	
	AI	2004/0114033	06/17/04	Eian et al.	348	42	
	AJ	60/413,180		Eian et al.			09/23/02

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	TRANSLATION YES	TRANSLATION NO
	AK	0151417	08/14/85	EP		
	AL	0493612	07/08/92	EP		
	AM	0951968	10/27/99	EP		
	AN	401124072	05/89	JP		
	AO	0911603 B1	04/28/99	EP (with machine translation)	X	

OTHER PRIOR ART *(Including Author, Title, Date, Pertinent Pages, Etc.)*

	AP		Denzler, J., et al., "Learning, Tracking and Recognition of 3D Objects," *Proceedings of the IEEE/RSJ/GI International Conference on Intelligent Robots and Systems*. (No date available.)
	AQ		"Advanced Robotic Systems and the Real World," *Proceedings of the International Conference on Intelligent Robots and Systems (IROS)*, XP000512662, Vol. 1, Munich, September 12, 1994, pp. 89-96.

EXAMINER	DATE CONSIDERED

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

599816_1

Date: June 23, 2005

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

FORM PTO-1449 (REV.7-80)	U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTY. DOCKET NO. 170154.401C1	APPLICATION NO. 10/634,874
INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)		APPLICANTS Babak Habibi et al.	
		FILING DATE August 6, 2003	GROUP ART UNIT ~~3661~~ 3664

U.S. PATENT DOCUMENTS

*EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUBCLASS	FILING DATE IF APPROPRIATE
	BA	60/587,488		Boca et al.			07/14/04
	BB						
	BC						
	BD						
	BE						
	BF						
	BG						
	BH						
	BI						
	BJ						

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	TRANSLATION YES	TRANSLATION NO
	BK					
	BL					
	BM					
	BN					
	BO					

OTHER PRIOR ART *(Including Author, Title, Date, Pertinent Pages, Etc.)*

	BP		W. Meyer, "One-Eyed Robots With 3D Vision," ISRA Vision Systems AG, Press News, Release No. 16, June 15, 2004, pp 1-7.
	BQ		~~"3D Robot Guidance with a Single Camera," ISRA Vision Systems AG. (No date available.)~~
	BR		3D Vision with One Camera, URL=http://neu.isravision.com/likecms/index.php?site=site.html&dir=isra&nav=162, download date April 12, 2005.

EXAMINER	/McDieunel Marc/	DATE CONSIDERED	02/09/2008

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

599816_1

Date: June 23, 2005

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

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	Art Unit
	Marc, McDieunel	3661

SEARCHED

Class	Subclass	Date	Examiner
700	245,246,253,257,258,259,279	2/9/08	MM
318	568.13,568.15.568.16,640	2/9/08	MM
901	6,14,17,46,47	2/9/08	MM
29	218,407.1,702,714,720	2/9/08	MM
348	42,94,154,190,,191,287,291,552	2/9/08	MM
382	154,103,106,154,276,293,295,298	2/14/08	MM

SEARCH NOTES

Search Notes	Date	Examiner
Palm inventor search	2/9/08	MM
West search see attached listings	2/9/08	MM

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner
PGPub search has been conducted		2/9/08	MM

WEST Search History

Hide Items | Restore | Clear | Cancel

DATE: Thursday, February 14, 2008

Hide?	Set Name	Query	Hit Count
	DB=PGPB,USPT,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=ADJ		
☐	L16	l14 and L15	5
☐	L15	distance sensor	17430
☐	L14	l12 and L13	89
☐	L13	target object	30470
☐	L12	image and L11	567
☐	L11	located and L9	568
☐	L10	locat$6 and L9	749
☐	L9	position and L8	837
☐	L8	measur$3 and L7	837
☐	L7	distance and L6	1060
☐	L6	position and L5	1288
☐	L5	l3 and L4	1405
☐	L4	2D or 3D and L3	234608
☐	L3	camera and L2	3798
☐	L2	(382/103,106,154,276,293,295,298).ccls.	6257
☐	L1	382(103,106,154,276,293,295,298).ccls.	0

END OF SEARCH HISTORY

ABB Inc. Exhibit 1002, Page 259 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	**Art Unit**
	Marc, McDieunel	3661

ORIGINAL		INTERNATIONAL CLASSIFICATION	
CLASS	SUBCLASS	CLAIMED	NON-CLAIMED
700	245	G 0 6 F 19 / 00 (2006.01.01)	

CROSS REFERENCE(S)

CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
700	246	253	257	258	259
318	568.13	568.15	568.16	640	
29	702	714	720		
901	6	14	17	46	47

Marc, McDieunel	02/09/2008		**Total Claims Allowed:**
(Assistant Examiner)	(Date)		28
Khoi H. Tran	2/18/08	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

ABB Inc. Exhibit 1002, Page 260 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	Art Unit
	Marc, McDieunel	3661

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

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

CLAIM		DATE								
Final	Original	09/22/2007	02/09/2008							
	1	-	-							
	2	-	-							
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2	33	✓	=							
3	34	✓	=							
4	35	✓	=							
5	36	✓	=							

ABB Inc. Exhibit 1002, Page 261 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10634874	HABIBI ET AL.
	Examiner	**Art Unit**
	Marc, McDieunel	3661

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

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

CLAIM		DATE								
Final	Original	09/22/2007	02/09/2008							
6	37	✓	=							
7	38	✓	=							
8	39	✓	=							
9	40	✓	=							
10	41	✓	=							
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17	49	✓	=							
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25	58	✓	=							
26	59	✓	=							
27	60	✓	=							
28	61	✓	=							

ABB Inc. Exhibit 1002, Page 262 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

B445 0014
BMG/cnr

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

Inventors: HABIBI, Babak; PESCARU, Simona, SAMMETI, Mohammad, BOCA, Remus Florinel

Title: METHOD AND APPARATUS FOR SINGLE IMAGE 3D VISION GUIDED ROBOTICS

Filed: Herewith

Date: 5 August 2003

Commissioner for Patents
Washington, D.C. 20231

Dear Sir/Madam:

LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT
[Form PTO-1449 (Modified)]

United States Patent Documents

Examiner	ID	Patent No.	Issue Date	Inventor(s)	Class	Sub-Cl	Filing Date
	US: 1	3,986,007	12 Oct 1976	Ruoff, Jr.			
	US: 2	4,146,924	27 Mar 1979	Birk et al.			
	US: 3	4,219,847	26 Aug 1980	Pinkney et al.			
	US: 4	4,305,130	8 Dec 1981	Kelley et al.			
	US: 5	4,334,241	8 Jun 1982	Kashioka et al.			
	US: 6	4,437,114	13 Mar 1984	LaRussa			
	US: 7	4,613,942	23 Sep 1986	Chen			
	US: 8	4,654,949	7 Apr 1987	Pryor			
	US: 9	4,942,539	17 Jul 1990	McGee et al.			
	US: 10	5,696,673	9 Dec 1997	Pryor			
	US: 11	5,956,417	21 Sep 1999	Pryor			
	US: 12	5,959,425	28 Sep 1999	Bieman et al.			
	US: 13	6,044,183	28 Mar 2000	Pryor			
	US: 14	6,141,863	7 Nov 2000	Hara et al.			

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

ABB Inc. Exhibit 1002, Page 263 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

	US: 15	6,167,607	2 Jan 2001	Pryor			
	US: 16	6,211,506	3 Apr 2001	Pryor et al.			
	US: 17	6,301,763	16 Oct 2001	Pryor			

Other Art

Examiner	ID	Author, Title, Date, Pertinent Pages, etc.
	OA: 1	Roger Y. Tsai and Reimar K. Lenz, "A New Technique for Fully Autonomous and Efficient 3D Robotics Hand/Eye Calibration", *IEEE Transactions on Robotics and Automation*, Vol. 5, No. 3, June 1989 p. 345
	~~OA: 2~~	~~Zhengyou Zhang, "A Flexible New Technique for Camera Calibration", http://research.microsoft.com/scripts/pubs/view.asp?TR_ID=MSR-TR-98-71~~
	OA: 3	Guo-Qing Wei, Klaus Arbter, and Gerd Hirzinger, "Active Self-Calibration of Robotic Eyes and Hand-Eye Relationship with Model Identification", *IEEE Transactions on Robotics and Automation*, Vol 14, No. 1, February 1998 p. 158
	OA: 4	Yuncai Liu, Thomas S. Huang and Olivier D. Faugeras, "Determination of Camera Location from 2-D to 3-D Line and Point Correspondences", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 12, No. 1, January 1990 p. 28
	OA: 5	Chien-Ping Lu, Gregory D. Hager and Eric Mjolsness, "Fast and Globally Convergent Pose Estimation from Video Images", *IEEE Transactions on Pattern Analysis and Machine Intelligence,* Vol. 22, No. 6, June 2000 p. 610
	OA: 6	Thomas Huang, Alfred M. Bruckstein, Robert J. Holt, and Arun N. Netravali, "Uniqueness of 3D Pose Under Weak Perspective: A Geometrical Proof", *IEEE Transactions on Pattern Analysis and Machine Intelligence,* Vol. 17, No. 12, December 1995 p. 1220

Examiner: /McDieunel Marc/

Date Considered: 02/09/2008

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; draw line through 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. /M.M./

ABB Inc. Exhibit 1002, Page 264 of 996
ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

WEST Search History

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Hide?	Set Name	Query	Hit Count
		DB=PGPB,USPT,EPAB,JPAB,DWPI,TDBD; PLUR=YES; OP=ADJ	
☐	L12	parameters and L10	67
☐	L11	extrinsic and parameters and L10	0
☐	L10	irobot	227
☐	L9	calibrat$6 and L8	134
☐	L8	reference frame and L7	261
☐	L7	(700/245 |700/246 |700/253 |700/257 |700/258 |700/259 |700/279 or 29/218 |29/702 |29/714 |29/720 |29/407.1 |29/407.04 or 318/568.13 | 318/568.15 |318/568.16 |318/640 or 348/42 |348/94 |348/154 |348/190 | 348/291 |348/287552 or 901/6 |901/14 |901/17 |901/46 |901/47 or 414/730 |414/737 or 382/154).ccls.	11775
☐	L6	('20050233770' |'20050190957' |'20050142293' |'20050045214' |'20040258514' |'20040243320')!.ABPN1,NRPN,PN,TBAN,WKU.	12
☐	L5	wafer and computer and L4	2307
☐	L4	camera and L3	7010
☐	L3	(robot$6 or articulat$3 or automat$6 or autonomous$2 or CNC or machine $2 or mechanical device or mechan$6 or servomechan$4) and L2	29515
☐	L2	calibrat$$ and semiconductor and (correct$3 or fix$3)	34537
☐	L1	10/126493	7

END OF SEARCH HISTORY

ABB Inc. Exhibit 1002, Page 265 of 996
ABB Inc. v. Roboticvisiontech, Inc.
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Key: IEEE JNL = IEEE Journal or Magazine, IEE JNL = IEE Journal or Magazine, IEEE CNF = IEEE Conference, IEE CNF = IEE Conference, IEEE STD = IEEE Standard

1. **Implementation of a neurophysiological model of saccadic eye movements on an anthropomorphic robotic head**
   Manfredi, L.; Maini, E.S.; Dario, P.; Laschi, C.; Girard, B.; Tabareau, N.; Berthoz, A.;
   Humanoid Robots, 2006 6th IEEE-RAS International Conference on
   4-6 Dec. 2006 Page(s):438 - 443
   IEEE CNF

2. **Automated calibration of a camera sensor network**
   Rekleitis, I.; Dudek, G.;
   Intelligent Robots and Systems, 2005. (IROS 2005). 2005 IEEE/RSJ International Conference on
   2-6 Aug. 2005 Page(s):3384 - 3389
   IEEE CNF

3. **Robotics and structural dynamics characterization of the space station remote manipulator system using photogrammetric techniques**
   Chandrashaker, R.; Kalaycioglu, S.; Graham, W.B.;
   Electrotechnical Conference, 1994. Proceedings., 7th Mediterranean
   12-14 April 1994 Page(s):691 - 694 vol.2
   IEEE CNF

4. **A vision system for safe robot operation**
   Yeh, P.-S.; Barash, S.; Wysocki, E.;
   Robotics and Automation, 1988. Proceedings., 1988 IEEE International Conference on
   24-29 April 1988 Page(s):1461 - 1465 vol.3
   IEEE CNF

5. **Shepherd: An Interface for Overcoming Reference Frame Transformations in Robot Control**
   Hosoi, Kazuhiro; Sugimoto, Masanori;
   Robotics and Biomimetics, 2006. ROBIO '06. IEEE International Conference on
   Dec. 2006 Page(s):908 - 913
   IEEE CNF

6. **Numerical optimization on the Euclidean group with applications to camera calibration**
   Seungwoong Gwak; Junggon Kim; Park, F.C.;
   Robotics and Automation, IEEE Transactions on
   Volume 19, Issue 1, Feb. 2003 Page(s):65 - 74
   IEEE JNL

7. **Remote teleassistance**
   Pook, P.K.; Ballard, D.H.;
   Robotics and Automation, 1995. Proceedings., 1995 IEEE International Conference on
   Volume 1, 21-27 May 1995 Page(s):944 - 949 vol.1
   IEEE CNF

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8. **Adaptive visual servoing in the presence of intrinsic calibration uncertainty**
Chen, J.; Behal, A.; Dawson, D.M.; Dixon, W.E.;
Decision and Control, 2003. Proceedings. 42nd IEEE Conference on
Volume 5, 9-12 Dec. 2003 Page(s):5396 - 5401 Vol.5
IEEE CNF

9. **Multisensor fusion of touch and vision using minimal representation size**
Joshi, R.; Sanderson, A.C.;
Intelligent Robots and Systems, 1997. IROS '97., Proceedings of the 1997 IEEE/RSJ International Conference on
Volume 3, 7-11 Sept. 1997 Page(s):V4 - V5 vol.3
IEEE CNF

10. **A Monocular Visual Servoing Control System for Mobile Robot**
Yang, Jie; Zhang, Mingjun; Wang, Yujia; Shang, Yunchao;
Automation and Logistics, 2007 IEEE International Conference on
18-21 Aug. 2007 Page(s):574 - 579
IEEE CNF

11. **Beating heart tracking in robotic surgery using 500 Hz visual servoing, model predictive control and an adaptive observer**
Ginhoux, R.; Gangloff, J.A.; de Mathelin, M.F.; Soler, L.; Sanchez, M.M.A.; Marescaux, J.;
Robotics and Automation, 2004. Proceedings. ICRA '04. 2004 IEEE International Conference on
Volume 1, 2004 Page(s):274 - 279 Vol.1
IEEE CNF

12. **Remote vehicle manoeuvring using augmented reality**
Brujic-Okretic, V.; Guillemaut, J.-Y.; Hitchin, L.J.; Michielen, M.; Parker, G.A.;
Visual Information Engineering, 2003. VIE 2003. International Conference on
7-9 July 2003 Page(s):186 - 189
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13. **Dead reckoning and cartography using stereo vision for an autonomous car**
Gehrig, S.K.; Stein, F.J.;
Intelligent Robots and Systems, 1999. IROS '99. Proceedings. 1999 IEEE/RSJ International Conference on
Volume 3, 17-21 Oct. 1999 Page(s):1507 - 1512 vol.3
IEEE CNF

14. **Rapid world modelling from a mobile platform**
Barry, R.E.; Jones, J.P.; Little, C.Q.; Wilson, C.W.;
Robotics and Automation, 1997. Proceedings., 1997 IEEE International Conference on
Volume 1, 20-25 April 1997 Page(s):72 - 77 vol.1
IEEE CNF

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ABB Inc. v. Roboticvisiontech, Inc.
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PTO/SB/30EFS (03/08)
Approved for use through 05/31/2008. OMB 0651-0031
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REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL
(Submitted Only via EFS-Web)

Application Number	10634874	Filing Date	2003-08-06	Docket Number (if applicable)	170154.401C1	Art Unit	3664
First Named Inventor	Babak Habibi			Examiner Name	McDieunel Marc		

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

SUBMISSION REQUIRED UNDER 37 CFR 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

- ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ☐ Other _____

☒ Enclosed

- ☐ Amendment/Reply
- ☒ Information Disclosure Statement (IDS)
- ☐ Affidavit(s)/ Declaration(s)
- ☒ Other Information Disclosure Statement Transmittal; Thirteen cited references

MISCELLANEOUS

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months _____ (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☐ Other _____

FEES

☒ **The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**
The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to Deposit Account No 191090

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

☒ Patent Practitioner Signature

☐ Applicant Signature

PTO/SB/30EFS (03/08)
Approved for use through 05/31/2008. OMB 0651-0031
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Signature of Registered U.S. Patent Practitioner			
Signature	/Frank Abramonte/	Date (YYYY-MM-DD)	2008-05-20
Name	Frank Abramonte	Registration Number	38066

This collection of information is required by 37 CFR 1.114. 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 1.11 and 1.14. This collection is estimated to take 12 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, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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 the Freedom of Information Act requires disclosure of these record s.

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 inspections 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.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	10634874
	Filing Date	2003-08-06
	First Named Inventor	Babak Habibi
	Art Unit	3664
	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

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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	6236896	B1	2001-05-22	Watanabe et al.	

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	1	20050273202	A1	2005-12-08	Bischoff	

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	1	0114505	EP	A1	1984-08-01	Pryor		☐
	2	07311610	JP		1995-11-28	Watanabe et al.		☐
	3	19515949	DE	A1	1996-11-14	Siebeneicher et al.	(+ Abstract in English)	☐

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	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

	4	0763406	EP	A1	1997-03-19	Ersu et al.	(+ Abstract in English)	☐
	5	9806015	WO		1998-02-12	Watanabe et al.	(+ Abstract in English)	☐
	6	10049218	JP		1998-02-20	Watanabe et al.		☐
	7	0106210	WO	A1	2001-01-25	Coulombe et al.		☐
	8	1172183	EP	A2	2002-01-06	Kleck	(+ Abstract in English)	☐
	9	2002018754	JP		2002-01-22	Naito et al.		☐
	10	1345099	EP	A2	2003-09-17	Schnell et al.	(+ Abstract in English)	☐
	11	10319253	DE	A1	2004-12-02	Tropf	(+ Abstract in English)	☐

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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]
	1	Nelson et al., "Robotic Visual Servoing and Robotic Assembly Tasks," IEEE Robotics & Automation Magazine 3 (2):23-31, 1996.	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	10634874
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	Art Unit	3664
	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

	2	Zhang, "A Flexible New Technique for Camera Calibration," Technical Report MSR-TR-98-71, Microsoft Corporation, December 2, 1998, 22 pages.	☐

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

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[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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
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	Filing Date	2003-08-06
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	Examiner Name	McDieunel Marc
	Attorney Docket Number	170154.401C1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

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☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Frank Abramonte/	Date (YYYY-MM-DD)	2008-05-20
Name/Print	Frank Abramonte	Registration Number	38066

This collection of information is required by 37 CFR 1.97 and 1.98. 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 1 hour 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, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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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)).

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EP0114505

Publication Title:

Apparatus and method for robot calibration.

Abstract:

Abstract of EP0114505

Robotic apparatus is guided by a computer 14 which is calibrated by cameras 20, 21, 22 mounted on the robot arm 11 which view targets 15, 16 fixed at a work station 13 and comprising a pattern of four dots. The viewing takes place as th fad e robot arm approaches the work station to carry out the intended operation and the sensing of any deviation relative to a predetermined target pattern is transmitted to the computer 14 to re-set the robot's computerized guidance system.

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(19) Europäisches Patentamt
European Patent Office
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(11) Publication number: **0 114 505**
A1

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **83307827.2**

(22) Date of filing: **21.12.83**

(51) Int. Cl.³: **B 25 J 19/00**

(30) Priority: **28.12.82 US 453910**

(43) Date of publication of application:
01.08.84 Bulletin 84/31

(84) Designated Contracting States:
DE FR GB IT SE

(71) Applicant: **DIFFRACTO LTD.**
2775 Kew Drive
Windsor Ontario N8T 3B7(CA)

(72) Inventor: **Pryor, Timothy R.**
105 Centennial Drive
Tecumseh Ontario N8N 2N7(CA)

(74) Representative: **Jennings, Guy Kenneth et al,**
GILL JENNINGS & EVERY 53-64 Chancery Lane
London WC2A 1HN(GB)

(54) **Apparatus and method for robot calibration.**

(57) Robotic apparatus is guided by a computer 14 which is calibrated by cameras 20, 21, 22 mounted on the robot arm 11 which view targets 15, 16 fixed at a work station 13 and comprising a pattern of four dots. The viewing takes place as the robot arm approaches the work station to carry out the intended operation and the sensing of any deviation relative to a predetermined target pattern is transmitted to the computer 14 to re-set the robot's computerized guidance system.

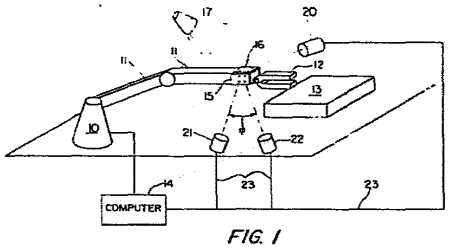


FIG. 1

EP 0 114 505 A1

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GJE/10/2179/02

DIFFRACTO LTD.

Apparatus and method for robot calibration

This invention relates to robotics, and in particular it relates to a method and apparatus for calibrating a robot.

The very essence of a robotic apparatus is that its movements are accurately predetermined so as to accurately carry out an intended operation such as handling or working on an object, the latter including, for example, welding or inspecting an object. Systems for guiding the robots through the course of their intended movements, to further enhance the accuracy of such movements have therefore been proposed.

However, no matter how perfect the original predetermined movements or no matter how accurate the guidance systems for enhancing the robot's movements, the nature of the environment in which the robots are utilised, including environmental conditions exterior to the robot make it virtually impossible to assure perfect positional accuracy at all times.

For example, many robots, particularly multi-joint articulated robots, are generally not capable of maintaining their positional actions over a long period of time. Furthermore, when approaching a given desired position from different paths, they often provide different results, even when functioning as a result of the same computer input commands. This can be extremely difficult in a fully flexible automatic factory situation where different path commands

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may have to be generated by the computer and the robot is expected to follow them under all conditions. Apparatus quite suitable for the purpose of enhancing the accuracy of the predetermined robot movements is shown in U.S. patent no: 4,219,847.

Hence, notwithstanding the improved means discussed above and known heretofore for enhancing guiding of the robot arm, there still exists a need to correct inaccuracies in the robot's position which cannot be corrected using known predetermined and improved guidance means and the primary object of the invention is to satisfy this need.

In principle this is achieved in accordance with the present invention by calibrating the robot's position as it approaches the work station, utilizing sensing means independent from the robot's own system for predetermining and guiding the robot's movements, and then sensing any deviation between a calibration signal and a reference signal. This deviation is then used to re-set the robot's basic computer guidance system. As a result thereof, as the robot's operative end approaches the work station, any error signals in its basic computerized program are re-set so that the robot's arm with its operating end are essentially given a fresh start from the location at which the calibration occurred, which will be in close proximity to the object, thereby in effect cancelling out any errors which preceded the point of calibration.

Apparatus in accordance with the invention and having an arm with an operative end for automatically handling or working on an object at a work station is thus characterised by a computerized guidance means for controlling movements of the arm and operative end for carrying out an intended handling or working on the object, a calibration means for checking and if

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necessary re-setting the guidance means, the calibration means comprising means for sensing the position of the arm and operative end independently of the guidance means, as the arm and operative end approach the work station, for generating a calibration signal, and means for comparing the calibration signal against a reference signal and noting any deviation therebetween and for re-setting the computerized guidance means in response to the deviation.

In a preferred arrangement, the calibration means comprises at least one target mounted on the arm and operative end, and including at least one camera mounted at a location independent of the arm and operative end appropriate for viewing the target as the arm and operative end approach the work station. In one arrangement, one or more cameras are located on the robot's arm while the target or targets are located at fixed locations in the vicinity of the work station such as on the floor, on a pillar, on the fixed part of a conveyor, or the like. In lieu of being mounted on the robot's arm, the cameras can be mounted at a remote location and in communication with sensing points on the robot's arm through fiber optics.

In another arrangement, the targets can be mounted on the robot's arm and the cameras located at fixed positions on the floor, pillars, or the like in the vicinity of the work station.

Examples in accordance with the present invention will now be described in more detail, with reference to the accompanying drawings, in which:-

Figure 1 is a perspective, schematic view of a robot and its work station, utilizing the features

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of the present invention;

Figure 2 is a schematic, perspective view similar to Figure 1 but showing a modification thereof; and

Figures 3A and 3B are diagrammatic views of the target, illustrating the operation of the invention.

There follows a detailed description of the preferred embodiments of the invention, to be read together with the accompanying drawings, wherein like elements are represented by like numerals throughout the several views.

Figure 1 illustrates a first preferred embodiment of the invention wherein a robotic apparatus 10 fixed to the floor includes an arm 11, in this case a multi-joint arm having an operative end 12. While this operative end can take any form for the purpose of handling or working on an object, including a camera which inspects an object, in the illustrated example there is shown an end effector 12. The work station 13, shown schematically in Figure 1, represents the area at which the operative end 12 would perform its function on the object.

In a known manner, the movements of the computer for purposes of carrying out the intended operation are controlled by computer 14. However, since it is impossible to guarantee positional accuracy of the operative end 12 under all conditions, there is provided in accordance with the present invention a system for checking and calibrating the position of the robot as it approaches the work station 13. In this embodiment this system includes one or more targets mounted on the robot arm 11, as illustrated at 15 and 16, and one or more cameras, as illustrated at 20, 21 and 22, each of which cameras are fixed relative to the surrounding environment, as illustrated by the floor level, independently of the robot arm 11. The cameras communicate

through lines 23 with the computer 14.

In the embodiment of Figure 1, as the robot's operative end 12 approaches the work station 13, it passes its target 15 over a camera unit, for example, camera 21 which may be fixed with respect to the floor and in fact buried in the floor of the plant at a location which is presighted with respect to the robot's own coordinate axis. Alternatively, if repeatability is the only factor in question, camera 21 does not have to be presighted but it can be assured that the camera is returned to a certain initial condition point or in any event, its position relative to the robot can be determined.

As illustrated, the target 15 has four dots. Three dots are the minimum for checking the position of the robot arm 11 up to six axes of coordinate data including X, Y, Z, roll, pitch and yaw. The fourth dot in the pattern provides a check and hence a more accurate calibration. Hence, as the target 15 approached the view of camera 21 the computer 14 dictated that the arm 11 should be in a certain predetermined position. Camera 21 will either confirm this position or note a deviation therein. If a deviation is noted, camera 21 will convey this information back to the computer 14 through lines 23, whereupon the computer 14 will make the corrections in the robot's memory for that position. Since the calibrating system is performing its function in a very limited area, i.e. only in the area close to the work station as the operative end 12 approaches same, it is only correcting the robot position over a very small range. This enables the system to have a high resolution, typically 0.02mm.

For further resolution, especially in other axes, a two camera solution may be desirable. In this case, a second camera 22 would be provided, which camera also views the target 15, this camera being spaced from the target 15 by an acute included angle ϕ . In the

alternative, the second camera can be located at position 20 which is 90° and in this case the camera would view a duplicate target 16. There may be provided a cube at the end of the robot arm having a plurality of these targets fixed thereon and of course geometrically fixed in reference with respect to each other. The targets may take many different forms such as white dots on a black background, illuminated points of diode lasers or light emitting diodes, fiber ends illuminated from a remote light source, etc. The camera units are typically solid state photo detector arrays of the type having a large number of separate photo detectors, and having an intrinsic digital measuring capability. Such units may have at least ten but preferably over a hundred separate photo detectors.

A flashed (strobe)target illumination light 17 or flashed target points (diode lasers or light emitting diodes) may be used. This provides the advantage of reading the dots and making the correction while the robot is in motion, i.e."on-the-fly". If such a flashed light source is utilized, then a position sensing analogue photo detector such as a UDT SC-10 can be used. However, this is drift prone and therefore not necessarily suited to the most accurate mensuration. For calibration over larger zones of the work area, it may be necessary to mechanically sweep the field of view.

Figure 2 illustrates a calibration system according to the present invention in which the basic features thereof have been reversed, i.e. in this case, the robot arm carries the cameras while the dotted targets are fixed with respect to the work station,i.e. on the floor, on pillars or the like, independently of the robot arm 11. Figure 2 illustrates a pair of cameras 25 and 26 mounted on the robot arm 11 and targets 28

and 29 fixed to the floor and to a pillar 30, respectively. A larger target 31 is mounted on a more distant pillar 32.

Adding the cameras to the robot arm has the disadvantage of adding additional weight thereto. However, these cameras are relatively light. Moreover, as an improvement thereof, the camera can be located at a remote position, as illustrated diagrammitically at 35, and connected to viewing points at the end of the robot arm 11 through fiber optics 36.

As illustrated in Figure 2, the robot arm 11 with the cameras thereon moves toward the work station 13 and as it approaches the work station the targets 28 or 29 come within view of the cameras 26 and 25, respectively. As in Figure 1, four dot matrix targets are desirable, although the system is operable for correcting in all six directions utilizing a minimum of three dots. In the embodiment of Figure 2, since the targets are not carried by the robot arm, the targets may be larger. Consequently, the accuracy of the solution may be considerably higher than in the case of a single closely spaced target. This is particularly true in range and angle dimensions.

In this embodiment with the targets fixed at selected locations in the vicinity of the work station, additional targets may be provided at especially advantageous points. For example, a target may be located directly behind a work object being conveyed such that when the work is transferred out, the target remains and is viewed by a camera, thus indicating removal of the object. Also, in the embodiment of Figure 2, many more target views can easily be utilized. Hence, the robot can be calibrated and hence corrected from a variety of angles by simply looking at the same target plate with different cameras or different points in

time. This can give improved resolution as encoder errors are statistically averaged and the average of multiple transform equations are used. Since targets are cheap, one or more target plates can be used very easily. In addition, more than one camera can be used on the robot. Two are illustrated in this embodiment. Given the fiber optic system for remotely locating the camera, each camera can view different directions simultaneously.

Also, in Figure 2, a strobe target illumination light 17 may be used for making readings on-the-fly. This can be important for maximum cycle rate since the robot need not stop. The flash source "freezes" the target image on the photodetector (for example, the matrix array) which then is read out subsequently. To accomplish this on the present matrix arrays, it may be necessary to provide a dump pulse to clear the array moments before the flash.

In this case the trigger to flash generally would come from the robot axis controller which would convey a signal indicating that the robot is at the calibration position. Use of flash sources also provides good background light level discrimination. Where laser or light emitting diode sources are used, further discrimination results by using wave length band pass filters in front of the detector.

It will be noted that the targets may also be located on pallets, on automation equipment or on the objects themselves to provide a very local calibration to the robot axes.

Figure 3 illustrates a practical example of the present invention using a typical four dot matrix target to correct in all six directions, X, Y, Z, θ, ϕ, χ. Figure 3A illustrates the correct reference position of the matrix, i.e. the view of the matrix if the robot arm 11 were perfectly positioned as the target came into

the view of the camera. However, Figure 3B illustrates the matrix as actually viewed by the camera. The target image, as viewed on the computer screen is off center and tilted such that the distances a' and b' are less than the reference distances a and b. This indicates a tilt and also a Z axis range lengthening. These variables can be solved independently given equations such as are known in the photogrammetric art and referred to in the above noted Pinkney et al U.S. patent no. 4,219,847.

In addition, the dots in Figure 3B illustrate that the target is off center in both axes. All of the correction data is then fed into the computer 14 to reset the memory which controls the computers movements, whereupon the servos operating the robot arm 11 are actually moved to reposition the robot so that its target appears as in Figure 3A. This new position of the correct reading is then locked into the memory and becomes a new reference point from which the robot goes forward.

It is noted that the calibration system does not have to be permanently attached to the robot but can be brought up to it at any time, assuming that some reliable procedure exists for accurately positioning the calibration system for each subsequent application. Thus, once the system has been operated, periodic calibration of may robots in a plant can be done with a single calibration system.

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C L A I M S

1. Robotic apparatus having an arm with an operative end for automatically handling or working on an object at a work station characterised by a computerized guidance means for controlling movements of the arm and operative end for carrying out an intended handling or working on the object, a calibration means for checking and if necessary re-setting the guidance means, the calibration means comprising means for sensing the position of the arm and operative end independently of the guidance means, as the arm and operative end approach the work station, for generating a calibration signal, and means for comparing the calibration signal against a reference signal and noting any deviation therebetween and for re-setting the computerized guidance means in response to the deviation.

2. Apparatus according to claim 1 in which the calibration means comprises at least one target mounted on the arm and operative end, and including at least one camera mounted at a location independent of the arm and operative end and appropriate for viewing the target as the arm and operative end approach the work station.

3. Apparatus according to claim 2 including a plurality of cameras positioned to view a single target.

4. Apparatus according to claim 1 in which the calibration means comprises at least one camera means on the arm and operative end, and at least one target mounted in the vicinity of the work station, independently of the arm and operative end.

5. Apparatus according to claim 4 in which the camera means comprises a camera device located remote from the arm and operative end, and fiber optics located on the arm and operative end and communicating with the camera device.

6. Apparatus according to any one of claims 2 to 5 in which the target comprises a pattern of at least three dots positioned to be viewed by the camera to ascertain the position of the arm and operative end in the X, Y, Z pitch, roll and yaw directions.

7. Apparatus according to claim 6 in which the target includes four dots arranged in a rectangular pattern.

8. A method for calibrating a robotic apparatus of the type having an arm and operative end for automatically handling or working on an object at a work station, characterised by the steps of guiding movements of the arm and operative end by means of a programmed guidance computer to carry out an intended handling or working on the object, and calibrating movements of the computerized arm and operative end as the arm and operative end approach the work station, by sensing the position of the arm and operative end, as they approach the work station, independently of the guidance means, to generate a calibration signal, comparing the calibration signal with a predetermined reference signal and re-setting the guidance computer in response to any deviation between the calibration signal and the reference signal.

9. A method according to claim 8 wherein the calibration step comprises viewing a target with a camera, either the camera or the target being located on the arm and operative end and the other being located in the vicinity of the work station and fixed independently of the arm and operative end.

10. A method according to claim 9 wherein at least one camera means is located on the arm and operative end and views at least one target located at the work station.

11. A method according to claim 9 wherein at least one camera is located at the work station, independently of the arm and operative end and at least one target is mounted on the arm and operative end.

12. A method according to claim 10 or claim 11 wherein the target comprises a pattern of at least three dots, and the deviation signal represents a distortion of this pattern of dots.

13. A method according to any one of claims 9 to 12 wherein the step of viewing the target with the camera is carried out under flashed light (strobe) illumination.

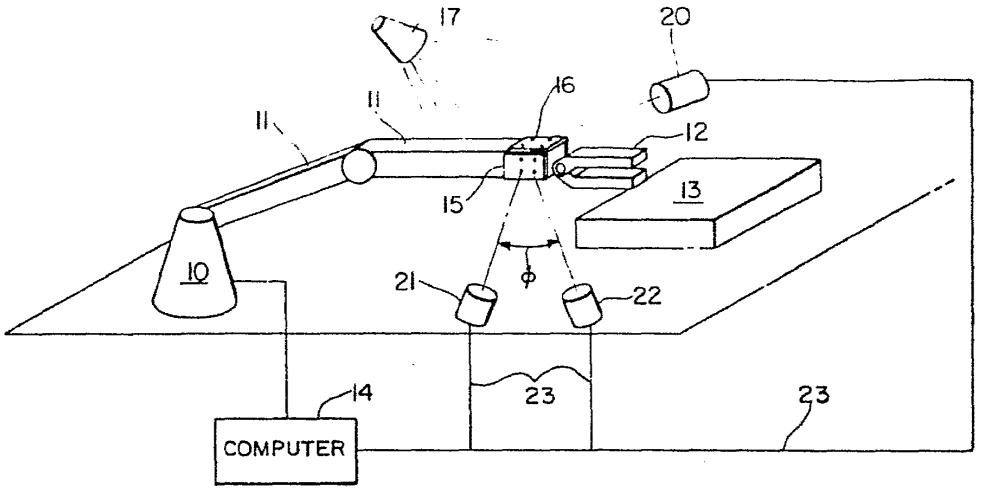


FIG. 1

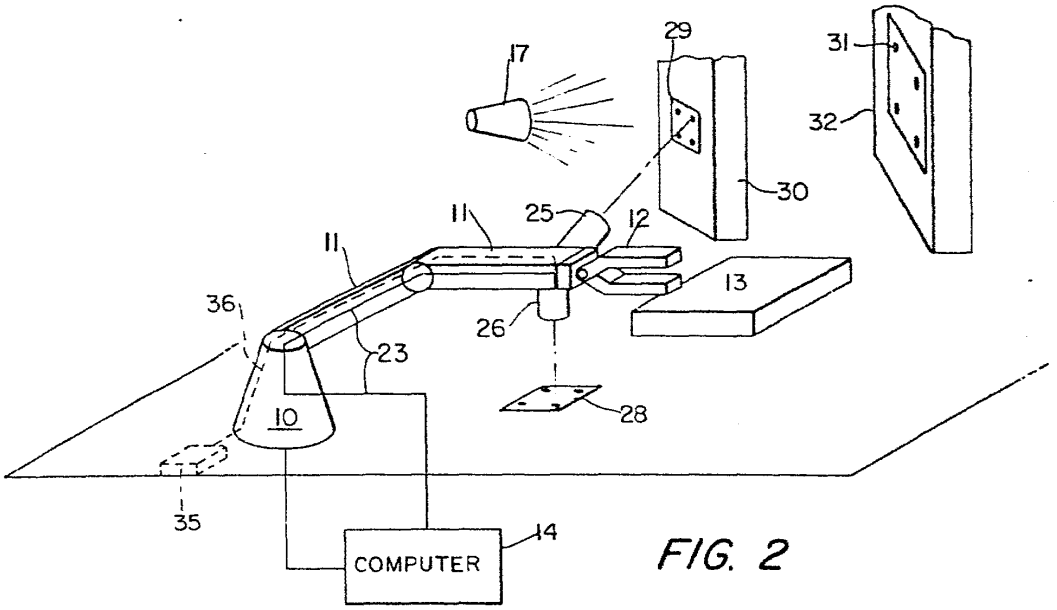


FIG. 2

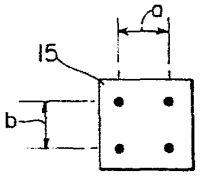


FIG. 3A

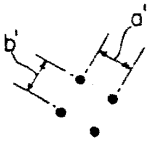


FIG. 3B

European Patent Office

EUROPEAN SEARCH REPORT

0114505
Application number

EP 83 30 7827

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Y	DE-A-2 430 058 (KYBORG GESELLSCHAFT FUER KYBERNETIK UND ORGANISATION mbH. UND CO SOFTWARE KG.) *The whole document*	1,2,8, 9,11	B 25 J 19/00
Y	EP-A-0 042 960 (I.B.M.) *Claims 1,2,4,6,7*	1,2,8, 9,11	
A	US-A-4 146 924 (BIRK et al.) *Claims 1,41,44; column 10, line 26 - column 11, line 15*	1,3,8, 11	
A	JP-A-53 004 964 (HITACHI SEISAKUSHO) *Abstract*	4,5,10	TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A	US-A-3 888 362 (FLETCHER et al.) *Column 3, lines 46-50*	7	B 25 J G 06 F
A	ROBOTICS TODAY, Winter 1979-80, Society of Manufacturing Engineers, pages 20-22; G.J.VANDERBRUG et al.: "A vision system for real-time robot control". *The whole document*	1,2,4, 10,12, 13	

-/-

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-04-1984	LAMMINEUR P.C.G.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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European Patent Office

EUROPEAN SEARCH REPORT

0114505
Application number

EP 83 30 7827

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
A	US-A-4 356 554 (SUSNJARA et al.)		

TECHNICAL FIELDS SEARCHED (Int. Cl. ³)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-04-1984	LAMMINEUR P.C.G.

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& : member of the same patent family, corresponding document

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PATENT ABSTRACTS OF JAPAN

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(43)Date of publication of application : **28.11.1995**

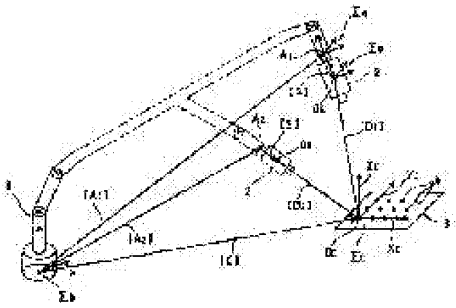
(51)Int.Cl. G05B 19/19
B25J 9/10
G05B 19/404
G05D 3/12

(21)Application number : **06-128005**
(22)Date of filing : **19.05.1994**

(71)Applicant : **FANUC LTD**
(72)Inventor : **WATANABE ATSUSHI**
WARASHINA FUMIKAZU

(54) COORDINATE SYSTEM SETTING METHOD USING VISUAL SENSOR

(57)Abstract:
PURPOSE: To set a coordinate system for operation which does not require skillfulness with stable precision by observing a coordinate system representing means, which visually represents the coordinate system, through the visual sensor which has a camera means supported on a robot, etc.
CONSTITUTION: An operator operates a robot controller to move the robot 1 to a 1st proper position A1 where a jig 3 is easily put in the visual field of the camera 2, and data on a matrix [A1] representing A1 are transferred from the controller 1 and stored. Then an observation is made at the position A1 through the camera 2 to store the image of a dot group 4 in a frame memory, and data of [D1] are found from pixel values are the respective dots in the dot group 4 and jig data. Similarly, the robot 1 is moved to a 2nd proper position A2 and data on a matrix [A2] are transferred and stored. An observation is made at the position A2 through the camera 2 and an image of a dot group 4 is inputted to find data of [D2]. Those data are used to calculate a matrix [C], thereby completing the setting of the coordinate system.



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Date of Publication 11.28.1995

CLAIMS

[Claim(s)]
[Claim 1]A coordinate-system-setting method characterized by comprising the following using a visual sensor.
(a) It is made to take several positions which make an automaton with which at least one standard coordinates are set up support a camera means of a visual sensor, and are different, A stage of observing a coordinate system expressive medium which expresses a coordinate system wishing setting out visually in each of a position of these plurality by said camera means, and gaining sensor data about said coordinate system wishing setting out.
(b) A stage of gaining data showing a position and a posture of said coordinate system wishing setting out to said at least one standard coordinates based on data showing said several mutually different positions of an automaton, and said gained sensor data.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application]Concerning the method of setting a coordinate system as automata, such as a robot, in more detail, a visual sensor is used in this invention. Therefore, it is related with the method of setting a coordinate system as coordinate system expressive media, such as a jig for coordinate system setting, by non-contact at automata, such as a robot.

[0002]
[Description of the Prior Art]In the automaton of the mold provided with the movable part which performs route movement according to the operation program which contains the data (only henceforth "position data") showing a position and a posture like a robot and a machine tool, two or more coordinate systems are set up and the conformity coordinate system at the time of operation is chosen according to work contents.
[0003]If the standard coordinates (henceforth a base coordinate system) fixed on the base of an automaton are ending with setting out, setting out of other coordinate systems will be attained by defining the transformation-matrix data showing the position and posture over the base coordinate system set [this] up.
[0004]In setting up a new coordinate system with such a method conventionally, Carry out fixed installation of the jig which expressed the coordinate system by the point group etc. to the position wishing setting out, and two or more prescribed spots of this jig are tagged up one by one in the portion representing the position of automata, such as a robot, Asking for transformation-matrix data is performed from the data of the touch position on a jig, and the position data of the automaton at the time of touch-up.
[0005]The point of specifically expressing the starting point as the 1st point, for example (0, 0, 0), The point of expressing X shaft orientation as the 2nd point (x0, 0, 0); Point (0, y0, 0);y0 !=0 on x0 !=0 and the Y-axis which expresses the direction of an XY plane as the 3rd point is chosen, The pin which an automaton tends to touch is set to these three

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points, manual operation (jogging) of the automaton is carried out, and these pins are touched directly [order]. And the data (transformation-matrix data) which expresses relative position and posture over the base coordinate system of the coordinate system expressed with the jig from the position data of the automaton at the time of each tatting and the data of a touch position is called for.
[0006]
[Problem(s) to be Solved by the Invention]However, very strict and delicate manual operation is required of work which contacts some specific "points" correctly with automata, such as a robot, and there is a problem of it being difficult to perform exact coordinate system setting for a short time, and being easy to come by factors, such as a skillful degree of an operator, out of gross errors.
[0007]Since the tatting by automata, such as a robot, is indispensable, the restrictions of the ability not to make an automaton recognizing the coordinate system expressive medium (for example, specific reference position distant near the automaton in working clearance) which exists in the position outside the working range of an automaton are not escaped.
[0008]Then, the purpose of the invention in this application is to conquer the problem of the coordinate-system-setting method of such a conventional contact method. Namely, the invention in this application can set a coordinate system as automata, such as a robot, with the non-contact method using a visual sensor in the accuracy stable by easy operation in which the level of skill is not required of an operator. Even if a coordinate system expressive medium exists outside the working range of an automaton, it is in providing the coordinate-system-setting method which an automaton is made to recognize a coordinate system and can set a coordinate system as it.
[0009]
[Means for Solving the Problem]as a means by which this invention solves an aforementioned problem -- "(a) -- several positions which make an automaton with which at least one standard coordinates are set up support a camera means of a visual sensor, and are different, [make take them and] A stage of observing a coordinate system expressive medium which expresses a coordinate system wishing setting out visually in each of a position of these plurality by said camera means, and gaining sensor data about said coordinate system wishing setting out, (b) Based on data showing said several mutually different positions of an automaton, and said gained sensor data, A coordinate-system-setting method using a visual sensor including a stage of gaining data showing a position and a posture of said coordinate system wishing setting out to said at least one standard coordinates" is proposed.
[0010]
[Function]The invention in this application is replaced with the contact method by automata, such as the conventional robot, and the method which observes the coordinate system expressive medium which expressed the coordinate system visually with the visual sensor which made automata, such as a robot, support a camera means is used for it. The robot which is a typical automaton of the mold provided with the movable part which performs route movement hereafter according to the operation program containing position data is taken for an example, and the setting-out principle of the coordinate system in the invention in this application is explained using drawing 1.
[0011]In drawing 1, the numerals 1 express a robot and the camera 2 (for example, video

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camera using a CCD element) which forms some visual sensors is supported by the arm tip. And the numerals 3 express the coordinate system expressive medium which expresses visually the position and posture of the coordinate system (it is called the following "setting-out coordinate system".) which wishes to set up. Here, it is sigmac about a setting-out coordinate system. ; It is referred to as Oc -Xc Yc Zc, The jig in which the home position Oc, Xc shaft orientations, Yc shaft orientations, and a Xc -Yc plane direction (Z shaft orientations turn into the direction of the outer product of the normal vector, i.e., the unit vector of Xc shaft orientations, and the unit vector of Yc shaft orientations) were expressed by the matrix form point group 4 is shown.

[0012]The coordinate system expressive medium 3 does not necessarily need to be the jig in which the point group was described, and if the position and posture of a setting-out coordinate system are expressed visually, it can use arbitrary means. For example, the characterizing portions (ridgeline etc.) of the mark described in the floor line and the work put on the prescribed position can be used.

[0013]Unlike conventional technology, the setting-out position (position of a coordinate system expressive medium) of a coordinate system does not have the restrictions which exist in the working range of the robot 1 that it will not become if it kicks, If the camera 2 is a range which can put a coordinate system expressive medium into a view normally by making it take the suitable position for the robot 1, a coordinate system can be set as arbitrary positions.

[0014]While base coordinate system sigmab used as the standard coordinates fixed in working clearance is set to the robot 1, centering on the face shield (or tool point), coordinate system sigmaa (a face shield coordinate system or a tool coordinate system) showing a robot position is set up. sigmas expresses the sensor coordinate system set as the visual sensor containing the camera 2.

[0015]Here, the robot 1 is made to take the two positions A1 and A2, and the position relationship of each coordinate system at the time of observing the coordinate system expressive medium 3 with the camera 2 in each robot position is considered. The procession (four-line four-row homogeneous transformation procession) expressing the relation between each coordinate system is carried out as follows.

[0016][C]; setting out of coordinate system sigmac is performed by the data of this procession in procession showing the position and posture of setting-out coordinate system sigmac seen from base coordinate system sigmab. That is, it is a strange procession which should be searched for for coordinate system setting.

[A1]; it is a procession showing the position and posture of the robot position A1 seen from base coordinate system sigmab, and is the known procession which the robot recognizes.

[0017][A2]; it is a procession showing the position and posture of the robot position A2 seen from base coordinate system sigmab, and is the known procession which the robot recognizes.

[0018][S]; it will become a known procession if the calibration of the visual sensor containing the camera 2 is performed in procession showing the position and posture of sensor coordinate system sigmas seen from the robot position.

[0019][D1]; it is in the state which has a robot in the position A1, and is a procession showing the position and the posture in which setting-out coordinate system sigmac was seen from sensor coordinate system sigmas. It is calculated by correcting the

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observational data based on the camera 2 of the coordinate system expressive medium (here point group 4) in the robot position A1 using calibration data.
[0020][D2]; it is in the state which has a robot in the position A2, and is a procession showing the position and the posture in which setting-out coordinate system sigmac was seen from sensor coordinate system sigmas. It is calculated by correcting the observational data based on the camera 2 of the coordinate system expressive medium (here point group 4) in the robot position A2 using calibration data.
[0021]If each procession is defined as above, both the following formulas will be materialized.
[C] -- =[A1] -[S] - [D1] ... [C] =[A2] -[S] - [D2] $[A1]^{-1}$, [S], and $[D1]^{-1}$=$[A2]^{-1}$, [S], and $[D2]^{-1}$ from (2), (1), and (2) types ... ... (3) is obtained. (1)
[0022]Here, the robot 1 is the quantity recognized as present position data in the position A1 and A2, and [A1] and [A2] are known. [D1] and [D2] are [in / are a procession showing the position and posture of setting-out coordinate system sigmac seen from sensor coordinate system sigmas in each robot position A1 and A2, and / each position] the characterizing portions (although it is the point group 4 which consists of two or more points here) on the jig 3 with the camera 2. for example, a line expresses -- it may have -- it is the quantity which observes and is calculated based on the data (interval of a point, etc.) about the observational data and point group 4.
[0023]Therefore, if it asks for the data which is equivalent to [D1] and [D2] in the two positions A1, A2, or a different position beyond it, a procession [C] can be searched for from (3) types.
[0024]Generally the calculation which asks for the data which is equivalent to [D1] and [D2] from the data about the observational data and the point group 4 which were acquired with the camera 2 is called the calibration of the camera.
Various methods are known.
Which method may be used in the invention in this application. From the point group 4 which consists of many points to for example, two or more points (at least three pieces theoretically) However, when taking the aberration of a camera lens into consideration, it is pointed out with Mr. Tsai's model that at least seven stations are required. There is a method of gaining calibration data from the related pixel value data. As an example of the literature in which the details of the calibration of the camera used for a visual sensor were described, "Roger Y. Tsai, "An efficient and accurate camera calibration technique for 3d machine vision ", Proc. Computer Vision and. There are Pattern Recognition'86 and pp.364-374-1986."
[0025]
[Example]Drawing 2 is the block diagram which illustrated the important section of the camera 2 which constitutes the visual sensor used when carrying out the invention in this application, and the image processing device 10 connected to this. Among a figure, the image processing device 10 has the central arithmetic unit (henceforth CPU) 11, and via the bus 21 to CPU1, The camera interface 12, the image processing processor 13, The console interface 4, the communication interface 15, The data memory 20 which comprised the TV monitor interface 16, the frame memory 17, the memory 18 for control soft that comprised a ROM, the program memory 19 which comprised RAM, and non-volatile RAM is connected. The camera 2 which put the jig 3 as a coordinate system expressive medium into the view in the mode of drawing 1 is connected to the camera

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interface 12.
[0026]It is connected by several sets if needed and this camera 2 detects the position of the work object (for example, important point working piece) performed after setting out of coordinate system sigmac, and it is constituted so that the data for position amendment may be transmitted to the robot control device (graphic display abbreviation) connected to the communication interface 15.
[0027]Although the camera 2 showed only one set, it may work by connecting several cameras to the communication interface 15 at once. In that case, common sensor coordinate system sigmas is set up, for example for every camera.
[0028]The picture caught with the camera 2 is changed into the shade image changed into the gray scale, and is stored in the frame memory 17. The image processing processor 13 processes the image data stored in the frame memory 17, the image of the focus of the jig J is recognized, and it has the function to detect the position (it is a central pixel value when a corresponding-picture-elements value and an image have a spread).
[0029]The console 23 is connected to the console interface 14, and the outside console 23 has a ten key for operating various kinds of instruction keys, input of an application program, edit, registration, execution, etc. outside a liquid crystal display, etc. And the menu for various data setting out, the list of programs, etc. can be displayed now on a liquid crystal display.
[0030]The control program for CPU11 to control a vision sensor system is stored in the memory 18 for control soft.
The program which a user produces is stored in the program memory 19.

[0031]The automaton (here robot) using the position information on the work etc. which the visual sensor detected, etc. are connected to the communication interface 15. The TV monitor 24 which can project selectively the picture stored in the picture or the frame memory 17 under photography with the camera C is connected to TV monitor interface 16.
[0032]Although there is no place which the above composition and function change fundamentally with the composition of the conventional vision sensor system, in operation of the invention in this application, It differs from a system conventionally in that it is said that a program and required data (data of the interval of the point group on the jig 3, the number, etc.) required in order to perform processing described into the flow chart of drawing 3 are stored in the memory 18 for control soft, or the data memory 20. Hereafter, the operating procedure for coordinate system sigmac setting out and processing are explained as what preparatory works, such as setting out of the camera 2 and an entry of data of the jig 3, have completed.
[0033]First, an operator operates a robot control device (graphic display abbreviation), and moves the robot 1 to the 1st suitable position A1 to which the jig 3 is easily settled in the view of the camera 2 (Step S1). And the data of a procession [A1] which expresses the position A1 from a robot control device is made to transmit, and it memorizes to the data memory 20 (Step S2).
[0034]Subsequently, observation (photography) with the camera 2 is performed in the robot position A1, and the image of the point group 4 is captured into the frame memory 17 (Step S3). If photography is completed, it will ask for the data of [D1] from the pixel value of each point of the point group 4, and jig data (data of the interval of a point

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group, a number, etc.) (step S4).
[0035]Similarly, an operator moves the robot 1 to the 2nd suitable position A2 to which the jig 3 is easily settled in the view of the camera 2 (Step S5), makes the data of a procession [A2] which expresses the position A2 from a robot control device transmit, and is memorized to the data memory 20 (Step S6).
[0036]Subsequently, observation (photography) with the camera 2 is performed in the robot position A2, and the image of the point group 4 is captured into the frame memory 17 (Step S7). If photography is completed, it will ask for the data of [D2] from the pixel value of each point of the point group 4, and jig data (data of the interval of a point group, a number, etc.) (Step S8).
[0037]By continuing step S9D, according to the above-mentioned formula (3), a procession [C] is calculated using these data, and a result is transmitted to a robot control device (Step S10). A robot control device stores the transmitted data in a predetermined memory area as coordinate-system-setting data, and ends processing.
[0038]The processing of those other than Step [under above-mentioned procedure] S3 and step S7 may perform all by the robot control device side in part.
[0039]
[Effect of the Invention]According to the invention in this application, a coordinate system can be set as automata, such as a robot, with the non-contact method using a visual sensor in the accuracy stable by easy operation in which the level of skill is not required of an operator. It became possible to make an automaton recognize a coordinate system and to set a coordinate system as it by the invention in this application, even if a coordinate system expressive medium exists outside the working range of automata, such as a robot.

TECHNICAL FIELD

[Industrial Application]Concerning the method of setting a coordinate system as automata, such as a robot, in more detail, a visual sensor is used in this invention. Therefore, it is related with the method of setting a coordinate system as coordinate system expressive media, such as a jig for coordinate system setting, by non-contact at automata, such as a robot.

PRIOR ART

[Description of the Prior Art]In the automaton of the mold provided with the movable part which performs route movement according to the operation program which contains the data (only henceforth "position data") showing a position and a posture like a robot and a machine tool, two or more coordinate systems are set up and the conformity coordinate system at the time of operation is chosen according to work contents.
[0003]If the standard coordinates (henceforth a base coordinate system) fixed on the base of an automaton are ending with setting out, setting out of other coordinate systems will be attained by defining the transformation-matrix data showing the position and posture over the base coordinate system set [this] up.
[0004]In setting up a new coordinate system with such a method conventionally, Carry out fixed installation of the jig which expressed the coordinate system by the point group

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etc. to the position wishing setting out, and two or more prescribed spots of this jig are tagged up one by one in the portion representing the position of automata, such as a robot, Asking for transformation-matrix data is performed from the data of the touch position on a jig, and the position data of the automaton at the time of touch-up.
[0005]The point of specifically expressing the starting point as the 1st point, for example (0, 0, 0), The point of expressing X shaft orientation as the 2nd point (x0, 0, 0); Point (0, y0, 0);y0 !=0 on x0 !=0 and the Y-axis which expresses the direction of an XY plane as the 3rd point is chosen, The pin which an automaton tends to touch is set to these three points, manual operation (jogging) of the automaton is carried out, and these pins are touched directly [order]. And the data (transformation-matrix data) which expresses relative position and posture over the base coordinate system of the coordinate system expressed with the jig from the position data of the automaton at the time of each tatting and the data of a touch position is called for.
[0006]

EFFECT OF THE INVENTION

[Effect of the Invention]According to the invention in this application, a coordinate system can be set as automata, such as a robot, with the non-contact method using a visual sensor in the accuracy stable by easy operation in which the level of skill is not required of an operator. It became possible to make an automaton recognize a coordinate system and to set a coordinate system as it by the invention in this application, even if a coordinate system expressive medium exists outside the working range of automata, such as a robot.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]However, very strict and delicate manual operation is required of work which contacts some specific "points" correctly with automata, such as a robot, and there is a problem of it being difficult to perform exact coordinate system setting for a short time, and being easy to come by factors, such as a skillful degree of an operator, out of gross errors.
[0007]Since the tatting by automata, such as a robot, is indispensable, the restrictions of the ability not to make an automaton recognizing the coordinate system expressive medium (for example, specific reference position distant near the automaton in working clearance) which exists in the position outside the working range of an automaton are not escaped.
[0008]Then, the purpose of the invention in this application is to conquer the problem of the coordinate-system-setting method of such a conventional contact method. Namely, the invention in this application can set a coordinate system as automata, such as a robot, with the non-contact method using a visual sensor in the accuracy stable by easy operation in which the level of skill is not required of an operator. Even if a coordinate system expressive medium exists outside the working range of an automaton, it is in providing the coordinate-system-setting method which an automaton is made to recognize a coordinate system and can set a coordinate system as it.

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MEANS

[Means for Solving the Problem]as a means by which this invention solves an aforementioned problem -- "(a) -- several positions which make an automaton with which at least one standard coordinates are set up support a camera means of a visual sensor, and are different, [make take them and] A stage of observing a coordinate system expressive medium which expresses a coordinate system wishing setting out visually in each of a position of these plurality by said camera means, and gaining sensor data about said coordinate system wishing setting out, (b) Based on data showing said several mutually different positions of an automaton, and said gained sensor data, A coordinate-system-setting method using a visual sensor including a stage of gaining data showing a position and a posture of said coordinate system wishing setting out to said at least one standard coordinates" is proposed.

OPERATION

[Function]The invention in this application is replaced with the contact method by automata, such as the conventional robot, and the method which observes the coordinate system expressive medium which expressed the coordinate system visually with the visual sensor which made automata, such as a robot, support a camera means is used for it. The robot which is a typical automaton of the mold provided with the movable part which performs route movement hereafter according to the operation program containing position data is taken for an example, and the setting-out principle of the coordinate system in the invention in this application is explained using drawing 1.

[0011]In drawing 1, the numerals 1 express a robot and the camera 2 (for example, video camera using a CCD element) which forms some visual sensors is supported by the arm tip. And the numerals 3 express the coordinate system expressive medium which expresses visually the position and posture of the coordinate system (it is called the following "setting-out coordinate system".) which wishes to set up. Here, it is sigmac about a setting-out coordinate system. ; It is referred to as Oc -Xc Yc Zc, The jig in which the home position Oc, Xc shaft orientations, Yc shaft orientations, and a Xc -Yc plane direction (Z shaft orientations turn into the direction of the outer product of the normal vector, i.e., the unit vector of Xc shaft orientations, and the unit vector of Yc shaft orientations) were expressed by the matrix form point group 4 is shown.

[0012]The coordinate system expressive medium 3 does not necessarily need to be the jig in which the point group was described, and if the position and posture of a setting-out coordinate system are expressed visually, it can use arbitrary means. For example, the characterizing portions (ridgeline etc.) of the mark described in the floor line and the work put on the prescribed position can be used.

[0013]Unlike conventional technology, the setting-out position (position of a coordinate system expressive medium) of a coordinate system does not have the restrictions which exist in the working range of the robot 1 that it will not become if it kicks, If the camera 2 is a range which can put a coordinate system expressive medium into a view normally by making it take the suitable position for the robot 1, a coordinate system can be set as arbitrary positions.

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[0014]While base coordinate system sigmab used as the standard coordinates fixed in working clearance is set to the robot 1, centering on the face shield (or tool point), coordinate system sigmaa (a face shield coordinate system or a tool coordinate system) showing a robot position is set up. sigmas expresses the sensor coordinate system set as the visual sensor containing the camera 2.
[0015]Here, the robot 1 is made to take the two positions A1 and A2, and the position relationship of each coordinate system at the time of observing the coordinate system expressive medium 3 with the camera 2 in each robot position is considered. The procession (four-line four-row homogeneous transformation procession) expressing the relation between each coordinate system is carried out as follows.
[0016][C]; setting out of coordinate system sigmac is performed by the data of this procession in procession showing the position and posture of setting-out coordinate system sigmac seen from base coordinate system sigmab. That is, it is a strange procession which should be searched for for coordinate system setting.
[A1]; it is a procession showing the position and posture of the robot position A1 seen from base coordinate system sigmab, and is the known procession which the robot recognizes.
[0017][A2]; it is a procession showing the position and posture of the robot position A2 seen from base coordinate system sigmab, and is the known procession which the robot recognizes.
[0018][S]; it will become a known procession if the calibration of the visual sensor containing the camera 2 is performed in procession showing the position and posture of sensor coordinate system sigmas seen from the robot position.
[0019][D1]; it is in the state which has a robot in the position A1, and is a procession showing the position and the posture in which setting-out coordinate system sigmac was seen from sensor coordinate system sigmas. It is calculated by correcting the observational data based on the camera 2 of the coordinate system expressive medium (here point group 4) in the robot position A1 using calibration data.
[0020][D2]; it is in the state which has a robot in the position A2, and is a procession showing the position and the posture in which setting-out coordinate system sigmac was seen from sensor coordinate system sigmas. It is calculated by correcting the observational data based on the camera 2 of the coordinate system expressive medium (here point group 4) in the robot position A2 using calibration data.
[0021]If each procession is defined as above, both the following formulas will be materialized.
[C] -- =[A1] -[S] - [D1] ... [C] =[A2] -[S] - [D2] $[A1]^{-1}$, [S], and $[D1]^{-1}$=$[A2]^{-1}$, [S], and $[D2]^{-1}$ from (2), (1), and (2) types ... ... (3) is obtained. (1)
[0022]Here, the robot 1 is the quantity recognized as present position data in the position A1 and A2, and [A1] and [A2] are known. [D1] and [D2] are [in / are a procession showing the position and posture of setting-out coordinate system sigmac seen from sensor coordinate system sigmas in each robot position A1 and A2, and / each position] the characterizing portions (although it is the point group 4 which consists of two or more points here) on the jig 3 with the camera 2. for example, a line expresses -- it may have -- it is the quantity which observes and is calculated based on the data (interval of a point, etc.) about the observational data and point group 4.
[0023]Therefore, if it asks for the data which is equivalent to [D1] and [D2] in the two

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positions A1, A2, or a different position beyond it, a procession [C] can be searched for from (3) types.
[0024]Generally the calculation which asks for the data which is equivalent to [D1] and [D2] from the data about the observational data and the point group 4 which were acquired with the camera 2 is called the calibration of the camera.
Various methods are known.
Which method may be used in the invention in this application. From the point group 4 which consists of many points to for example, two or more points (at least three pieces theoretically) However, when taking the aberration of a camera lens into consideration, it is pointed out with Mr. Tsai's model that at least seven stations are required. There is a method of gaining calibration data from the related pixel value data. As an example of the literature in which the details of the calibration of the camera used for a visual sensor were described, "Roger Y. Tsai, "An efficient and accurate camera calibration technique for 3d machine vision ", Proc. Computer Vision and. There are Pattern Recognition'86 and pp.364-374-1986."

EXAMPLE

[Example]Drawing 2 is the block diagram which illustrated the important section of the camera 2 which constitutes the visual sensor used when carrying out the invention in this application, and the image processing device 10 connected to this. Among a figure, the image processing device 10 has the central arithmetic unit (henceforth CPU) 11, and via the bus 21 to CPU1, The camera interface 12, the image processing processor 13, The console interface 4, the communication interface 15, The data memory 20 which comprised the TV monitor interface 16, the frame memory 17, the memory 18 for control soft that comprised a ROM, the program memory 19 which comprised RAM, and non-volatile RAM is connected. The camera 2 which put the jig 3 as a coordinate system expressive medium into the view in the mode of drawing 1 is connected to the camera interface 12.
[0026]It is connected by several sets if needed and this camera 2 detects the position of the work object (for example, important point working piece) performed after setting out of coordinate system sigmac, and it is constituted so that the data for position amendment may be transmitted to the robot control device (graphic display abbreviation) connected to the communication interface 15.
[0027]Although the camera 2 showed only one set, it may work by connecting several cameras to the communication interface 15 at once. In that case, common sensor coordinate system sigmas is set up, for example for every camera.
[0028]The picture caught with the camera 2 is changed into the shade image changed into the gray scale, and is stored in the frame memory 17. The image processing processor 13 processes the image data stored in the frame memory 17, the image of the focus of the jig J is recognized, and it has the function to detect the position (it is a central pixel value when a corresponding-picture-elements value and an image have a spread).
[0029]The console 23 is connected to the console interface 14, and the outside console 23 has a ten key for operating various kinds of instruction keys, input of an application program, edit, registration, execution, etc. outside a liquid crystal display, etc. And the menu for various data setting out, the list of programs, etc. can be displayed now on a

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liquid crystal display.
[0030]The control program for CPU11 to control a vision sensor system is stored in the memory 18 for control soft.
The program which a user produces is stored in the program memory 19.

[0031]The automaton (here robot) using the position information on the work etc. which the visual sensor detected, etc. are connected to the communication interface 15. The TV monitor 24 which can project selectively the picture stored in the picture or the frame memory 17 under photography with the camera C is connected to TV monitor interface 16.
[0032]Although there is no place which the above composition and function change fundamentally with the composition of the conventional vision sensor system, in operation of the invention in this application, It differs from a system conventionally in that it is said that a program and required data (data of the interval of the point group on the jig 3, the number, etc.) required in order to perform processing described into the flow chart of drawing 3 are stored in the memory 18 for control soft, or the data memory 20. Hereafter, the operating procedure for coordinate system sigmac setting out and processing are explained as what preparatory works, such as setting out of the camera 2 and an entry of data of the jig 3, have completed.
[0033]First, an operator operates a robot control device (graphic display abbreviation), and moves the robot 1 to the 1st suitable position A1 to which the jig 3 is easily settled in the view of the camera 2 (Step S1). And the data of a procession [A1] which expresses the position A1 from a robot control device is made to transmit, and it memorizes to the data memory 20 (Step S2).
[0034]Subsequently, observation (photography) with the camera 2 is performed in the robot position A1, and the image of the point group 4 is captured into the frame memory 17 (Step S3). If photography is completed, it will ask for the data of [D1] from the pixel value of each point of the point group 4, and jig data (data of the interval of a point group, a number, etc.) (step S4).
[0035]Similarly, an operator moves the robot 1 to the 2nd suitable position A2 to which the jig 3 is easily settled in the view of the camera 2 (Step S5), makes the data of a procession [A2] which expresses the position A2 from a robot control device transmit, and is memorized to the data memory 20 (Step S6).
[0036]Subsequently, observation (photography) with the camera 2 is performed in the robot position A2, and the image of the point group 4 is captured into the frame memory 17 (Step S7). If photography is completed, it will ask for the data of [D2] from the pixel value of each point of the point group 4, and jig data (data of the interval of a point group, a number, etc.) (Step S8).
[0037]By continuing step S9D, according to the above-mentioned formula (3), a procession [C] is calculated using these data, and a result is transmitted to a robot control device (Step S10). A robot control device stores the transmitted data in a predetermined memory area as coordinate-system-setting data, and ends processing.
[0038]The processing of those other than Step [under above-mentioned procedure] S3 and step S7 may perform all by the robot control device side in part.

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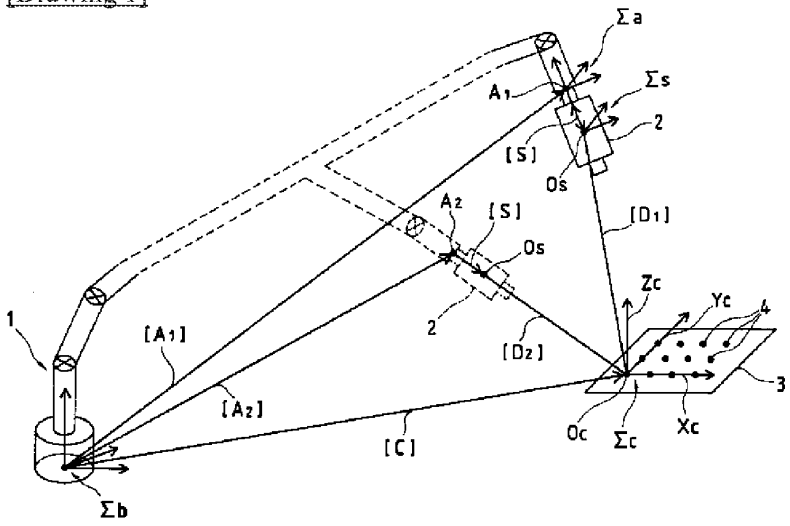
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]It is a figure for taking a robot for an example and explaining the setting-out principle of the coordinate system in the invention in this application.
[Drawing 2]It is the block diagram which illustrated the important section of the camera which constitutes the visual sensor used when carrying out the invention in this application, and the image processing device connected to this.
[Drawing 3]It is a flow chart explaining the operation for setting up a coordinate system according to the invention in this application, and procedure.
[Description of Notations]
1 Robot
2 Camera
3 Coordinate system expressive medium (jig)
4 Point group
10 Image processing device
11 Central arithmetic unit (CPU)
12 Camera interface
13 Image processing processor
14 Console interface
15 Communication interface
16 TV monitor interface
17 Frame memory
18 The memory for control soft
19 Program memory
20 Data memory
21 Bus
23 Console
24 TV monitor

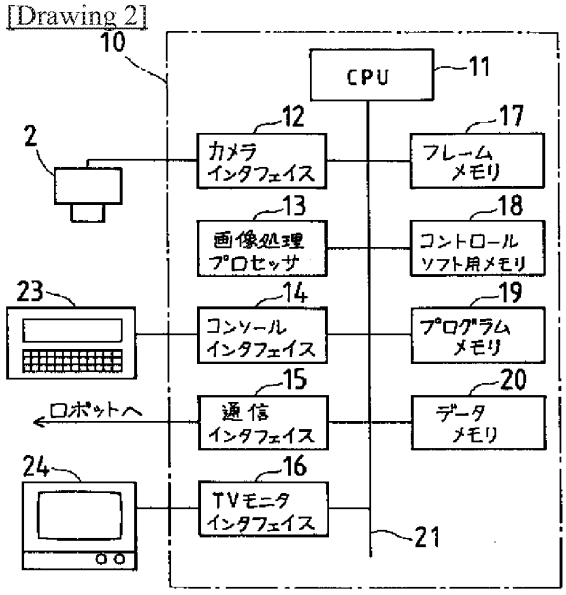
Publication No. 07-311610
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DRAWINGS

[Drawing 1]

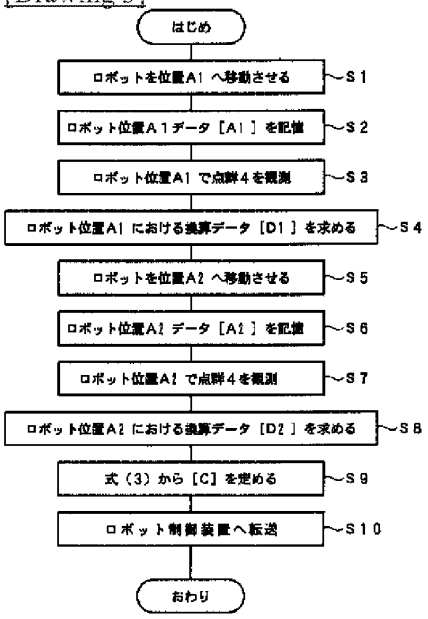


[Drawing 2]



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[Drawing 3]



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Profile abrasion measurement method for vehicle tyre

Publication number: DE19515949
Publication date: 1996-11-14

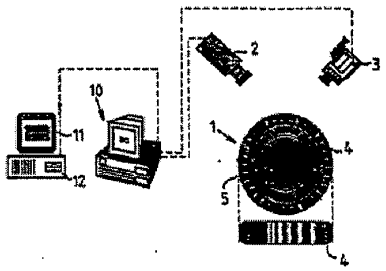
Inventor: SIEBENEICHER RENE DIPL ING (DE); DUWE HANS-PETER DR (DE)
Applicant: CONTINENTAL AG (DE)

Classification:
- international: ***B60C11/24; G01B11/22; G01B11/25;*** **B60C11/24; G01B11/22; G01B11/24**; (IPC1-7): G01B11/24; G01B9/023
- European: B60C11/24; G01B11/22; G01B11/25F4
Application number: DE19951015949 19950502
Priority number(s): DE19951015949 19950502

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Abstract of **DE19515949**

The abrasion measurement includes subdividing the profile surface of the tyre over its extent in several measuring sections, and performing a topographic measurement by recording at least three phase-shifted strip projections for the production of an interference pattern. A topographic measurement of each measuring section is performed in addition to the phase-shift method, according to the Gray-code method. The ambiguity of the height values is eliminated by comparison of the height values from the phase-shift method, and the height associations from the Gray-code method. The height values are compared with a reference contour, and calibrated absolute height values of the profile surface are determined through subtraction and stored. The tyre is rotated over several measuring sections, over which measurements are repeated until the tyre is measured over his full extent.



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(19) BUNDESREPUBLIK DEUTSCHLAND

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(12) **Offenlegungsschrift**

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(71) Anmelder:
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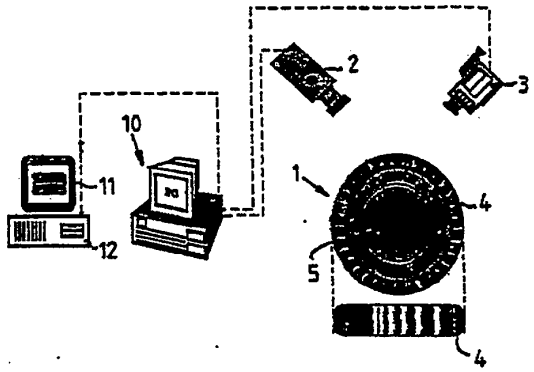
(72) Erfinder:
Siebeneicher, René, Dipl.-Ing., 31535 Neustadt, DE;
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(56) Entgegenhaltungen:
DE 38 29 925 C2
EP 05 47 364 A2

Prüfungsantrag gem. § 44 PatG ist gestellt

(54) **Verfahren und Vorrichtung zur flächenhaften Vermessung und Erfassung des Profilabriebs eines Fahrzeugreifens**

(57) Es wird ein Verfahren und eine Vorrichtung zur flächenhaften Vermessung und Erfassung des Profilabriebs auf der Lauffläche eines Fahrzeugreifens vorgeschlagen, bei dem die Profiloberfläche zunächst über ihren Umfang in mehrere Meßabschnitte unterteilt wird und eine topometrische Vermessung durch eine Kombination des Phasenshift- und des Cray-Code-Verfahrens erfolgt. Durch Vergleich der aus beiden Verfahren gewonnenen Meßwerte wird die Mehrdeutigkeit der Höhenwerte eliminiert und nach Vergleich mit einer Referenzkontur werden dann absolute Höhenwerte des Reifenprofils erhalten, die in unterschiedlichen Grautönungen oder in Falschfarbenzuordnung abgebildet werden können.



DE 195 15 949 A 1

Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

Beschreibung

Die Erfindung betrifft ein Verfahren zur flächenhaften Vermessung und Erfassung des Profilabriebs auf der Lauffläche eines Fahrzeugreifens sowie eine Vorrichtung zur Durchführung des Verfahrens.

Die von einem fahrenden Fahrzeug verursachte Geräuschentwicklung wird, insbesondere bei höheren Geschwindigkeiten, auch von dem Abrollgeräusch der Reifen mitbestimmt. Auf die Entstehung des Abrollgeräuschs hat die Profilform eine nicht geringe Bedeutung.

Aber auch während des Betriebes hervorgerufene ungleichmäßige Abnutzungen des Reifenprofils führen dazu, daß sich mit steigender Laufleistung das Abrollgeräusch gegenüber einem Neureifen erhöht. Dies führt nicht nur zu einer Belästigung der Umwelt, sondern infolge der bei der Fahrzeugentwicklung gezielt betriebenen Reduktion der Fahrtwindgeräusche, werden für die Fahrzeuginsassen Abrollgeräusche der Reifen hörbar, was zu einer deutlichen Komforteinbuße führt. Darüberhinaus werden durch Erscheinungen des unregelmäßigen Abriebs natürlich auch die Fahreigenschaften negativ beeinflußt.

Weiterhin wird durch das Auftreten unregelmäßigen Abriebs die mögliche Laufleistung eines Reifens durch das partielle Erreichen der gesetzlich vorgeschriebenen Mindestprofiltiefe reduziert. Dies steht jedoch sowohl zur angestrebten Kundenzufriedenheit auch als zur gebotenen Ressourcenschonung im Widerspruch.

Für die Weiter- bzw. Neuentwicklung von Fahrzeugreifen ist es daher wichtig, den Profilabrieb auf der Lauffläche eines im Gebrauch gewesenen Fahrzeugreifens zu kennen, um hieraus Schlußfolgerungen für gezielte konstruktive Veränderungen zu finden.

Die EP-A-0 547 364 offenbart ein Verfahren und eine Vorrichtung zum Messen unregelmäßiger Profilabnutzung. Ein aus Reifen und Felge bestehendes Rad ist auf einer Achse drehbar angeordnet. Parallel zu der Drehachse des Rades ist gegenüber der Lauffläche ein Lasersensor angeordnet, der in einer parallel zur Drehachse verlaufenden Richtung verschiebbar ist und senkrecht zur Drehachse einen Laserstrahl auf die Reifenlauffläche wirft und das von der Reifenlauffläche reflektierte Licht wieder empfängt. Aus dem reflektierten Licht wird in einer mit dem Lasersensor in Wirkverbindung stehenden Rechner-/Auswerteeinheit der Abstand zwischen dem Lasersensor und der Oberfläche des Reifens, an der das Licht reflektiert wird, ermittelt. Aus den bekannten Koordinaten des Lasersensors und dem Abstand des Sensors zum Reflexpunkt am Reifen (Meßpunkt) kann die Lage des Meßpunktes im Raum ermittelt werden. Zur Ermittlung der Reifenkontur wird der Sensor vor einer Profilrippe des Reifens ausgerichtet, das Rad mit einer definierten Geschwindigkeit gedreht und der Laserstrahl des Lasersensors getaktet. Auf diese Art werden nach einer vollen Umdrehung des Rades eine Vielzahl von auf einer Linie des Umfangs liegenden Meßpunkte erfaßt. Nach einem Umlauf wird der Sensor parallel zur Drehachse des Rades verschoben und entlang einer neuen Umfangslinie eine Vielzahl von Meßpunkten ermittelt. In der Auswerteeinheit werden die Meßpunkte zu einem Abbild der Reifenlauffläche zusammengesetzt, so daß unterschiedliche Abnutzungen des Reifens auf einem Bildschirm sichtbar gemacht werden können.

Außerdem ist es bekannt, unregelmäßige Abriebeffekte durch Fotografieren des Versuchsreifens bildhaft darzustellen, um damit einen visuellen Eindruck zu erzeugen. Weitere Möglichkeiten zur Erfassung der Ausprägung und Ausdehnung von Abriebphänomenen bestehen im Betrachten und Ertasten derselben.

Hiervon ausgehend soll ein neues Verfahren zur flächenhaften Vermessung geschaffen werden, mit dem unregelmäßig abgeriebenes Reifenprofil vermessen und erfaßt werden kann. Außerdem soll eine Vorrichtung zur Ausführung des neuen Verfahrens zur Verfügung gestellt werden.

Hinsichtlich des Verfahrens erfolgt die Lösung der Aufgabe durch folgende Schritte:

- die Profiloberfläche des Reifens wird über ihren Umfang in mehrere Meßabschnitte unterteilt,
- für jeden Meßabschnitt erfolgt mittels strukturierten Lichts eine topometrische Vermessung nach dem Phasenshift-Verfahren, wobei zur Erzeugung des Interferenzmusters mindestens drei phasenverschobene Streifenprojektionen aufgezeichnet werden,
- zusätzlich zum Phasenshift-Verfahren erfolgt eine topometrische Vermessung jedes Meßabschnitts nach dem Gray-Code-Verfahren,
- durch Vergleich der aus dem Phasenshift-Verfahren erhaltenen Höhenwerte und der aus dem Gray-Code-Verfahren erhaltenen eindeutigen Höhenzuordnungen wird die Mehrdeutigkeit der Höhenwerte eliminiert,
- die so erhaltenen eindeutigen Höhenwerte werden mit einer Referenzkontur verglichen und durch Subtraktion werden kalibrierte, absolute Höhenwerte der Profiloberfläche ermittelt,
- die kalibrierten absoluten Höhenwerte werden gespeichert, der Reifen um einen Meßabschnitt weitergedreht und die einzelnen Schritte so oft wiederholt, bis der Reifen über seinen vollen Umfang vermessen wurde.

Mit dem erfindungsgemäßen Verfahren kann in vorteilhafter Weise eine flächenhafte 3D-Vermessung in sehr kurzer Aufnahmezeit durch Kombination von Phasenshift-Verfahren mit Gray-Code-Verfahren erfolgen. Zur Bildaufnahme kann eine Videokamera mit CCD-Chip verwendet werden. Die erreichbare Flächenauflösung erfolgt aus der Pixelauflösung der Kamera und der Digitalisierung des Bildverarbeitungssystems. Zur Vermessung einer kompletten Lauffläche werden, abhängig von der Reifengröße, zwischen 10 und 20 Einzelbilder bei äquidistanten Drehwinkeln aufgenommen. Mit einer kalibrierten Aufnahmegeometrie lassen sich die kartesischen Koordinaten dieser Einzelmessungen in ein lokales, polares Koordinatensystem umrechnen.

Die Referenzkontur wird vorteilhaft durch azimutale Mittelung der zuvor ermittelten kalibrierten, absoluten Höhenwerte entlang einzelner Meßspuren analog der Gleichung:

$$r_z = 1/2\pi \int_{\omega=0}^{2\pi} r_z(\omega)\, d\omega$$

ermittelt. Wenn die Kontur des zu vermessenden Reifens infolge der aufgetretenen Abriebeffekte nicht mehr mit der Ausgangskontur vergleichbar ist, kann die Referenzkontur durch interaktive Bestimmung ausgewählter Konturpunkte und anhand dieser Konturpunkte

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durchgeführter geeigneter mathematischer Interpolationsverfahren, wie beispielsweise die Spline-Interpolation, ermittelt werden. Damit ist es auch möglich, beispielsweise Schulterschrägabnutzungen oder eine Freilaufrille zu berücksichtigen. Bei Berücksichtigung der hier beim Ergebnis verursachten gleichzeitigen Darstellung von Abrieb- und Konturveränderungen ist dies Verfahren auch unter Zuhilfenahme eines Neureifens anwendbar. Um den Anteil der Konturveränderungen möglichst gering zu halten, ist es vorteilhaft, wenn der Neureifen dementsprechend zuvor einem Wachstumslauf unterzogen wird.

Bei asymmetrischem Verschleiß der Reifenkontur ist es vorteilhaft, die Referenzkontur nur über einer Profilhälfte zu ermitteln und die erhaltene Referenzkonturhälfte an der Profilmittelachse, dem Zenit, zu spiegeln. Sinnvollerweise wird die Referenzkontur an der Profilhälfte ermittelt, die die geringeren Abriebserscheinungen aufweist, da die Referenzkontur ja die theoretisch erwartete gleichmäßige Abnutzung des Reifenprofils unter Berücksichtigung der Laufleistung widerspiegelt.

Zur Eliminierung von Einflüssen der sogenannten Tire Uniformity, das heißt also Schwankungen der Reifengleichförmigkeit, wird über den Umfang des Reifens jeweils der Radius des Zenits am Abriebreifen bestimmt, und an den daraus erhältlichen Kurvenverlauf der kalibrierten absoluten Höhenwerte die ermittelte Referenzkontur angehängt. Durch die Bestimmung der Radien des Zenits erhält man den Kurvenverlauf der absoluten Höhenwerte des Zenits über der Drehachse. Die Auflösung wird vorteilhafterweise 400 gon betragen. Wird nun die ermittelte Referenzkontur an diese Kurve angehängt und winkelrichtig von den Original-Meßdaten abgezogen erhält man als Differenz die Darstellung der ungleichmäßig abgeriebenen Profilbereiche.

Die Radiusbestimmung des Zenits erfolgt vorteilhafterweise über ein im Zenit auf den Abriebreifen aufgelegtes flexibles Band. Zur Berechnung einer Referenzkontur können auch die Höhenwerte mehrerer über den Reifen gelegter Bänder ermittelt werden.

Damit der ungleichmäßige Profilabrieb visuell erkennbar ist, werden den kalibrierten absoluten Höhenwerten von einem Bildverarbeitungssystem entsprechende unterschiedliche Grauwerte zugewiesen und auf einem Bildschirm dargestellt, wodurch sich dann ein Abbild des unterschiedlichen Profilabriebes einstellt.

Wenn den unterschiedlichen Grauwerten unterschiedliche Falschfarben zugewiesen werden, ist die farbliche Darstellung des Profilabriebes kontrastreicher und kann vom Betrachter schneller erfaßt werden, ohne daß er exakte Kenntnis über definierte Höhenwerte benötigt.

Eine Vorrichtung zur Durchführung des Verfahrens ist gekennzeichnet durch eine antreibbare Drehvorrichtung für einen Reifen, einen oberhalb des Reifens in einem Winkel zur Lotrechten angeordneten programmierbaren LCD-Streifenprojektor zur Erzeugung von Linienmustern auf der Profiloberfläche, eine oberhalb des Reifens gegenüber dem Streifenprojektor und in einem Winkel zur Lotrechten angeordneten Kamera, zur Erfassung der Linienverläufe auf der Profiloberfläche, einen mit dem Streifenprojektor und der Kamera verbundenen Rechner zur Bildverarbeitung mit einer Einrichtung zur Erfassung, Auswertung und Darstellung der Meßdaten, einen mit dem Rechner verbundenen Monitor, und einem mit dem Rechner verbundenen Drucker zur Ausgabe der Meßdaten.

Der Streifenprojektor und die Kamera sind vorzugsweise in zwei zur Drehachse des Reifens senkrechten Richtungen bewegbar und um eine zur Drehachse des Reifens parallele Achse schwenkbar angeordnet.

Zur Kalibrierung des Meßsystems ist ein linear verschiebbarer Tisch mit einer der Größe des ausgewählten Meßabschnittes am Reifen entsprechenden planen Oberfläche auf die Drehachse des Reifens aufsetzbar, über die Höhe des Profils des Reifens verschiebbar und in mehrere Winkelpositionen drehbar.

Anhand einer Zeichnung soll die Erfindung nachfolgend näher erläutert werden. Es zeigt:

Fig. 1 den Aufbau des Meßsystems,

Fig. 2 die Anordnung der Meßapparatur,

Fig. 3 die Darstellung des Meßausschnittes des Reifens bei der Streifenprojektion,

Fig. 4 die Darstellung des unregelmäßigen Abriebbildes eines Reifens in verschiedenen Grauwerten,

Fig. 5 die Darstellung einzelner Schnittlinien in dem Reifen nach Fig. 4,

Fig. 6 das Abriebniveau unter der Referenzkontur gemäß Schnittlinie 1 nach Fig. 5,

Fig. 7 das Abriebniveau unter der Referenzkontur gemäß Schnittlinie 2 nach Fig. 5,

Fig. 8 das Abriebniveau unter der Referenzkontur gemäß Schnittlinie 3 nach Fig. 5,

Fig. 9 eine Vorrichtung zur Kalibrierung des Meßsystems.

Das aus Reifen 4 und Felge 5 bestehende Rad 1 ist drehbar in äquidistanten Schritten von beispielsweise 400 gon drehbar in einer nicht näher dargestellt Vorrichtung gelagert. Oberhalb des Rades 1 sind an einer Schiene 6 ein LCD-Streifenprojektor 2 und eine Videokamera 3 hängend angeordnet. Der Streifenprojektor 2 und die Kamera 3 sind in vertikaler Richtung verschiebbar an Aufhängungen 7, 8 befestigt. Die Aufhängungen 7, 8 sind wiederum auf der Schiene 6 in horizontaler Richtung linear verschiebbar. Über eine entsprechende Gelenkausbildung sind der Projektor 2 und die Kamera 3 um ihre Aufhängungsachse schwenkbar an der Aufhängung 7, 8 befestigt. Die einzelnen Freiheitsgrade des Meßsystemes sind in Fig. 2 durch Doppelpfeile dargestellt.

Sowohl der LCD-Streifenprojektor 2 als auch die Videokamera 3 sind über einen Computer 10 untereinander und mit einem Kontrollmonitor 11 und einem Videoprinter 12 verbunden. Im Computer 10 ist eine geeignete Bildverarbeitungssoftware, beispielsweise "Holon-View" vorgesehen.

Der programmierbare LCD-Streifenprojektor 2 beleuchtet die Profiloberfläche streifenförmig mit strukturiertem Licht (Streifenprojektion). Aufgrund der nicht glatten Oberfläche des Reifens ergibt sich ein nicht geradliniger Linienmusterverlauf. Über die Videokamera 3 wird dieser Linienmusterverlauf aufgezeichnet (vergl. Fig. 3). Durch Überlagerung von mindestens drei phasenverschobenen Streifenprojektionen läßt sich aus dem Interferenzmuster (Moiré-Linien), das bekanntlich aus der bei der Überlagerung resultierenden Auslöschung und Verstärkung der überlagerten Linien entsteht, jedem Punkt auf der Profiloberfläche ein Höhenwert zuordnen. Voraussetzung hierzu ist natürlich, was dem Fachmann geläufig ist, daß das Meßsystem in seiner Aufnahmegeometrie zuvor kalibriert worden ist.

Bei gutem Kontrast der projizierten Linien ist mit dem Phasenshift-Verfahren eine Genauigkeit der Phasenbestimmung von etwa 5% erreichbar. Die mit dem Phasenshift-Verfahren ermittelten Höhenwerte besit-

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zen aber noch keine eindeutige Zuordnung, weil der Phasenwinkel nur Modulo 2π eindeutig berechnet werden kann. Das heißt, die tatsächliche Profilhöhe kann aus den Höhenlinien, die durch das Phasenbild gegeben sind, nicht eindeutig angegeben werden.

Hierzu werden im Anschluß an das Phasenshift-Verfahren vom Rechner 10 gesteuert über den Streifenprojektor 2 aufeinanderfolgende Linienmuster nach dem Gray-Code-Verfahren projiziert. Bekanntlich werden bei dem Gray-Code-Verfahren hintereinander Hell-/Dunkelbilder projiziert, wobei die Flächen der Hell- und Dunkelfelder jeweils bei dem nachfolgenden Bild halbiert wird. Die Sequenz der Projektion ist frei wählbar.

Die auf die Profiloberfläche projizierte Linienmustersequenz wird wiederum über die Kamera aufgezeichnet. An den Linienkanten, der Binarisierung des Linienmuster, kann im Rechner 10 eine Höhenbestimmung des vermessenen Profils erfolgen. Eine Höhenzuordnung der Profiloberfläche kann zwar nur grob erfolgen, da sie nur über die Linienkanten möglich ist, dafür ist die Höhenzuordnung aber eindeutig. Im Rechner 10 werden nun die darin gespeicherten aus dem Phasenshift-Verfahren gewonnenen Daten mit denen aus dem Gray-Code-Verfahren gewonnenen Daten verglichen, so daß die Mehrdeutigkeit der Ergebnisse aus den Phasenshift-Verfahren eliminiert werden kann. Es ist nun ein Satz relativer Höhenwerte vorhanden. Um aus den relativen Höhenwerten zu absoluten Höhenwerten zu gelangen werden diese Daten mit den Daten einer Referenzkontur verglichen.

Um eine Referenzkontur zu bestimmen kommen mehrere Verfahren in Betracht, die vom Zustand des Abriebreifens abhängen. Solange der zu vermessende Reifen (Abriebreifen) noch mit der Ausgangskontur vergleichbar ist, erfolgt die Bestimmung der Referenzkontur durch azimutale Mittelung der Höhenwerte auf der Profiloberfläche entlang der einzelnen Meßspuren analog der Gleichung:

$$r_z = 1/2\pi \int_{\omega=0}^{2\pi} r_z(\omega)\, d\omega$$

Sind die Abriebeffekte so stark, daß die Kontur des Reifens nicht mehr mit der Ausgangskontur vergleichbar ist (Freilaufrille, Schulterschrägabnutzung) kann die Bestimmung der Referenzkontur durch Spline-Interpolation interaktiv bestimmter Konturpunkte, die für sich mit der Ausgangskontur des Reifens vergleichbar sind, bestimmt werden.

Die ermittelte Referenzkontur wird ebenfalls im Rechner 10 gespeichert. Die aus dem kombinierten Phasenshift-Verfahren und Gray-Code-Verfahren erhaltenen relativen Höhendaten werden von den absoluten Höhendaten der Referenzkontur subtrahiert, wodurch nun absolute Höhendaten der ausschnittsweise vermessenen Profiloberfläche resultieren. Diese absoluten Höhenwerte werden nun ebenfalls im Rechner 10 gespeichert, das Rad 1 um einen Meßabschnitt weitergedreht und die zuvor beschriebenen Projektionen und Berechnungen erneut durchgeführt. Dies wird so oft wiederholt, bis die Profilfläche vollständig vermessen wurde. Die Anzahl der Schritte hängt ab von der Größe des Meßfeldes.

Die ermittelten kalibrierten absoluten Höhenwerte werden nun durch die Bildverarbeitungssoftware im Rechner 10 unterschiedlichen Grauwerten zugeordnet, so daß auf dem Kontrollmonitor 11 eine Darstellung der Oberfläche des Reifens 4 in unterschiedlichen Tönungen möglich ist (vergl. Fig. 4), so daß der Betrachter aufgrund der unterschiedlichen Tönungen erkennt, wie weit ein Bereich gegenüber der Referenzkontur stärker oder geringer abgenutzt ist. Bei der in Fig. 4 gezeigten Darstellung sind in weiß die Bereiche erkennbar, die gegenüber der Referenzkontur nicht abweichen und in schwarz, die, die zwischen 3,4 und 3,8 mm stärker abgenutzt sind. Um die Darstellung weiter zu verdeutlichen, werden die Grauwerte vorzugsweise unterschiedlichen Falschfarben zugeordnet, wodurch der Kontrast erhöht wird. Die Zwischenbereiche, für die in der Darstellung hier kaum Unterschiede erkennbar sind, wurden dann in völlig anderen Farben erscheinen, so daß sie deutlich erkennbar wären. Fig. 6 bis 8 zeigen das Abriebniveau entlang den Schnittlinien 1, 2, 3 in Fig. 5, die aus den zuvor ermittelten Daten berechnet wurden.

Der LCD-Streifenprojektor 2 ist unter einem Winkel von ca. 30° zur Orientierung der Kamera montiert. Der optimale Winkel für die Aufnahme ist abhängig von der Meßaufgabe. Je größer der Winkel gewählt werden kann, desto besser ist natürlich die erreichbare Auflösung. Andererseits ist bei kleinerem Winkel aufgrund geringerer Abschattung das Profil besser aufnehmbar. Die Geometrie von Projektor 2, Kamera 3, Reifen 4 muß daher abhängig von der Meßaufgabe, dem Reifenprofil und der Reifengröße empirisch bestimmt werden. Aufgrund der Krümmung des Reifens 4, die eine perspektivische Entzerrung und Koordinatentransformation der Meßdaten erfordert ist für das Meßsystem eine auf die Nabe des Rades 1 aufsetzbare Kalibriervorrichtung 15 vorgesehen, die in vertikaler Richtung verschiebbar und in Drehrichtung des Rades 1 schwenkbar ist. Zum Kalibrieren wird die Vorrichtung 15 auf die Nabe aufgesetzt und eine ebene Platte 16 in vertikaler Richtung seitlich am Rad 5 so weit nach oben gefahren, daß sie mit der Profiloberfläche abschließt (obere Meßvolumenbegrenzung). Anschließend wird sie in die Mittellage und die untere Meßvolumenbegrenzung, zur Berücksichtigung der Reifenkrümmung entsprechend des Meßbildausschnittes verfahren und zur Kalibrierung der Drehachse um die Drehachse des Rades 1 in verschiedene Winkelpositionen geschwenkt. Dabei werden jeweils nach den zuvor beschriebenen Verfahren Aufnahmen gemacht. Mit Hilfe der in den verschiedenen Stellungen gemachten Aufnahmen lassen sich die kartesischen Koordinaten der Originalmessung in Polarkoordinaten überführen. Somit wird dann eine eindeutige Zuordnung der Meßdaten zu ihrer Lage am Reifen 4 (bezogen auf den Radius und den Winkel) ermöglicht.

Die Vorrichtung 15 zum Kalibrieren ist aus Fig. 9 ersichtlich und besteht aus den beiden in vertikaler Richtung relativ zueinander verschiebbaren Schlitten 18a, 18b. Am Schlitten 18a ist die Nabenaufnahme 20 und am Schlitten 18b der Adapter 19 befestigt, beispielsweise verschraubt. Am Adapter 19 ist ein Winkel 17 befestigt, auf dem wiederum die Platte 16, die Kalibrierplatte, angeordnet ist.

Patentansprüche

1. Verfahren zur flächenhaften Vermessung und Erfassung des Profilabriebs auf der Lauffläche eines Fahrzeugreifens, gekennzeichnet durch folgende Schritte:

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— die Profiloberfläche des Reifens wird über ihren Umfang in mehrere Meßabschnitte unterteilt,
— für jeden Meßabschnitt erfolgt mittels strukturierten Lichts eine topometrische Vermessung nach dem Phasenshift-Verfahren, wobei zur Erzeugung des Interferenzmusters mindestens drei phasenverschobene Streifenprojektionen aufgezeichnet werden,
— zusätzlich zum Phasenshift-Verfahren erfolgt eine topometrische Vermessung jedes Meßabschnitts nach dem Gray-Code-Verfahren,
— durch Vergleich der aus dem Phasenshift-Verfahren erhaltenen Höhenwerte und der aus dem Gray-Code-Verfahren erhaltenen eindeutigen Höhenzuordnungen wird die Mehrdeutigkeit der Höhenwerte eliminiert,
— die so erhaltenen eindeutigen Höhenwerte werden mit einer Referenzkontur verglichen und durch Subtraktion werden kalibrierte absolute Höhenwerte der Profiloberfläche ermittelt,
— die kalibrierten absoluten Höhenwerte werden gespeichert, der Reifen um einen Meßabschnitt weitergedreht und die einzelnen Schritte so oft wiederholt, bis der Reifen über seinen vollen Umfang vermessen wurde.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Referenzkontur durch azimutale Mittelung der zuvor ermittelten kalibrierten, absoluten Höhenwerte entlang einzelner Meßspuren (r_z) analog der Gleichung:

$$r_z = 1/2\pi \int_{\omega=0}^{2\pi} r_z(\omega)\, d\omega$$

ermittelt wird.

3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß ausgewählte Konturpunkte interaktiv bestimmt und anhand dieser Konturpunkte mit Hilfe geeigneter mathematischer Interpolationsverfahren (beispielsweise Spline-Interpolation) die Referenzkontur ermittelt wird.

4. Verfahren nach Anspruch 2 oder 3, dadurch gekennzeichnet, daß zunächst nur über einer Profilhälfte die Referenzkontur ermittelt und die erhaltene Referenzkonturhälfte an der Profilmittelachse gespiegelt wird.

5. Verfahren nach einem der Ansprüche 2 bis 4, dadurch gekennzeichnet, daß zur Eliminierung von Einflüssen der Schwankungen der Reifengleichförmigkeit über den Umfang des Reifens jeweils der Radius des Zenits bestimmt wird, und an den daraus erhältlichen Kurvenverlauf der kalibrierten absoluten Höhenwerte die ermittelte Referenzkontur angehängt wird.

6. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß den kalibrierten absoluten Höhenwerten von einem Bildverarbeitungssystem entsprechende unterschiedliche Grauwerte zugewiesen und auf einem Bildschirm dargestellt werden, wodurch sich ein Abbild des unterschiedlichen Profilabriebs ergibt.

7. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß den unterschiedlichen Grauwerten unterschiedliche Falschfarben zugewiesen werden, zur farblichen Darstellung des Profilabriebs auf dem Bildschirm.

8. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß die Radiusbestimmung über ein im Zenit aufgelegtes flexibles Band erfolgt.

9. Verfahren nach Anspruch 8, dadurch gekennzeichnet, daß zur Berechnung einer Referenzkontur die Höhenwerte mehrerer über den Reifen gelegter Bänder ermittelt werden.

10. Vorrichtung zur Durchführung des Verfahrens nach einem der Ansprüche 1 bis 9, gekennzeichnet durch
— eine antreibbare Drehvorrichtung für einen Reifen,
— einen oberhalb des Reifens in einem Winkel zur Lotrechten angeordneten programmierbaren LCD-Streifenprojektor, zur Erzeugung von Linienmustern auf der Profiloberfläche,
— eine oberhalb des Reifens gegenüber dem Streifenprojektor und in einem Winkel zur Lotrechten angeordneten Kamera, zur Erfassung der Linienverläufe auf der Profiloberfläche,
— einen mit dem Streifenprojektor und der Kamera verbundenen Rechner zur Bildverarbeitung mit einer Einrichtung zur Erfassung, Auswertung und Darstellung der Meßdaten,
— einen mit dem Rechner verbundenen Monitor,
— einen mit dem Rechner verbundenen Drukker zur Ausgabe der Meßdaten.

11. Vorrichtung nach Anspruch 10, dadurch gekennzeichnet, daß der Drucker ein Farbdrucker ist.

12. Vorrichtung nach Anspruch 10, dadurch gekennzeichnet, daß der Streifenprojektor und die Kamera in zwei zur Drehachse des Reifens senkrechten Richtungen bewegbar und um eine zur Drehachse des Reifens parallele Achse schwenkbar angeordnet sind.

13. Vorrichtung nach Anspruch 10, dadurch gekennzeichnet, daß zur Kalibrierung des Meßsystems ein linear verschiebbarer Tisch mit einer der Größe des ausgewählten Meßabschnittes am Reifen entsprechenden planen Oberfläche auf die Drehachse des Reifens aufsetzbar, über die Höhe des Profils des Reifens verschiebbar und in mehrere Winkelpositionen drehbar ist.

Hierzu 6 Seite(n) Zeichnungen

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FIG. 1

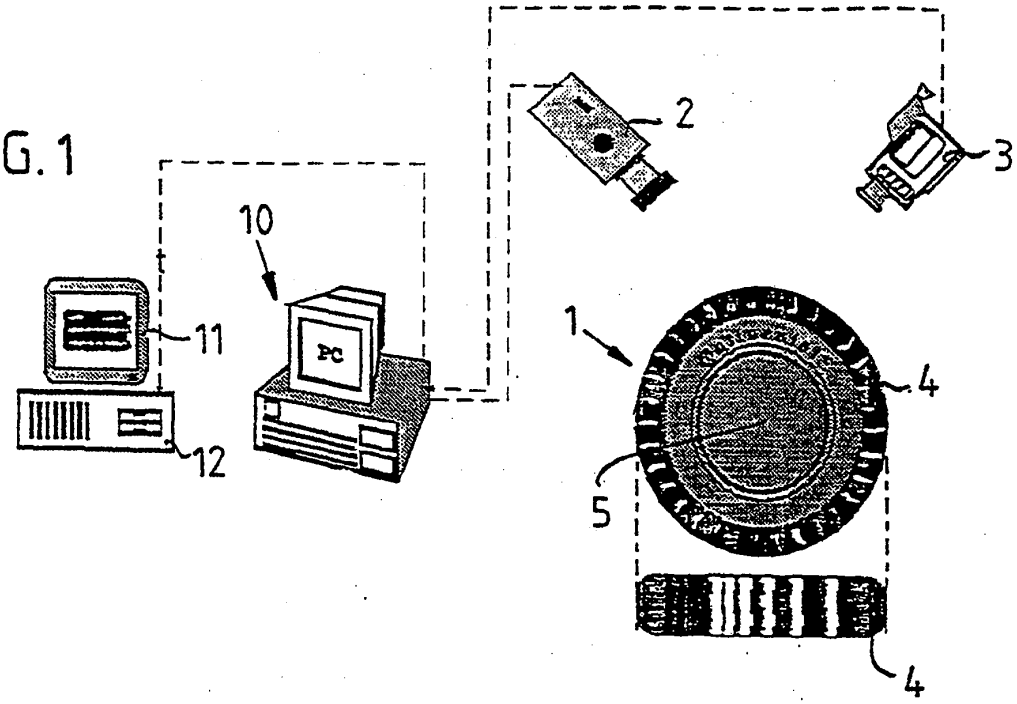
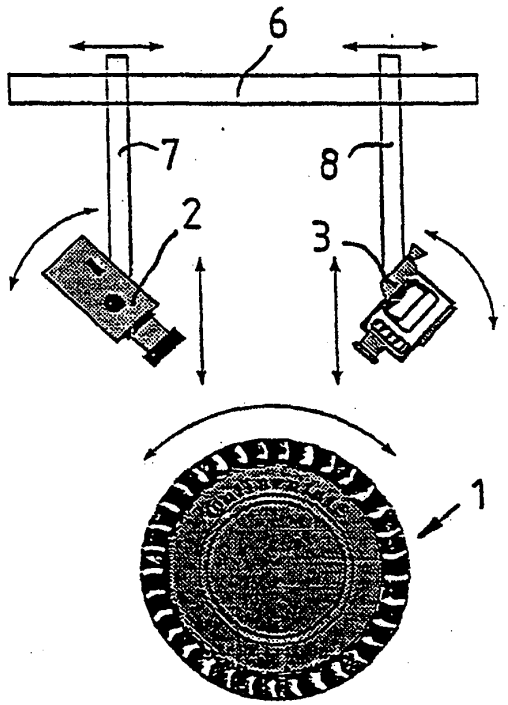


FIG. 2



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Nummer: DE 195 15 949 A1
Int. Cl.[6]: G 01 B 11/24
Offenlegungstag: 14. November 1996

FIG. 3



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Int. Cl.[6]: G 01 B 11/24
Offenlegungstag: 14. November 1996

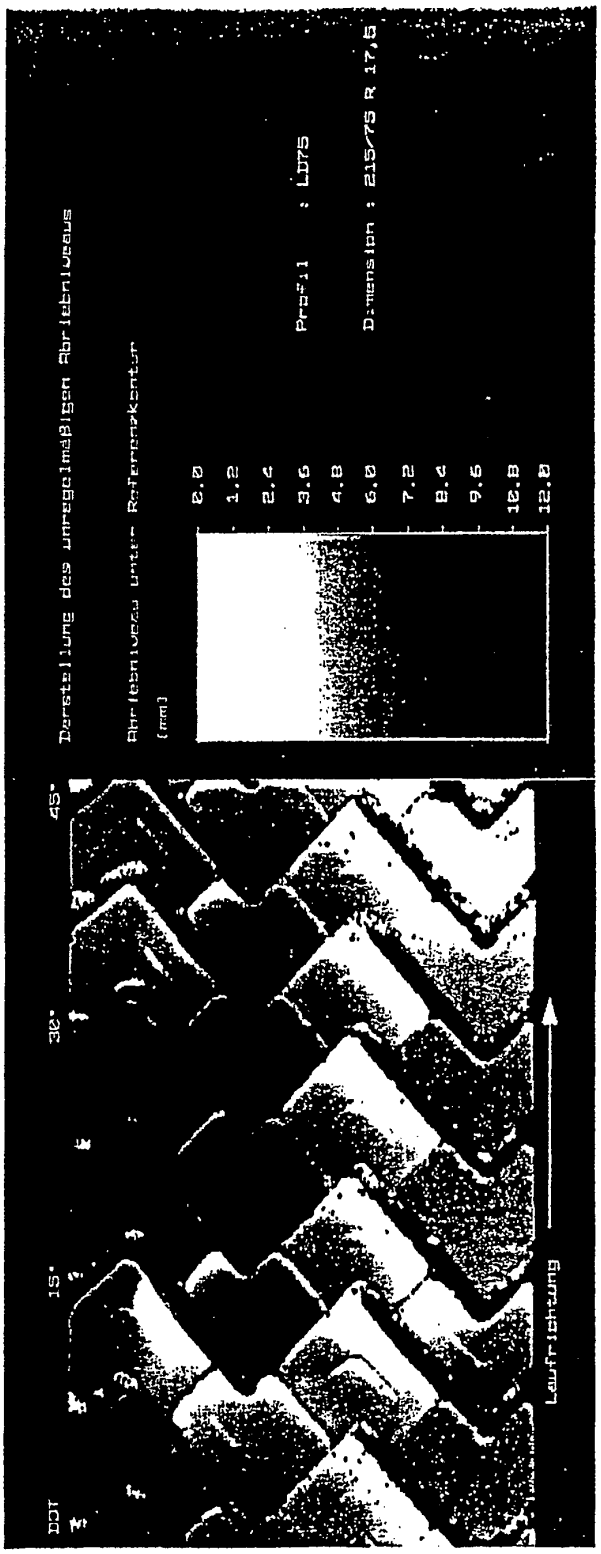


FIG. 4

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Nummer: DE 195 15 949 A1
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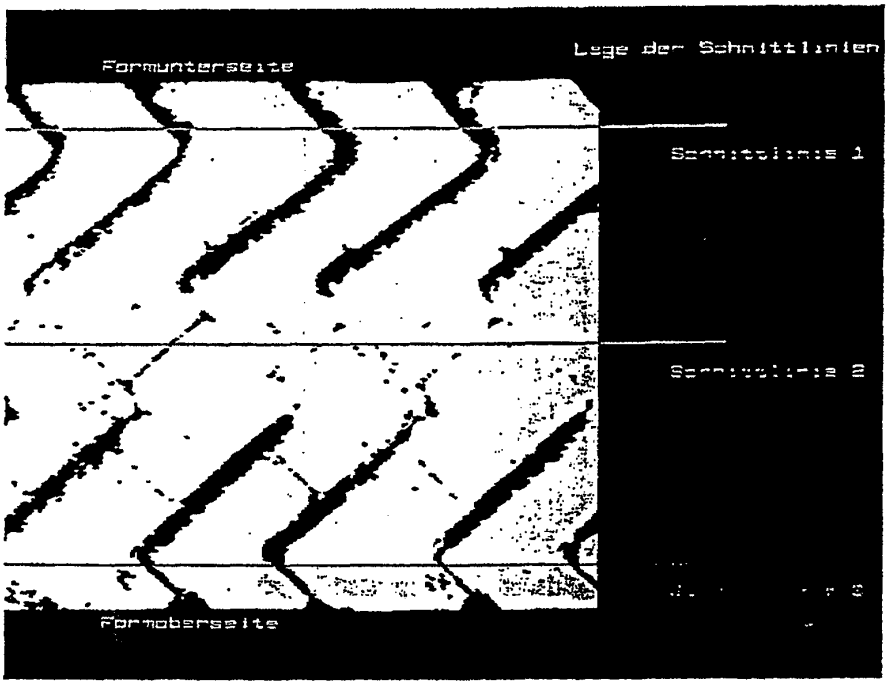
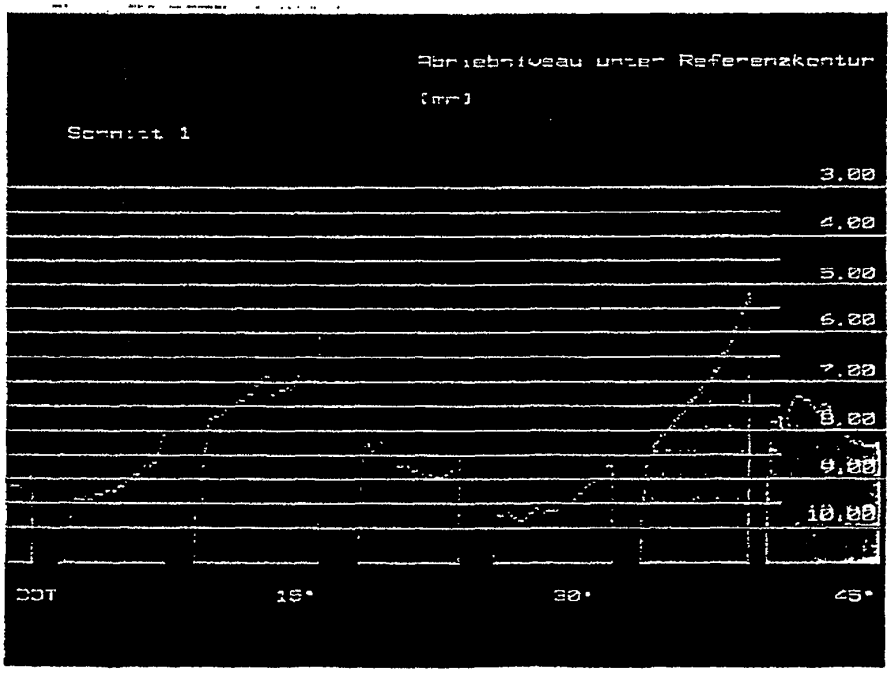


FIG. 5

FIG. 6



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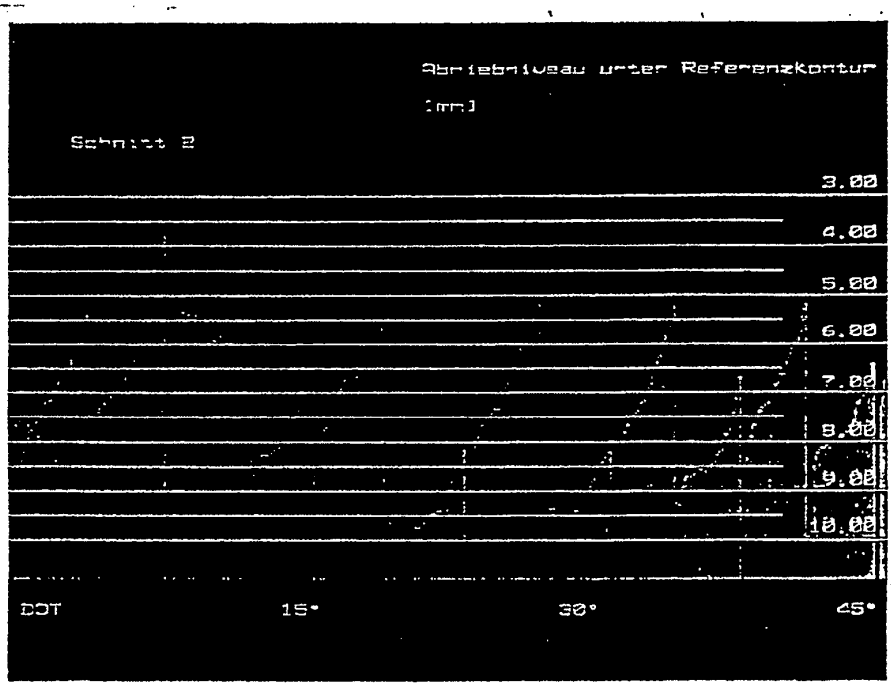
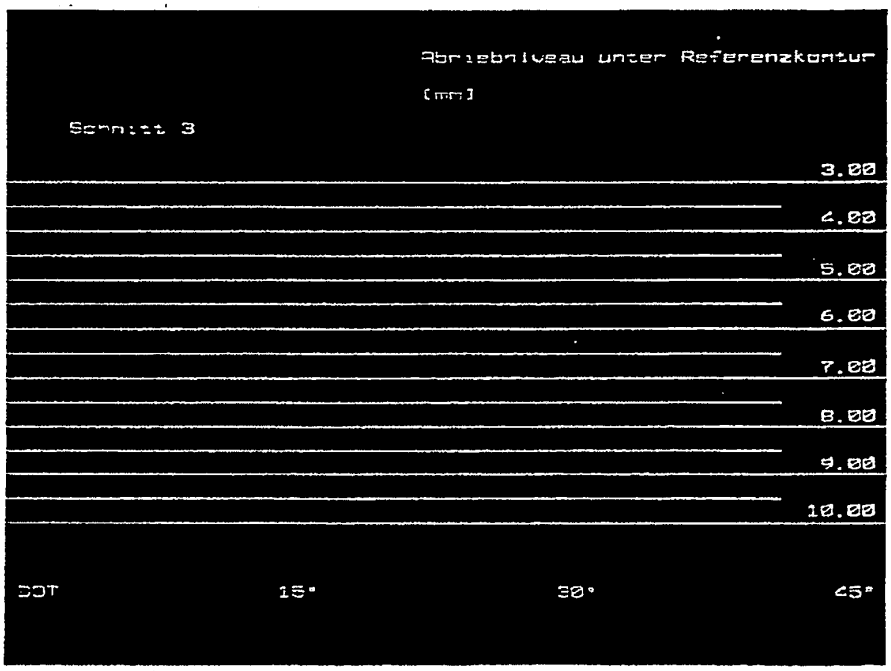


FIG. 7

FIG. 8



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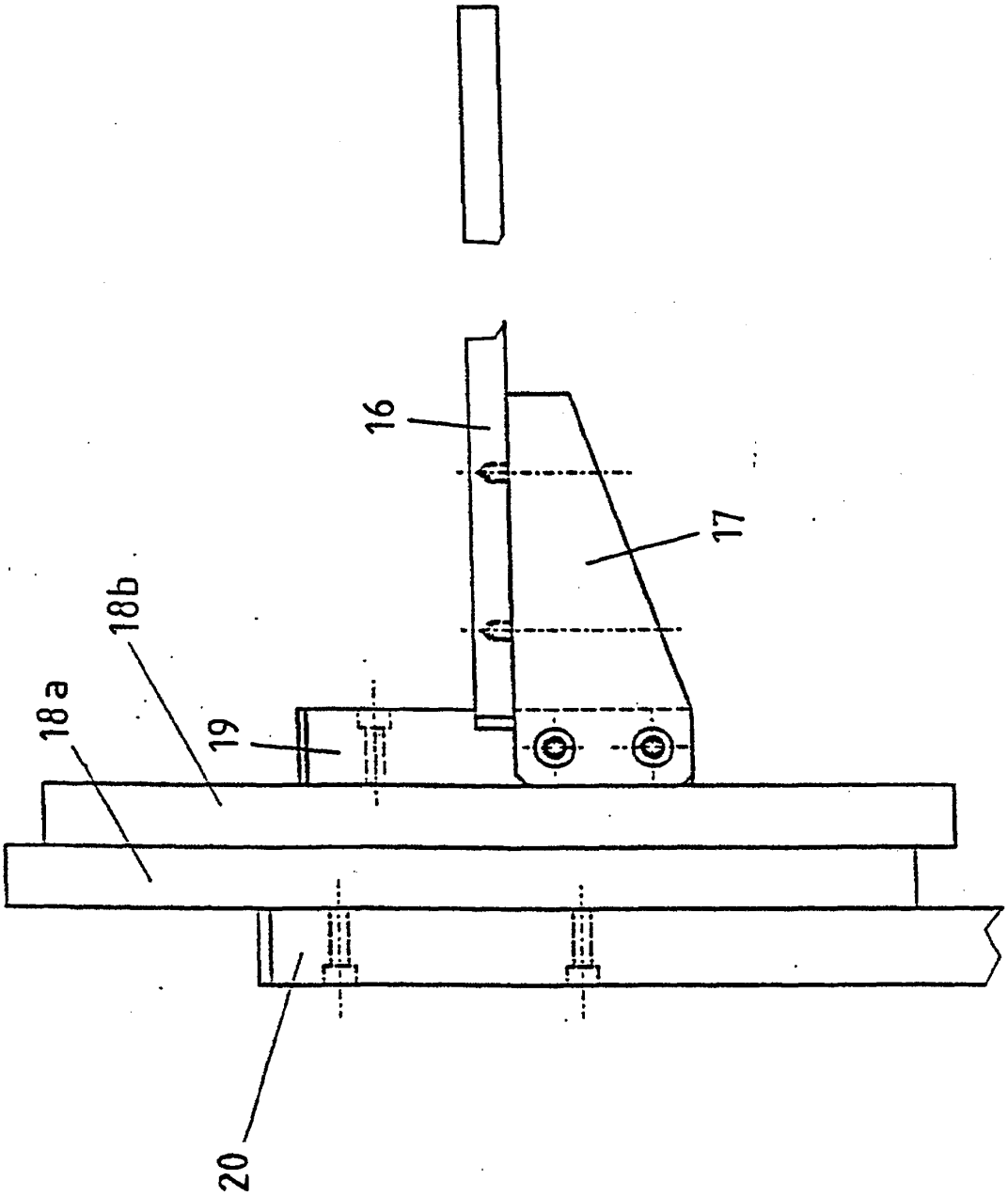


FIG. 9

602 046/18

EP0763406

Publication Title:

Method of determination of the spatial position of an object

Abstract:

1322 Abstract of EP0763406

The method involves using several spatially separated electronic cameras with image processing function which is calibrated by imaging a calibration board with a point pattern associated with each camera, and using the resulting images to determine the position of each camera w.r.t. the calibration board. The position of each camera is stored, the calibration board is independently measured and the resulting measurements are also stored. An object is entered into the space between the cameras and a determined point on the object is imaged on each camera. The relative position of that point in the image is processed together with the constructive, predetermined position of the characteristic point on the object and the stored data. All processed values describe the position of the object in the six spatial degrees of freedom.

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(54) Verfahren zum Bestimmen der Lage eines Körpers im Raum

(57) Bei einem Verfahren zum Bestimmen der Lage eines Körpers im Raum, um Manipulationen an diesem durchzuführen, wird zur Lösung der Aufgabe, ein zu manipulierendes Element in Bezug zum Manipulator direkt zu bringen, vorgeschlagen, daß jede von mehreren räumlich getrennten elektronischen Kameras mit Bildverarbeitung bei deren Einmessen eine ihr zugeordnete Kalibriertafel mit Punktmuster aufnimmt, deren Bilder sowie das Punktmuster zur Bestimmung der Lage der einzelnen Kamera im Raum verarbeitet und deren Lage speichert, daß eine Vermessung der Kalibriertafeln zueinander getrennt hiervon erfolgt, daß diese Werte ebenfalls gespeichert werden, daß anschließend der Körper in den Raum zwischen den elektronischen Kameras verbracht wird, daß je ein charakteristischer Punkt auf dem Körper in je einer diesem zugeordneten elektronischen Kamera abgebildet wird, daß dessen Lage im Bild mit seiner konstruktiven, vorgegebenen Position des charakteristischen Punktes auf dem Körper zusammen mit den gespeicherten Werten verarbeitet wird und daß alle derart verarbeiteten Werte, die Lage des Körpers im Raum, in den sechs räumlichen Freiheitsgraden charakterisieren.

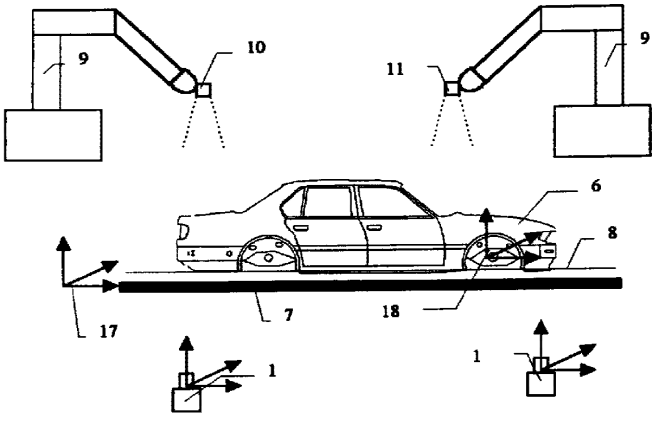


Fig. 2

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Beschreibung

Die Erfindung betrifft ein Verfahren zum Bestimmen der Lage eines Körpers im Raum, um Manipulationen an diesem durchzuführen.

Derartige Verfahren zur Bestimmung der Lage eines Körpers in einem Raum sind insbesondere bei der Herstellung von Kraftfahrzeugen erforderlich, wenn es bei der Serienherstellung und Serienmanipulation darum geht, Körper gleichen Typs mit Zusatzteilen wie Türen, Kotflügeln, Radaufhängungen oder Kofferraumdeckeln zu versehen. Auch ist es einsetzbar, um erforderliche Manipulationen beim Schweißen, Lackieren oder Abdichten von Nähten raschestmöglich durchzuführen.

Jedoch nicht nur auf dem Gebiet der Fahrzeugtechnik, sondern auf allen anderen Gebieten, bei welchen ein Bauteil aus mehreren Bauteilen zusammengesetzt werden soll, ist zur raschen Herstellung eines derartigen Elements, insbesondere im Hinblick auf die Genauigkeit und die Schnelligkeit eine Lagebestimmung unumgänglich.

Um derartige Vermessungen durchzuführen, fehlt es nicht an Versuchen, dies zu bewerkstelligen. So ist es beispielsweise bekannt geworden, Kanten einer Fahrzeugkarosserie mit Hilfe einer Laserabtastung festzustellen, diese Werte zu speichern und entsprechend diesen Werten nachfolgende Bauteile auszurichten, um dann anschließend daran, beispielsweise mit Hilfe von Robotern, Türen anzuschweißen oder auch das Befestigen von Kofferraumdeckeln oder Motorhauben zu bewerkstelligen.

Es ist jedoch bekannt, daß durch Laserstahl eine Gesundheitsschädigung nicht auszuschließen ist. Für die Verbindung eines Bauteils mit einem Grundkörper, beispielsweise einer Autotür mit einem Grundrahmen, ist es erforderlich, Lagetoleranzen auszugleichen, weil sonst ein Verscheißen nicht sicher durchgeführt werden kann, wenn nicht die Stellen für die Scharniere der Tür am Rahmen genau erreicht werden oder wenn zwischen diesen Stellen und den Türscharnieren zu Beginn des Schweißvorgangs ein zu großer Abstand besteht. Die Folge derartiger Mißeinstellungen sind dann zwangsläufig Ausschußherstellungen, die erst mühselig entweder nachgearbeitet oder direkt verschrottet werden müssen.

Als Hilfsmittel verwendet man deshalb auch mechanische Arretierungen, welche auf den Förderbändern die zusammenzubauenden Bauteile, d. h. den Grundkörper sicher führen, damit von dieser Seite aus bereits eine grobe Voreinstellung gegeben ist. Derartige Hilfseinrichtungen sind jedoch nicht nur einem Verschleiß und einer Verschmutzung ausgesetzt, sondern es tritt wie oben ausgeführt auch die Toleranz bei der Herstellung des Grundkörpers sehr stark in Erscheinung. Dies und die zunehmende Forderung nach flexibler Fertigung bei einem Produktmix führen dazu, daß solche Einrichtungen praktisch nicht mehr einsetzbar sind. Unter Produktmix versteht man im vorliegenden Fall eine nicht sortenreine Fertigung auf einer Fertigungslinie.

Ausgehend hiervon liegt der vorliegenden Erfindung die Aufgabe zugrunde, ein zu manipulierendes Element in Bezug zum Manipulator direkt zu bringen. Diese Aufgabe wird erfindungsgemäß dadurch gelöst, daß jede von mehreren räumlich getrennten elektronischen Kameras mit Bildverarbeitung bei deren Einmessen eine ihr zugeordnete Kalibriertafel mit Punktmuster aufnimmt, deren Bilder sowie das Punktmuster zur Bestimmung der Lage der einzelnen Kamera im Raum verarbeitet und deren Lage speichert, daß eine Vermessung der Kalibriertafeln zueinander getrennt hiervon erfolgt, daß diese Werte ebenfalls gespeichert werden, daß anschließend der Körper in den Raum zwischen den elektronischen Kameras verbracht wird, daß je ein charakteristischer Punkt auf dem Körper in je einer diesem zugeordneten elektronischen Kamera abgebildet wird, daß dessen Lage im Bild mit seiner konstruktiven, vorgegebenen Position des charakteristischen Punktes auf dem Körper zusammen mit den gespeicherten Werten verarbeitet wird und daß alle derart verarbeiteten Werte, die Lage des Körpers im Raum, in den sechs raumlichen Freiheitsgraden charakterisieren. Hierdurch wird erreicht, daß unabhängig von der Genauigkeit der Herstellung des Grundkörpers jeweils an der richtigen Stelle, bezogen auf den Manipulator, Elemente an der richtigen Stelle am Grundkörper angebracht werden können, da die Ausrichtung des Körpers nunmehr zwangsläufig durch eine Koordinatentransformation zwischen dem die räumliche Lage des Körpers darstellenden Koordinatensystem und dem Koordinatensystem des Roboters oder Manipulators, der zwangsläufig zu den Fahrzeugkoordinaten ausgerichtet sein muß, um ein sicheres und ausschußfreies Bearbeiten des Körpers beispielsweise des Grundgestells einer Karosserie zu bewirken. Auch ist es hierdurch möglich, Lackierungen oder Abdichtungen oder Ummantellungen zielgenau am zu fertigenden Bauteil anzubringen.

Darüberhinaus ist auch eine mechanische Bearbeitung eines so in den Raum verbrachten Körpers möglich, wenn zusätzlich erfindungsgemäß die Führung eines Gegenhalters das Bauteil bzw. die Karosse abstützt, so daß mittels spanabhebender Bearbeitung beispielsweise eine Bearbeitung durchgeführt werden kann.

Eine Ausgestaltung des erfinderischen Gegenstandes besteht darin, daß die Position eines Nullkörpers des selben Typs bestimmt wird und daß die Messung aller folgenden Körper auf diesen bezogen werden. Damit wird erreicht, daß eventuelle Fehler bei der Einmessung sowie der Vermessung zufolge ungenauer Herstellung der Grundkarosse beispielsweise minimiert werden, da diese Fehler sich beim Bezug der weiteren Karossen auf die Nullkarosse als Fehler höherer Ordnung wesentlich verringern.

Im Nachfolgenden wird an einem Ausführungsbeispiel die erfinderische Verfahrensweise näher erläutert.

Es zeigen in schematischer Darstellung:

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Figur 1 einen Einmeßvorgang für die Position einer Kamera bezüglich des Raums

Figur 2 eine Bestimmung der räumlichen Lage eines Körpers an welchem Manipulationen durchgeführt werden

Figur 3 Einfluß einer Positionierung eines Nullkörpers

In der Beschreibung werden in den einzelnen Figuren gleiche Bauteile mit denselben Bezugziffern bezeichnet.

Gemäß Figur 1 wird eine Kamera 1, bei der es sich um eine bekannte CCD-Kamera mit bekannter Bildverarbeitung handelt, optisch mit einer Kalibriertafel 2 in Verbindung gebracht. Auf der Kalibriertafel 2 sind Markierungen 3 angeordnet, deren gegenseitiger Abstand bekannt ist. Die Kamera 1 wird an den Rand des Raumes verbracht, beispielsweise bei einer Lackierkabine zum Lackieren von Fahrzeugkarossen hinter einer Wand der Lackierkabine, um die Kamera vor Beschädigung und Verschmutzen zu schützen, dergestalt, daß lediglich eine kleine Öffnung in der Wand verbleibt, durch welche die Kamera 1 eine optische Verbindung mit der ihr zugeordneten Kalibriertafel 2 aufnehmen kann.

Voraussetzung für eine richtige Einmessung ist lediglich, daß die Kamera 1 nicht senkrecht zur Kalibriertafel 2 steht.

Die nunmehr über die Kamera aufgenommenen Informationen dienen dazu, die räumliche Lage, bzw. das Koordinatensystem der Kamera 1, festzulegen. In den anderen Wänden 4 der Lackierkabine sind mindestens noch zwei weitere Kameras 1 in der selben Weise angeordnet und arbeiten ebenfalls mit weiteren Kalibriertafeln zusammen. Der Vorgang des Einmessens wurde der Einfachheit halber nur mit einer Kamera erläutert. Es ist jedoch verständlich, daß jede der beiden anderen Kameras in der selben Weise eingemessen werden kann.

Nach Einmessen der Kameras in der oben beschriebenen Weise wird in einem getrennten Vorgang wie ebenfalls auf Figur 1 dargestellt, nunmehr die Lage der Kalibriertafeln 2 bestimmt. Im Ausführungsbeispiel handelt es sich um drei Kalibriertafeln, die durch ein anderes Meßmittel, beispielsweise Theodoliten 5, vermessen und deren Ergebnis gespeichtert wird. Das in der Figur 1 dargestellte Koordinatensystem 17 stellt das Bezugskoordinatensystem für die gesamte Messung dar.

Aufgrund dieser Einmeßwerte, bestehend aus den in der Kamera mittels Bildverarbeitung gemessenen und gespeicherten Werten und den durch die theodolitische Vermessung der drei Kalibriertafeln erhaltenen Werte, ist die Position der Kamera bestimmt.

Wird nun, wie in Figur 2 dargestellt, ein Körper 6 in den Raum verbracht, beispielsweise über am Boden 7 verlegte Schienen 8, so kann, nachdem die Kameras 1 auf den Raum eingemessen wurden, nun ein beliebieger Punkt bzw. beliebige Punkte am Körper 6, bei dem es sich im Ausführungsbeispiel um eine Karosserie handelt, ausgewählt werden, an welchen Manipulationen am Körper 6 durchgeführt werden müssen, beispielsweise das Einsetzen von Türen oder das Anbringen von Deckeln oder das Einstellen von Spritzpistolen bei einer Lackieranlage zu der jeweiligen Oberfläche des Körpers mit Hilfe von Robotern 9. Mittels der Kameras wird die Postition je eines Merkmals, dessen Position in dem dem Objekt zugeordneten Koordinatensystem 18 gespeichert ist, im aufgenommenen Kamerabild mittels Bildverarbeitung erkannt und mit dem bei der Einmessung gespeicherten Werten verarbeitet. Hieraus ist der Bezug des Koordinatensystems 18 zum Koordinatensystem 17 bestimmt. So tragen im Ausführungsbeispiel die beiden Roboter 9 Farbdüsen 10 und 11, welche eine fehlerfreie Lackierung des Fahrzeugs ermöglichen. Anstelle dieser Farbdüsen 10/11 können auch andere Hilfswerkzeuge treten, beispielsweise Versiegelungseinrichtungen, welche Schweißnähte versiegeln oder auch Schraubeinrichtungen, welche Blechteile mit oder ohne entsprechende Gegenhalterungen an den Karossen anbringen.

Hierzu ist, wie bereits in der Einleitung gesagt, erfindungsgemäß gleichartig eingestellt ein Gegenhalter verwendbar, um beispielsweise die Bohrkräfte, welche beim Bohrvorgang auftreten, aufnehmen zu können, ohne daß die Karosserie während der Manipulation in eine andere Lage verschoben wird.

In Figur 3 ist ein Ausführungsbeispiel dargestellt, mit welchem der Einfluß einer Positionierung eines Nullkörpers auf die hierdurch zu steigernde Bearbeitungsgenauigkeit erläutert wird. Ein Nullkörper 12 wird, wie zu Figur 1 und Figur 2 insbesondere beschrieben, vermessen. Hierbei handelt es sich bei dem Nullkörper um einen Körper des selben Typs der nachfolgend zu bearbeitenden Körper. Durch diese Vorgehensweise lassen sich Fehler, die beispielsweise durch Ungenauigkeiten in der Herstellung oder des Einmessens, oder Meßfehler, die bei der Vermessung des Nullkörpers aufgetreten sind, minimieren. Es bleiben nur noch Fehler höherer Ordnung übrig. Bei nachfolgenden Messungen wird aus einem bei der Nullmessung bestimmten Lagewert zufolge Verschiebung des nächsten zu manipulierenden Körpers 13 ein Verschiebevektor festgestellt, welcher dann bei der Einstellung des in Figur 9 dargestellten Roboters durch Vergleich zwischen Istposition des nächsten zu manipulierenden Körpers 13 mit der Sollposition bzw. Nullposition des Nullkörpers 12 verglichen wird und hiermit berücksichtigbar bleibt.

Patentansprüche

1. Verfahren zum Bestimmen der Lage eine Körpers im Raum, um Manipulationen an diesem durchzuführen, dadurch gekennzeichnet, daß jede von mehreren räumlich getrennten elektronischen Kameras mit Bildverarbeitung bei deren Einmessen eine ihr zugeordnete Kalibriertafel mit Punktmuster aufnimmt, deren Bilder sowie das Punktmuster zur

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Bestimmung der Lage der einzelnen Kamera im Raum verarbeitet und deren Lage speichert, daß eine Vermessung der Kalibriertafeln zueinander getrennt hiervon erfolgt, daß diese Werte ebenfalls gespeichert werden, daß anschließend der Körper in den Raum zwischen den elektronischen Kameras verbracht wird, daß je ein charakteristischer Punkt auf dem Körper in je einer diesem zugeordneten elektronischen Kamera abgebildet wird, daß dessen Lage im Bild mit seiner konstruktiven, vorgegebenen Position des charakteristischen Punktes auf dem Körper zusammen mit den gespeicherten Werten verarbeitet wird und daß alle derart verarbeiteten Werte die Lage des Körpers im Raum in den sechs räumlichen Freiheitsgraden charakterisieren.

2. Verfahren nach Anspruch 1 dadurch gekennzeichnet, daß die Position eines Nullkörpers des selben Typs bestimmt wird und daß die Messung aller folgenden Körper auf diesen bezogen wird.

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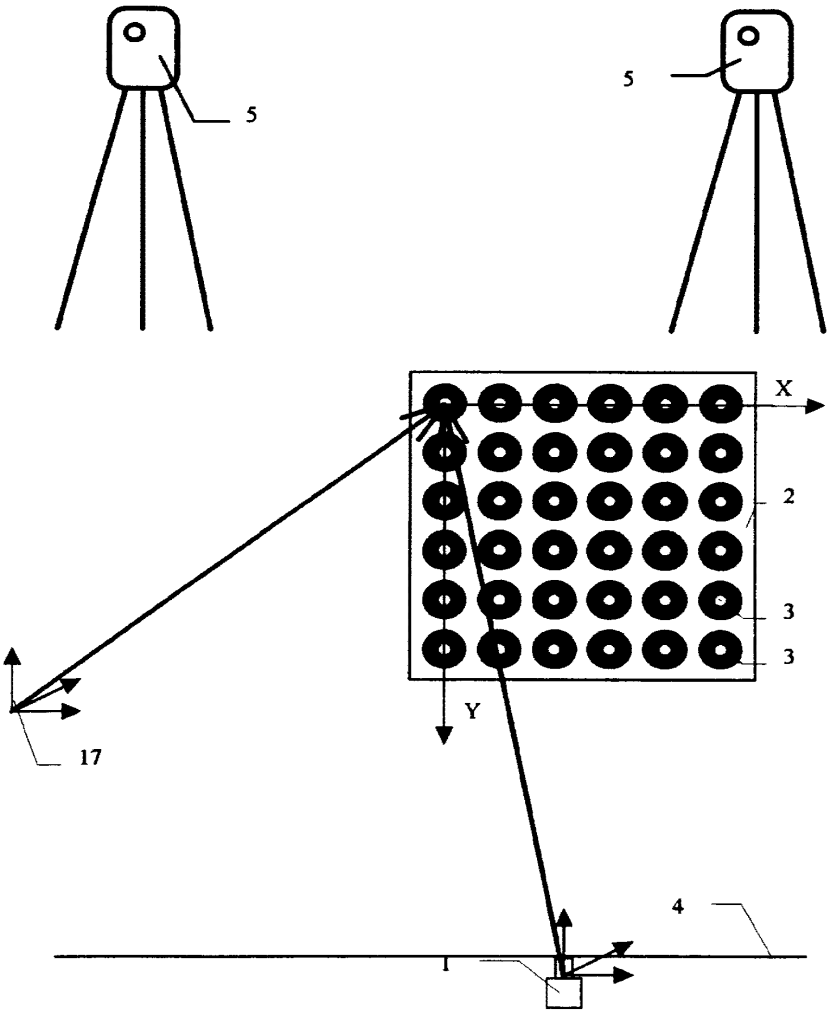


Fig. 1

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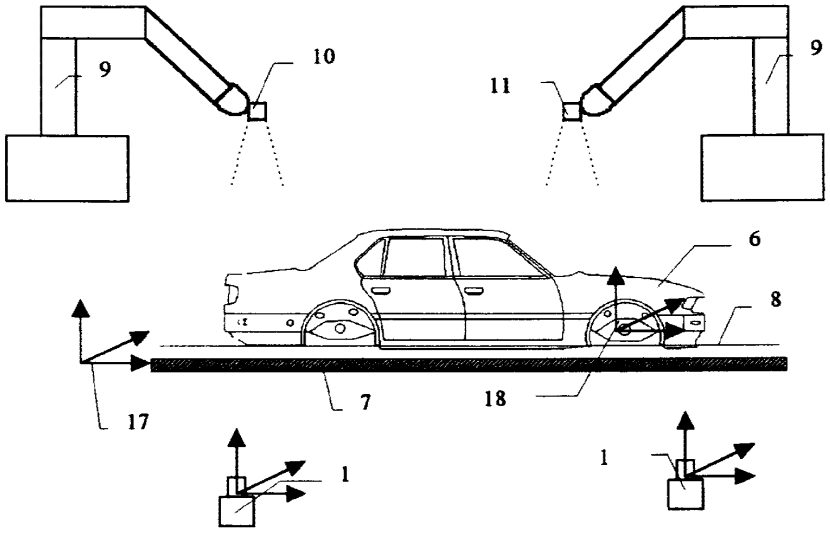


Fig. 2

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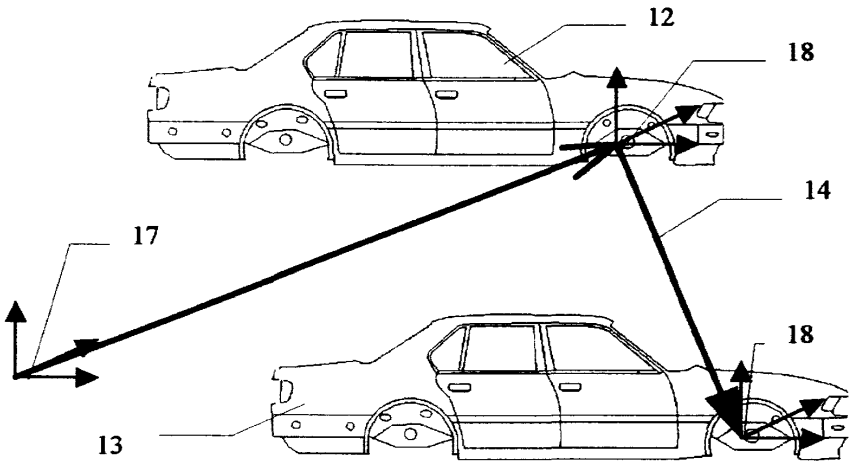


Fig. 3

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Europäisches Patentamt

EUROPÄISCHER RECHERCHENBERICHT

Nummer der Anmeldung
EP 95 11 4588

EINSCHLÄGIGE DOKUMENTE

Kategorie	Kennzeichnung des Dokuments mit Angabe, soweit erforderlich, der maßgeblichen Teile	Betrifft Anspruch	KLASSIFIKATION DER ANMELDUNG (Int.Cl.6)
X	US-A-4 639 878 (DAY CHIA P ET AL) 27.Januar 1987 * Spalte 7, Zeile 66 - Spalte 12, Zeile 40; Abbildungen 1-9 *	1,2	B25J9/16 G05B19/401
X	EP-A-0 489 919 (FANUC LTD) 17.Juni 1992 * Seite 2, Spalte 2, Zeile 41 - Seite 3, Spalte 4, Zeile 55; Abbildungen 1-4 *	1,2	
A	WO-A-94 29774 (BERTIN & CIE ;LORRAINE LAMINAGE (FR); ABITBOL MARC (FR); MAILLART) 22.Dezember 1994 * Seite 3, Zeile 36 - Seite 10, Zeile 13; Abbildungen 1-3 *	1,2	
A	WO-A-93 05479 (CIMETRIX INC.) 18.März 1993 * Seite 10, Zeile 5 - Seite 40, Zeile 22; Abbildungen 1-26 *	1,2	
A	US-A-4 796 200 (PRYOR TIMOTHY R) 3.Januar 1989 * Spalte 3, Zeile 11 - Spalte 5, Zeile 29; Ansprüche 1,8; Abbildungen 1-5B *	1,2	RECHERCHIERTE SACHGEBIETE (Int.Cl.6) G05B B25J
A	FR-A-2 706 999 (AUTOMOBILES PEUGEOT S.A. & AUTOMOBILES CITROEN S.A.) 30.Dezember 1994 * das ganze Dokument *	1,2	

Der vorliegende Recherchenbericht wurde für alle Patentansprüche erstellt

Recherchenort	Abschlußdatum der Recherche	Prüfer
DEN HAAG	26.Februar 1996	Hauser, L

KATEGORIE DER GENANNTEN DOKUMENTE

X : von besonderer Bedeutung allein betrachtet
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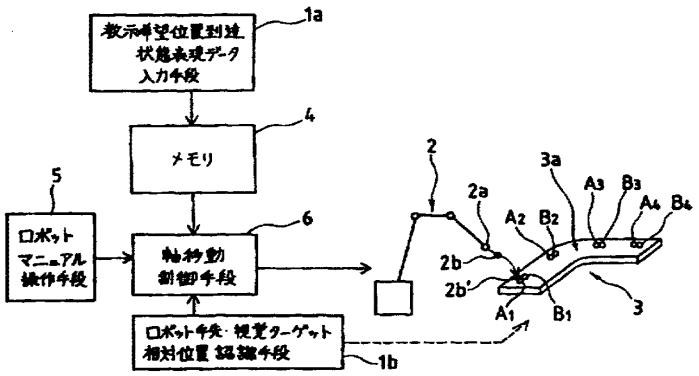
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(54)Title: MOVEMENT CONTROL METHOD FOR TEACHING POSITION OF ROBOT

(54)発明の名称 ロボットの位置教示のための移動制御方法

(57) Abstract

A mark member (A1) is stuck onto a work (3) with a certain relation with a teaching desired position on the work (3). The movement of the robot is autonomously controlled and the position teaching is performed in accordance with the present positions of the robot hand at the respective timings of the robot movement, the positions on a camera coordinate system of the mark member at the respective timings of the robot movement and the postures of the robot viewed from the camera coordinate system, the position on the camera coordinate system of the mark member (A1) when the robot reaches the teaching desired position and the posture of the robot viewed from the camera coordinate system, and the position on the camera coordinate system and the posture of the robot viewed from the robot hand.



1a ... means for inputting data for expressing the state that the robot reaches the teaching desired position
1b ... means for recognizing relative positions of the hand of the robot and the visual target
4 ... memory
5 ... robot manual operating means
6 ... shaft movement control means

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（５７）要約

ワーク（３）上の教示希望位置と一定の関係をもってマーク部材（Ａ１）をそのワーク（３）上に貼り付ける。そして、ロボットの移動各時点におけるロボットの手先の現在位置と、カメラ座標形から見た、ロボットの移動各時点における上記マーク部材における座標形の位置・姿勢と、カメラ座標形から見た、ロボットが教示希望位に到達したときのマーク部材（Ａ１）における座標形の位置・姿勢と、上記ロボットの手先から見たカメラ座標形位置・姿勢とに基づいて、ロボットを自律的に移動制御して位置教示する。

参考情報

ＰＣＴに基づいて公開される国際出願のパンフレット第一頁に記載されたＰＣＴ加盟国を同定するために使用されるコード

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明　細　書

ロボットの位置教示のための移動制御方法

技　術　分　野

本発明はロボットの位置教示のための移動制御方法に関し、更に詳しく言えば、視覚ターゲットとこれを認識する視覚センサを用いてロボットを教示希望位置に素早く移動させるための移動制御方法に関する。

背　景　技　術

ロボットの位置教示方法として最も一般的に利用されているのは、ジョグ送り（マニュアル入力によるロボット動作）による方法である。この教示方法によれば、オペレータは教示操作盤のジョグ送りボタンを操作してロボットを教示希望位置へ移動させ、その時の位置をロボットに教示するという作業が行なわれる。オフライン教示がなされている場合、粗い位置教示が済んでいる場合あるいは教示位置の修正を行なう場合などには、ジョグ送りによる教示位置の微調整が行なわれる。

いずれにしろ、希望する位置へロボットを移動させる作業は、ロボット手先（あるいはエンドエフェクタ）と教示希望点との相対的な位置・姿勢関係を目視により確かめながら行なわれるから、オペレータに熟練を要する。また、教示が必要な点（位置・姿勢）の数は多数に及ぶことが通例であるから、教示作業に多大な時間を費やすことも珍しくない。また、オペレータの目視に頼る教示作業は教示精度にバラツキが生じ易く、信頼性の点でも問題があった。

発　明　の　開　示

本発明の目的は、教示作業時にオペレータにかかる負担を軽減し、教示作業の効率と信頼性の向上を可能にしたロボットの位置教示のための移動制御方法を提供することにある。

本発明は上記従来技術の問題点に鑑みてなされたもので、視覚センサと適当な視覚ターゲット手段を利用して、ロボットを自律的に教示希望位置へ移動出来るようにすることで上記従来技術における問題点を解決したものである。

本発明の方法の諸段階には、ロボットの教示希望位置到達状態を表現する教示希望位置到達状態表現データをロボットと視覚センサを含むシステムの制御手段

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に記憶させる教示希望位置到達状態記憶段階と、該制御手段によるロボットの移動制御によってロボットを教示希望位置へ移動させる教示希望位置移動段階と、教示位置データを制御手段に記憶させる教示位置記憶段階が含まれる。

そして、この教示希望位置移動段階に、教示希望位置への移動を記憶された教示希望位置到達状態表現データに基づいて自律的に行なわせる自律移動実行段階が含まれていることが、本発明の重要な特徴である。

この自律移動を可能にするために、教示希望位置到達状態表現データは、視覚センサによって認識可能な視覚ターゲット手段を用いて表現された、視覚センサから見て教示希望位置到達状態と等価な教示希望位置到達等価状態を、前記視覚センサが認識することを通して取得される。

また、視覚ターゲット手段は、自律移動段階においては、視覚センサによって認識されることを通してロボットを前記教示希望位置へ案内するための案内視覚ターゲット手段として用いられる。

自律移動のために制御手段内で実行されるソフトウェア処理は、視覚センサによる案内視覚ターゲット手段の認識状態が、教示希望位置到達状態表現データに対応する認識状態と一致するようにロボットを誘導するように実行される。

視覚ターゲット手段は、視覚センサによって認識可能なマーク座標系を含むマーク手段の形態をとることが出来る。その場合、教示希望位置到達状態記憶段階で記憶される教示希望位置到達状態表現データには、画像上におけるマーク座標系の位置・姿勢を表わすデータが含まれることになる。一方このマーク手段は、ロボットの自律移動のための案内視覚ターゲット手段を提供するために、教示希望位置と一定の相対関係を持つ位置にマーク座標系を用意するために使用される。そして、制御手段内で実行されるソフトウェア処理に基づく移動制御により、視覚センサによるマーク座標系の認識状態が、教示希望位置到達状態表現データに対応する認識状態と一致するようにロボットが誘導される。

マーク手段には、教示作業の対象とされる代表ワークの面上に固定可能なマーク部材を用いることが出来る。このマーク部材上には、マーク座標系がドットパターンなどで描かれる。

別の利用可能な視覚ターゲット手段の形態として、ロボットに支持された光ビ

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ーム投光手段によって投光面上に形成される光スポットがある。このような光スポットを視覚ターゲット手段として使用する場合、教示希望位置到達状態記憶段階において、教示希望位置到達等価状態を視覚センサに対して用意するために、光スポットをロボットの教示対象点（教示希望位置に一致させようとする点のこと。通常は、ツール先端点；ＴＣＰである。）に一致する位置に形成するための参照投光面が配置される。

光ビーム投光方向を調整し、該参照投光面上の教示対象点位置に光スポットを形成する。この状態は、視覚センサにとっての教示位置到達等価状態に相当している。そこで、視覚センサによって光スポットが認識され、光スポットの画像上の位置を表わすデータを含むように教示希望位置到達状態表現データが取得される。

自律移動段階は、参照投光面を除去し、且つ、教示希望位置到達等価状態においてカメラから見た光ビーム投光方向を維持した状態で実行される。即ち、自律移動実行段階におけるロボットの移動制御は、教示希望位置の存在する面上に光ビームを投光して形成される光スポットを案内視覚ターゲット手段として用いて行なわれる。ロボットの移動制御のためのソフトウェア処理は、視覚センサによる光スポットの認識状態が、教示希望位置到達状態表現データに対応する認識状態と一致するようにロボットを誘導するように実行される。

教示希望位置への自律移動に先だって、教示希望位置への予備的なアプローチを行なうためにジョグ送りを行なうようにしても良い。その際、ジョグ送り段階から自律移動段階への移行は、視覚センサの出力に基づく制御手段内の処理によって自動的に行なわれることが好ましい。

また、教示希望位置への自律移動実行段階におけるソフトウェア処理は、当該時点において視覚センサによって認識される案内視覚ターゲット手段の画像上の位置を表わすデータと教示希望位置到達状態表現データとを比較する処理と、比較結果に基づいてロボットの各軸を移動制御するための処理と、教示希望位置到達状態の完了／未完了を判定する処理を、教示希望位置到達状態完了の判定がなされるまで逐次的に繰り返すとすることが出来る。

本発明においては、教示希望位置に到達した際に観測されるところの視覚ター

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ゲット手段の画像上の位置のデータが予め入力され、教示希望位置への自律移動時には、視覚ターゲット手段を視覚センサで観測することでロボット移動のナビゲート指標のように用い、ロボットを教示希望位置へ向けて誘導させる。

この特徴により、オペレータに負担をかけることなく教示希望位置到達状態が効率的に達成される。また、ジョグ送りから自律移動への移行をシステム内の自動切換で行うことで、位置教示作業時のロボットの至便性を更に向上させることも出来る。従って、教示希望位置の数が多数あるような場合でも、教示作業の負担が少なくてすむ。

図面の簡単な説明

図１は、本発明に従ったロボットの位置教示のための移動制御方法の全体像を概念的に説明する図である。

図２は、本実施形態で使用されるシステムのハードウェア構成の概略をロボット制御装置を中心とした要部ブロック図で示したものある。

図３は、教示操作盤４０のパネル面の概略構成を示す図である。

図４は、方式１による実施形態における自律移動の動作を説明する図である。

図５は、方式１による実施形態で使用されるマーク部材の構成を説明する図である。

図６は、方式１による実施形態において、カメラがマーク座標系を見る視線方向を記述するベクトルについて説明する図である。

図７は、方式１による実施形態における教示希望位置自律移動に必要なアルゴリズムの大要を説明する図である。

図８は、方式１による実施形態における教示希望位置自律移動の処理の概要を記したフローチャートである。

図９は、方式２による実施形態における準備作業の諸段階の内ＰＲ１～ＰＲ３を説明するための図である。

図１０は、方式２による実施形態における準備作業の諸段階の内ＰＲ４～ＰＲ６を説明するための図である。

図１１は、方式２による実施形態における教示作業の諸段階の内ＴＨ１～ＴＨ３を説明するための図である。

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図１２は、方式２による実施形態における教示作業の諸段階の内ＴＨ４，ＴＨ５を説明するための図である。

図１３は、方式２による実施形態において、ベクトル＜ｅｈ＞を求める方法を説明する図である。

図１４は、方式２による実施形態に関して、ベクトル＜ｄｍ＞，＜ｄｓ＞について説明する図である。

図１５は、方式２による実施形態における自律移動の制御のための処理のアルゴリズムの概要を記したフローチャートの前半部分（Ｌ１～Ｌ１２）である。

図１６は、方式２による実施形態における自律移動の制御のための処理のアルゴリズムの概要を記したフローチャートの後半部分（Ｌ１３～Ｌ１９）である。

図１７は、方式１あるいは方式２による実施形態において、ジョグ送りのモードから自律移動のモードへの切換をシステム内部で行なう場合について、教示操作盤の操作手順と処理の大要をフローチャートで示したものである。

発明を実施するための最良の形態

図１は、本発明に従ったロボットの位置教示のための移動制御方法の全体像を概念的に説明する図である。符号１ａは教示希望位置到達状態を表現するデータを入力する教示希望位置到達状態表現データ入力手段を表わしている。この教示希望位置到達状態表現データ入力手段１ａは、視覚ターゲットＢ１他に対するロボット２の教示希望位置への移動が完了した状態における、視覚ターゲットＢ１とロボット手先２ａの相対的な位置関係を表現するデータ（以下、「教示希望位置到達状態表現データ」と言う。）を予めメモリ４に入力しておく機能を有している。

教示希望位置は、代表ワーク３の面３ａ上の４個の符号Ａ１～Ａ４で例示されている。Ａ１～Ａ４の各近傍に描かれた符号Ｂ１～Ｂ４は、Ａ１～Ａ４の表わす位置を代表する視覚ターゲット手段であり、各対応する教示希望位置Ａ１～Ａ４と一定の関係を以て与えられる。視覚ターゲット手段の具体例については後述する。通常の形態においては、各視覚ターゲット位置Ｂ１～Ｂ４と各教示希望位置Ａ１～Ａ４とは近接してはいるが一致はしないように与えられるが、場合によっては両者を一致させることも可能である。

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符号２ａはロボットの手先位置を表し、符号２ｂはロボットの教示対象点（通常はツール先端点；ＴＣＰ）を表わしている。以下の説明において、ロボットの手先位置２ａは最終アーム先端のフランジ上に設定された座標系の原点で代表させるものとする。

実際の作業時にあたっては、オペレータがジョグ送りボタン等のロボットマニュアル操作手段（ロボット動作指令マニュアル入力手段；教示操作盤など）５を操作し、軸移動制御手段６にロボット２の各軸を制御させ、教示希望位置への移動を開始させる。この移動開始時から、あるいは移動開始後のある時点から、教示希望位置への自律的な移動のための移動制御が行なわれる。この自律的移動のための移動制御は、教示希望位置到達状態表現データ入力手段１ａによって入力された教示希望位置到達状態表現データと、各時点におけるロボット手先（これに固定されたカメラ等）と視覚ターゲット手段との間の相対的な位置関係を表わす相対位置認識データに基づいて行われる。

上記の相対位置認識データは、移動制御の過程において、ロボット手先視覚ターゲット間相対位置認識手段１ｂによって少なくとも１回与えられる。教示希望位置到達状態においては、当然、ＴＣＰ２ｂは教示希望位置の一つＡ１（またはＡ２～Ａ４内の一つ）と一致する（符号２ｂ'で例示）。

後述するように、教示希望位置到達状態表現データ入力手段１ａ及び相対位置認識手段１ｂは、視覚センサを利用する形で具体化される。また、視覚ターゲット手段Ｂ１～Ｂ４は、視覚センサによって認識可能なマーク座標系あるいはレーザビームによって形成される光スポットの形で具体化される。以下の説明では、視覚ターゲット手段をマーク座標系の形で具体化する形態を「方式１」と呼び、レーザビームによって形成される光スポットの形で具体化する形態を「方式２」と呼ぶ。

図２は、本実施形態で使用されるシステムのハードウェア構成の概略をロボット制御装置を中心とした要部ブロック図で示したものある。符号３０で全体を指示されたロボット制御装置にはプロセッサボード３１が装備され、このプロセッサボード３１はマイクロプロセッサからなる中央演算処理装置（以下、ＣＰＵと言う。）３１ａ、ＲＯＭ３１ｂ並びにＲＡＭ３１ｃを備えている。

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ＣＰＵ３１ａは、ＲＯＭ３１ｂに格納されたシステムプログラムに従ってロボット制御装置全体を制御する。ＲＡＭ３１ｃには、作成済みの動作プログラムや各種設定値等の他に、教示希望位置への自律移動を方式１あるいは方式２に従って実行するに必要なロボット側の処理を定めたプログラムと関連設定値等が格納される。また、ＲＡＭ３１ｃの一部はＣＰＵ３１ａが実行する計算処理等の為の一時的なデータ記憶に使用される。なお、プログラムデータや設定値の保存には、適宜外部装置として用意されたハードディスク装置などが利用される。

プロセッサボード３１はバス３７に結合され、このバス結合を介してロボット制御装置３０内の他の部分との間で、指令やデータの授受が行なわれるようになっている。先ず、ディジタルサーボ制御回路３２がプロセッサボード３１に接続されており、ＣＰＵ３１ａからの指令を受けて、サーボアンプ３３を経由してサーボモータ５１～５６を駆動する。各軸を動作させるサーボモータ５１～５６は、ロボット２の各軸の機構部に内蔵されている。

通信用インターフェイスを内蔵したシリアルポート３４は、バス３７に結合される一方、液晶表示部付の教示操作盤４０、画像処理装置２０並びにレーザ発振器６０に接続されている。但し、レーザ発振器６０は方式２で使用されるもので、方式１では不要である。

教示操作盤４０は、オペレータにより持ち運びができる程度の大きさと重さを有し、そのパネル上にはロボットマニュアル操作手段として使用されるジョグ送りボタン等が設けられている。この他、バス３７には、ディジタル信号用の入出力装置（ディジタルＩ／Ｏ）３５、アナログ信号用の入出力装置（アナログＩ／Ｏ）３６が結合されている。エンドエフェクタとの信号授受が必要な場合、エンドエフェクタの制御部は、ディジタルＩ／Ｏ３５あるいはアナログＩ／Ｏ３６に接続される。後述する例では、アーク溶接ロボットのアプリケーションを考えているので、ディジタルＩ／Ｏ３５にはアーク溶接トーチの電源装置が接続される。

画像処理装置２０は、ＣＰＵにプログラムメモリ、フレームメモリ、画像処理プロセッサ、データメモリ、カメラインターフェイス等をバス結合させた通常のものである。画像処理装置２０は、カメラインターフェイスを介してカメラ２１が接続されている。このカメラは、後述する態様で視覚ターゲット手段の画像を

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取得するための撮影に使用される。プログラムメモリには、方式１あるいは方式２で必要とされる画像解析用のプログラムデータが格納される。

図３は、教示操作盤４０のパネル面の概略構成を示す図である。表示画面４１は例えば液晶画面であり、移動指令プログラムの詳細データ等が切替え表示される。ファンクションキー４２は、表示画面４１の下端部に表示されるメニューを選択するキーである。教示操作盤有効スイッチ４３は、教示操作盤４０の操作が有効か無効かを切り換えるスイッチである。

非常停止ボタン４４は、ロボット２の動作を非常停止させるボタンである。カーソルキー４５は、表示画面４１上で表示されるカーソルの移動を行うキーである。テンキー部４６には、数字キーやその他のキーが設けられており、数値および文字の入力、削除等を行うことができる。

一連のジョグ送りボタン４７（Ｊ１～Ｊ６）は、従来方法のジョグ送りを行なう通常モードでは、並進／回転方向及び＋－方向を指定して移動指令の入力を行うボタンであるが、本実施形態（自律移動モード）では、後述するように、教示希望位置への自律移動指令入力手段として使用する。

以上の事項を前提に、方式１と方式２について実施形態の詳細を以下に説明する。

［方式１］

［１］概要

図４は、方式１による実施形態における自律移動の動作を説明する図である。図１と同じく符号３で指示された代表ワークの面３ａ上には、希望する教示点Ａ１～Ａ４の数に見合った数（ここでは４個）のマーク部材ＭＫ１～ＭＫ４が貼付されている。各マーク部材上には、後述するように、同一のマーク座標系がドットパターンで描かれている。マーク部材ＭＫ１は、教示希望点Ａ１の位置・姿勢に正確に対応するような位置・姿勢を以て貼付されている。同様に、マーク部材ＭＫ２～ＭＫ４は、教示希望点Ａ２～Ａ４の位置・姿勢に各々正確に対応するような位置・姿勢を以て貼付されている。

ロボット（手先部周辺のみを図示している）は、手先部に溶接トーチ２ｃとカメラ２１を搭載しており、ＴＣＰ２ｂは溶接トーチ２ｃ先端に設定されている。

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本実施形態では、ロボットを移動開始位置Ｐｓから出発して、溶接トーチ２ｃの先端に設定されたＴＣＰ２ｂを教示希望点Ａ1 ～Ａ4 に順次自律移動させ、各教示希望位置で位置教示を行なうケースを考える。なお、自律移動の開始位置Ｐｓは最初のマークＭＫ１がカメラ２１の視野に入る位置であれば、一般には任意である。

図５は、方式１による実施形態で使用されるマーク部材の構成を説明する図である。同図を参照すると、マーク座標系ΣＭ は、マーク部材ＭＫ上に間隔ａを以て格子状に配列された５個の円形ドットＤ０，Ｄ１，Ｄ-1，Ｄ２，Ｄ-2で構成されている。ドット間隔ａは正の一定値である。従って、各ドットの中心位置は、Ｄ０（０，０，０），Ｄ１（ａ，０，０），Ｄ-1（－ａ，０，０），Ｄ２（ａ，ａ，０），Ｄ-2（－ａ，ａ，０）となる。なお、３次元直交座標系を表現出来るものであれば、他のパターンでマーク座標系を構成しても良い。

マーク部材ＭＫの適当な定位置には穴ＭＨが設けられている。この穴ＭＨは教示希望位置を指し示すもので、代表ワーク３の面３ａ上に貼付する際には、その代表点（例えば、中心）が教示希望位置と一致するように貼付位置が選ばれる。貼付姿勢はマーク座標系ΣＭ の向きを参照して選ぶ。即ち、貼付姿勢が異なると、後に教示される姿勢も異なって来る。例えば、図４におけるＭＫ１とＭＫ４の貼付姿勢は９０度違うため、後に教示される姿勢も９０度異なったものとなる。

［２］準備（カメラのキャリブレーションと教示希望位置到達状態表現データの取得）

１．作業開始に先だって、適当なキャリブレーション法を適用してカメラのキャリブレーションを行なっておく。カメラのキャリブレーションには種々の手法が知られているが、ここに示したマーク部材を利用することも出来る。その概略については、説明の都合上、後で述べる。

２．教示希望位置到達状態表現データの取得作業を行なう。先ず、マーク部材ＭＫを適当な位置に固定する。勿論、代表ワーク３に貼付されたマーク部材の一つをそのまま使用することも出来る。

先ず、通常モード（従来方法）のジョグ操作によってロボットを移動させ、ツール先端点２ｂをマーク部材ＭＫの穴ＭＨの代表点ＭＡに一致させ、教示希望姿

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勢をとらせる。これにより、マーク部材ＭＫに関して教示希望位置到達状態が実現されたことになる。

３．マーク部材ＭＫに関して教示希望位置到達状態を実現したら、ロボット制御装置３０を介してカメラ２１による撮影を行なわせ、教示希望位置到達状態表現データを作成するための画像を取得する。

４．取得された画像は画像処理装置２０内で画像処理され、カメラ２１のカメラ座標系に対するマーク座標系ΣＭ の相対的な位置姿勢を表わすデータが作成される（詳細は後述）。

［３］方式１における教示希望位置自律移動時の処理

図４に示したアプローチ開始位置Ｐｓ（フランジ位置で表現）から自律教示希望位置への移動を開始して、教示希望位置Ｐｔ（フランジ位置で表現）への移動を達成するための処理のアルゴリズムを説明する。なお、以下の説明において、記号＜＞はベクトルを表わすために使用する。

１．アルゴリズムの骨格

図７は、自律的な教示希望位置への移動に必要なアルゴリズムの骨格を記したものである。フランジの現在位置（教示希望位置への移動中の各時点における位置）Ｔ０、カメラ座標系とマーク座標系の現在相対位置（教示希望位置への移動過程における各時点における相対位置）Ｍ０と、教示希望位置到達状態におけるフランジ位置Ｔｇ、教示希望位置到達状態におけるカメラ座標系とマーク座標系の相対位置（目標相対位置）Ｍｇとの幾何学的な関係は、図４中に記されているようなものである。

そして、Ｍｇは上記準備作業で取得される教示希望位置到達状態表現データに相当するものである。また、Ｃはフランジから見たカメラ座標系の位置・姿勢を表現する行列であり、そのデータはカメラ２１のキャリブレーションによって得られる。これらＴ０，Ｍ０，Ｔｇ，Ｍｇの間の関係を規定する基本方程式は下記のようになる。

$$T0\ C\ M0 = Tg\ C\ Mg \qquad \cdots (1)$$

従って、これをＴｇについて解いた次式（２）がロボットの直交座標系上での移動目標位置を表わす基本式となる。

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$$Tg = T0\ CM0\ Mg^{-1}\ C^{-1} \quad \cdots (2)$$

このTgを最終的な移動目標点とする位置指令をサーボに与えれば、ロボットを教示希望位置へ向けて自律的に移動させることが出来る。故に、教示希望位置への自律移動のアルゴリズムを定めることは、（2）式の右辺を具体的に求める問題に帰着する。

（2）式の右辺中、T0はロボットの現在位置データを表わしており、随時ロボット制御装置内で得られる性質のデータである。Cのデータは適当なカメラキャリブレーションによって別途獲得されるものである（キャリブレーションの例は後述）。そこで、M0及びMgの求め方から説明する。

2．M0及びMgの方程式

M0，Mgは、いずれもカメラ座標系から見たマーク座標系ΣMの位置・姿勢（現在及びアプローチ完了時）を表わしている。

本実施形態で用いられるマーク座標系ΣM（図5参照）を構成する円形ドットD0，D1，D-1，D2，D-2の配列間隔aは正の一定値であるから、

$$a > 0 \quad \cdots (3)$$

である。M0とMgは、3次元直交座標系間の位置・姿勢の関係を表現する4×4の同次変換行列であり、次式（4）のように置くことが出来る。

$$M = \begin{bmatrix} RM & IM \\ {}^{t}0 & 1 \end{bmatrix} \quad \cdots (4)$$

ここで、RMは回転を表わす3×3行列、IMは位置を表わす3×1行列（ベクトル）である。以下、M0とMgが満たす方程式として、RMとIMが満たす方程式を求めることを考える。先ず、次式（5），（6）でベクトル<e1>，<e2>を定義する。

$$<e1> = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \cdots (5)$$

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$$<e2>=\begin{bmatrix}0\\1\\0\end{bmatrix} \quad \cdots (6)$$

マーク座標系ΣM に関して視覚センサから得られる情報は、各円形ドットD0，D1，D-1，D2，D-2の中心がカメラ座標系の原点から見える方向（視線方向）である。これらの方向は、図6に示したように、5個の単位ベクトル<d0>，<d1>，<d-1>，<d2>，<d-2>で表わすことが出来る。

これらベクトルの内積について、次式（7）で定義されるδijを導入する。

$$\delta ij = <di> \cdot <dj> \quad (i,j=-2,-1,0,1,2) \quad \cdots (7)$$

ここで、<d0>，<d1>，<d-1>，<d2>，<d-2>の長さはすべて1であるから、δijの絶対値は1を越えることはない。

$$|\delta ij| \leqq 1 \quad (\text{等号成立の必要十分条件は } i=j) \quad \cdots (8)$$

また、カメラ座標系原点から各ドット中心までの距離は不明であるが、これをti（i=-2,-1,0,1,2）と置く。当然これらは正の値をとる。

$$ti > 0 \quad (i=-2,-1,0,1,2) \quad \cdots (9)$$

すると、次の方程式（10）～（12b）が得られる。

$$t0 <d0> = 1M \quad \cdots (10)$$

$$t1 <d1> = 1M + aRM <e1> \quad \cdots (11a)$$

$$t-1 <d-1> = 1M - aRM <e1> \quad \cdots (11b)$$

$$t2 <d2> = t1 <d1> + aRM <e2> \quad \cdots (12a)$$

$$t-2 <d-2> = t-1 <d-1> + aRM <e2> \quad \cdots (12b)$$

従って、tiを求めながらこれらの方程式をRMと1Mに関して解いて行けば、M0，Mgを定めることが出来る。具体的な解法については、4．M0及びMgの求め方の項で説明することにし、カメラ座標系の位置・姿勢を表わすCについて簡単に触れておく。

3．Cの方程式

Cはフランジから見たカメラ座標系の位置・姿勢を表現する行列であり、そのデータはカメラ21のキャリブレーションによって得られる。キャリブレーションについては種々の手法が公知になっており、それらを利用することが出来るが、

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マーク座標系ΣM を用いてもカメラ２１のキャリブレーションを行なうことも出来る。ここでは、その要点のみを簡単に記しておく。

図４中に符号ＣＢ１～ＣＢ３で示したような異なる３点において、カメラ２１による撮影を各々実行し、画像処理を行なって、マーク座標系ΣM とカメラ座標系の原点の間の相対位置に関するデータＰi （i=1,2,3 ）を得る。それらと各撮影時のロボット位置のデータＴi （i=1,2,3 ）を組み合わせると、次の３組の方程式が得られる。なお、Ｐi （i=1,2,3 ）を求める要領はＭ0 やMg と同様である。

Ｔ1 ＣＰ1 ＝Ｔ2 ＣＰ2 ＝Ｔ3 ＣＰ3 ・・・（13）

３点ＣＢ１～ＣＢ３のロボットの姿勢が互いに異なる条件下では、この方程式をＣに関して解くことが可能である。この条件を（14）とする。

条件：Ｔ1 ，Ｔ2 ，Ｔ3 の各姿勢成分は互いに異なる ・・・（14）

求められたＣのデータは、ロボット制御装置あるいは画像処理装置に記憶される。なお、方程式の解法については、５．Ｃの求め方で補足説明を行なう。

４．Ｍ0 及びMg の求め方

方程式（10），（11ａ），（11ｂ），（12ａ），（12ｂ）を解いてＲM ，ｌM を求めるにあたって、先ずｔi （i=-2,-1,0,1,2 ）を求めることを考える。そのために、次式（15）の置き換えを行う。

$$<r_M>=\begin{bmatrix} r_{Mx} \\ r_{My} \\ r_{Mz} \end{bmatrix} = R_M^{-1} <l_M> \quad \cdots (15)$$

そして、これを用いて方程式（10），（11ａ），（11ｂ）を次式（16）～（18）のように変形する。

$$<r_M> = t0\ R_M^{-1} <d0> \quad \cdots (16)$$

$$<r_M> + a<e1> = t1\ R_M^{-1} <d1> \quad \cdots (17)$$

$$<r_M> - a<e1> = t{-1} R_M^{-1} <d{-1}> \quad \cdots (18)$$

ここで、R_M^{-1} が回転を表わす行列であることに注意すると、次式（19）が成立する。

$$(R_M^{-1} <di>) \cdot (R_M^{-1} <dj>) = <di> \cdot <dj>$$

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$$(i,j=-2,-1,0,1,2) \quad \cdots (19)$$

この（19）式と、（５）～（８）式及び（16）～（18）式を用いると、次の関係式（20）～（23）が得られる。

$$\| < rM > \|^2 = t0^2 \quad \cdots (20)$$

$$\| < rM > \|^2 + 2arMx + a^2 = t1^2 \quad \cdots (21a)$$

$$\| < rM > \|^2 - 2arMx + a^2 = t-1^2 \quad \cdots (21b)$$

$$\| < rM > \|^2 + arMx = t0\ t1\ \delta 0,1 \quad \cdots (22a)$$

$$\| < rM > \|^2 - arMx = t0\ t-1\delta 0,-1 \quad \cdots (22b)$$

$$\delta 0,1^2 < 1,\ \delta 0,-1^2 < 1 \quad \cdots (23)$$

これらの式から条件（３），（９）と式（22a），（22b）から、$\| < rM > \|^2 + arMx$と$a\delta 0,1$、$\| < rM > \|^2 - arMx$と$a\delta 0,-1$とが各々同符号になる事に注意して整理すれば、次式（24a）～（25b）が得られる。

$$\| < rM > \|^2 + arMx = a\alpha + \sqrt{rMy^2 + rMz^2} \quad \cdots (24a)$$

$$\| < rM > \|^2 - arMx = a\alpha - \sqrt{rMy^2 + rMz^2} \quad \cdots (24b)$$

但し、

$$\alpha + \overset{def}{=} \frac{\delta 0,1}{\sqrt{1-\delta 0,1^2}} \quad \cdots (25a)$$

$$\alpha - \overset{def}{=} \frac{\delta 0,-1}{\sqrt{1-\delta 0,-1^2}} \quad \cdots (25b)$$

式（24a），（24b）は更に変形すると、次式（26），（27）が得られる。

$$\| < rM > \|^2 = (a^2\beta+^2) / (1+\beta-^2) \quad \cdots (26)$$

$$rMx = (a\beta+ \beta-) / (1+\beta-^2) \quad \cdots (27)$$

但し、$\beta+$，$\beta-$は次式（28a），（28b）で定義されるものとする。

$$\beta+ = (\alpha+ + \alpha-) / 2 \quad \cdots (28a)$$

$$\beta- = (\alpha+ - \alpha-) / 2 \quad \cdots (28b)$$

そして、式（20）（21a），（21b）に式（26）（27）を代入して条件（３），（９）を用いれば、t0，t1 及びt-1が次式（29）（30a），（30b）で求ま

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る。

$$t0 = a\sqrt{\frac{\beta_+^2}{1+\beta_-^2}} \quad \cdots (29)$$

$$t1 = a\sqrt{\frac{1+\alpha_+^2}{1+\beta_-^2}} \quad \cdots (30a)$$

$$t-1 = a\sqrt{\frac{1+\alpha_-^2}{1+\beta_-^2}} \quad \cdots (30b)$$

これらを用いて更に、t2, t-2, <IM>及びRMが次のように求められる。

$$t2 = \frac{t1 - t-1\delta 1,-1}{t1\delta 1,2 - t-1\delta -1,2}\, t1 \quad \cdots (30c1)$$

(t1δ1,2 − t-1δ-1,2 ≠ 0の場合)

$$t-2 = \frac{t-1 - t1\delta 1,-1}{t-1\delta -1,-2 - t1\delta 1,-2}\, t-1 \quad \cdots (30c2)$$

(t1δ1,2 − t-1δ-1,2 = 0の場合)

$$<IM> = t0<d0> \quad \cdots (30d)$$

$$<RM> = (<f1><f2><f3>) \quad \cdots (30e)$$

但し、 $$<f1> = \frac{1}{2a}(t1<d1> - t-1<d-1>) \quad \cdots (30f)$$

$$<f2> = \begin{cases} \frac{1}{a}(t2<d2> - t1<d1>) \\ (t1\delta 1,2 - t-1\delta -1,2 \neq 0 \text{の場合}) \\ \frac{1}{a}(t-2<d-2> - t-1<d-1>) \\ (t1\delta 1,2 - t-1\delta -1,2 = 0 \text{の場合}) \end{cases} \quad \cdots (30g)$$

$$<f3> = <f1> \times <f2> \quad \cdots (30h)$$

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5．Cの求め方

前述の条件（14）の下で、前述の方程式（13）を解く。方程式（13）を変形すると、次の（31），（32）が得られる。

$$C^{-1}T1^{-1}T3\ C = P1\ P3^{-1} \quad \cdots (31)$$

$$C^{-1}T2^{-1}T3\ C = P2\ P3^{-1} \quad \cdots (32)$$

ここで次式（33）～（37）に従った置き換えを行なう。

$$\begin{bmatrix} Rc & Ic \\ {}^{t}0 & 1 \end{bmatrix} \overset{def}{=} C \quad \cdots (33)$$

$$\begin{bmatrix} R1 & I1 \\ {}^{t}0 & 1 \end{bmatrix} \overset{def}{=} T1^{-1}T3 \quad \cdots (34)$$

$$\begin{bmatrix} R2 & I2 \\ {}^{t}0 & 1 \end{bmatrix} \overset{def}{=} P1P3^{-1} \quad \cdots (35)$$

$$\begin{bmatrix} R3 & I3 \\ {}^{t}0 & 1 \end{bmatrix} \overset{def}{=} T2^{-1}T3 \quad \cdots (36)$$

$$\begin{bmatrix} R4 & I4 \\ {}^{t}0 & 1 \end{bmatrix} \overset{def}{=} P2P3^{-1} \quad \cdots (37)$$

すると、方程式（31），（32）は次の式（38）～（41）に分解される。

$$RC^{-1}\ R1\ RC = R2 \quad \cdots (38)$$

$$RC^{-1}\ R3\ RC = R4 \quad \cdots (39)$$

$$(I - R1) < IC > = < I1 > - RC < I2 > \quad \cdots (40)$$

$$(I - R3) < IC > = < I3 > - RC < I4 > \quad \cdots (41)$$

従って、RC及び$< IC >$を求めることが目標となる。ここで、方程式（38），（39）の形から、回転行列間の相似R1～R2，R3～R4及びそれらの相似関係を表現する相似変換行列がともにRCであることが判る。

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そこで、Ｒｉ （i=1,2,3,4 ）の回転方向を表わすベクトルを＜ｖｉ ＞（i=1,2,3,4 ）として、次式（42），（43）が得られる。ここで、＜ｖｉ ＞（i=1,2,3,4 ）は、条件（14）と定義式（34），（36）から一意的に定めることが出来る。

＜ｖ1 ＞＝ＲＣ ＜ｖ2 ＞ ・・・（42）

＜ｖ3 ＞＝ＲＣ ＜ｖ4 ＞ ・・・（43）

更に、次式（44）の関係を用いれば、ＲＣ を求めることが出来る。

（＜ｖ1 ＞，＜ｖ3 ＞，＜ｖ1 ＞×＜ｖ3 ＞）

＝ＲＣ （＜ｖ2 ＞，＜ｖ4 ＞，＜ｖ2 ＞×＜ｖ4 ＞） ・・・（44）

方程式（40），（41）に関しては、次式（45）の形にひとまとめにして、最小２乗法を適用すれば＜ｌＣ ＞が求められる。

$$\begin{bmatrix} I & -R1 \\ I & -R3 \end{bmatrix} <IC> = \begin{bmatrix} <I1> \\ <I3> \end{bmatrix} - RC \begin{bmatrix} <I2> \\ <I4> \end{bmatrix} \quad \cdots (45)$$

６．方式１による移動制御の処理フローの概略

以上１．～５．の説明事項を前提として、方式１における準備作業と自律教示希望位置への移動のための処理フローの概略を説明する。先ず、準備作業について補足すれば、次のようになる。

（１）作業開始に先だって、上記３．で説明したように、３つの位置ＣＢ１～ＣＢ３にロボットを順次移動させる。

（２）各位置ＣＢ１～ＣＢ３で、代表ワーク３上のマーク部材ＭＫ１のマーク座標系ΣＭ （１個）の画像を取得し、画像処理装置２０内の画像処理によって各ドット中心の視線方向を表わすデータを取得する。

（３）上記５．で説明したアルゴリズムに従った処理を画像処理装置２０内で行い、カメラ座標系Ｃのデータ（ＲＣ，＜ｌＣ ＞のデータ）を算出・記憶する。

（４）カメラキャリブレーションが完了したら、ロボットを図４に示した位置Ｐｔに移動させ、マークＭＫ１に対する教示希望位置到達状態を現出させる。

（５）マーク座標系ΣＭ の画像を取得し、画像処理装置２０内の画像処理によって各ドット中心の視線方向を表わすデータを取得する。

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（６）上記１．２．４．で説明したアルゴリズムに従った処理を画像処理装置２０内で行い、教示希望位置到達状態表現データ（Ｍｇ のデータ）を算出・記憶する。

教示希望位置への自律的な移動は、図８のフローチャートに示したように、次の諸ステップを含む処理サイクルによって実行される。

〔Ｋ１〕＜ｄ０＞，＜ｄ１＞，＜ｄ-１＞，＜ｄ２＞，＜ｄ-２＞を画像処理で求め、Ｍ０ を計算する。

〔Ｋ２〕記憶されているＭｇ のデータとステップＫ１で求めた＜ｄ０＞，＜ｄ１＞，＜ｄ-１＞，＜ｄ２＞，＜ｄ-２＞から計算されるＭ０ とを比較し、両者の一致／不一致を判定する。一致していれば教示希望位置への到達状態を意味するから、ステップＫ６へ進む。不一致であれば、教示希望位置に到達していないことを意味するから、ステップＫ３～Ｋ５を経由してステップＫ１へ戻る。Ｍｇ とＭ０ の一致度の評価には種々のアルゴリズムが利用出来る。例えば、次式（46）で判定指標Δを算出し、Δ＜ε（εは十分小なる正値）であればアプローチ完了、Δ≧εであればアプローチ未完了とすれば良い。

$$\Delta \overset{def}{=} \left\| (Mo-Mg) \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \right\|^2 \quad \cdots (46)$$

〔Ｋ３〕ロボットの手先（フランジ上に設定された座標系の原点）の位置・姿勢を表わす４行４列の行列Ｔ０ を計算・記憶する。

〔Ｋ４〕準備作業で取得したデータ（Ｃ，Ｍｇ のデータ）と上記説明したアルゴリズムを用いて、（２）式の右辺を計算し、直交移動目標位置Ｔｇ を求める。

〔Ｋ５〕直交移動目標位置Ｔｇ へ向かうための移動指令を作成してサーボへ渡し、ロボットを移動させる。

システムが無誤差の完璧なものであれば、以上のステップＫ１～Ｋ５の１サイクルで教示希望位置到達状態に至る筈であるが、実際には視覚センサの誤差、計

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算の誤差等のために、教示希望位置到達状態は、逐次近似的に達成される。

〔Ｋ６〕ロボットを停止させて処理を終了する。

［方式２］

［１］概要

方式２による実施形態においては、視覚ターゲット手段として、レーザビームによって形成される光スポットが利用される。先ず、準備作業と教示作業の概略を、図９～図１４を参照図に加えて説明する。図９は準備作業の諸段階の内ＰＲ１～ＰＲ３を説明するための図であり、図１０は残りの段階ＰＲ４～ＰＲ６を説明するための図である。また、図１１は、教示作業の諸段階の内ＴＨ１～ＴＨ３を説明するための図、図１２は段階ＴＨ４．ＰＲ５を説明するための図である。

［２］準備作業（教示希望位置到達状態表現データの取得とカメラのキャリブレーション）

（ＰＲ１）先ずフランジ位置２ａで代表されるロボットの手先に、カメラ２１に加えて、レーザヘッド２２（図２中に示したレーザ発振器６０の照射ヘッド）と参照ツール２５を取り付ける。レーザヘッド２２は適当な調整機構２３を介して取り付けられており、レーザビーム２４の投光方向を調整出来るようになっている。参照ツール２５の先端付近の矢印２７で示した部分には、ＴＣＰ（２ｂ）を表わすマーク２６が設けられている。但し、このマーク２６は目視用のものであることに注意する必要がある。図示されているように、レーザヘッド２２を取り付けただけの状態では、一般に、レーザビーム２４が参照ツール２５上のマーク２６には入射しない。

（ＰＲ２）レーザヘッド２２の向きを調整して、レーザビーム２４が参照ツール２５上のマーク２６に入射するようにする。これにより、マーク２６の位置、即ち、ＴＣＰの位置２ｂに光スポットが形成される。レーザヘッド２２は、以後、この状態で固定される。

（ＰＲ３）この状態で、ロボット制御装置３０を介してカメラ２１による撮影を行なわせ、教示希望位置到達状態表現データを作成するための画像を取得する。取得された光スポットの画像は画像処理装置２０内で画像処理され、カメラ２１のカメラ座標系（原点Ｏｃ）から見た光スポット（ＴＣＰ位置２ｂにある。）

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の方向を表わすベクトル＜ｅｔ＞のデータが作成・記憶される。このデータが、教示希望位置到達状態表現データとして後に利用される。

（ＰＲ４）＜ｅｔ＞のデータを取得したら、参照ツール２５を取り外す。レーザヘッド２２は固定されたままなので、図示されているように、レーザビーム２４は空中でＴＣＰ（２ｂ）を通ることになる。

（ＰＲ５）カメラ座標系の原点Ｏｃから見たレーザビーム２４の存在方向を表わすベクトルとして、ベクトル＜ｅｈ＞のデータを作成・記憶する。＜ｅｈ＞は、次の２条件を満たすベクトルである。

条件１；ベクトル＜ｅｔ＞とレーザビーム２４が張る平面内にある。

条件２；＜ｅｈ＞⊥＜ｅｔ＞を満たす＜ｅｈ＞の内、カメラ２１からレーザヘッド２２を見た方向に近い方のベクトルである。＜ｅｈ＞は、例えば図１３に示した方法で求めることが出来る。

即ち、ロボットをジョグ送りで適当な平面（ここでは代表ワーク面３ａを利用する。）の上方に移動させ、レーザビーム２４のスポットＦを形成する。そして、図１３の（１）に示したようにＴＣＰ位置２ｂが面３ａの上方にある状態から、ロボットの面３ａへの接近により、図１３の（２）に示したようにＴＣＰ位置２ｂが面３ａの下方に来る状態を作る。換言すれば、スポットＦの位置がＴＣＰ位置（２ｂ）を見るカメラ２１の視線２１ａと面３ａの交点Ｎを越えて図１３の（１）の状態から反対側に来るようにする。

この状態で、カメラ２１による撮影を行ない、スポットＦの画像を取得する。そして、画像処理装置２０内で画像処理を行い、カメラ座標系から見たスポットＦの方向を表わすベクトル＜ｅｓ＞のデータを求める。ベクトル＜ｅｈ＞は、この＜ｅｓ＞を用いて次式（47）で算出される。

$$<eh> = \frac{<et> \times <es>}{\| <et> \times <es> \|} \quad \cdots (47)$$

（ＰＲ６）カメラ２１のキャリブレーションを行なう。これは、ロボット手先のフランジ面上に設定されているフランジ座標系（２ａが原点）とカメラ座標系の関係を求めるためのものである。カメラのキャリブレーションの手法については方式１の説明で述べた通り種々のものが利用可能である（マーク部材による

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手法を利用しても良い）。

［３］方式２による教示作業

（ＴＨ１）先ず、ロボットをジョグ送りで最初の教示希望位置が存在する代表ワーク面３ａの上方に移動させ、レーザビーム２４のスポットＦを代表ワーク面３ａ上に形成する。教示希望位置Ａは、視覚センサで認識可能な適当な教示点マークで予めマーキングしておくものとする。図１１で示した状態のフランジ位置２ａを自律移動開始位置Ｐｓとし、位置Ｐｓから自律移動を開始するものとする。なお、後述するように、ジョグ送りから自律移動への移行は、例えば視覚センサ出力を利用した自動切換とすることが出来る。

図１１に示されているように、ＴＣＰ位置２ｂは面３ａの上方にあり、レーザビーム２４はこの点を経て面３ａ上にスポットＦを形成する。この段階ＴＨ１では、一般に、教示点マークＡ、スポット位置Ｆ及びＴＣＰ（２ｂ）の３点は互いに別の位置にある。また、カメラ２１から教示点マークＡを見た視線２１ａはＴＣＰ（２ｂ）を通らない。

（ＴＨ２）自律移動の処理によってロボットを動作させ、カメラ２１から教示点マークＡを見た視線２１ａがＴＣＰ（２ｂ）を通るようにする。ロボットの動作としては、カメラ座標系の原点Ｏｃ 周りの回転が合理的である。

（ＴＨ３）自律移動の処理によってロボットを動作させ、視線２１ａがＴＣＰ（２ｂ）を通る条件を出来るだけ守りながら、スポットＦの形成位置を教示点マークＡに接近させる。ロボットの動作としては、視線２１ａ方向の前進に適宜Ｏｃ 周りの回転を組み合わせたものとする。

（ＴＨ４）視線２１ａ方向の前進が過剰になったら、視線２１ａがＴＣＰ（２ｂ）を通る条件を出来るだけ守りながら、適宜視線２１ａ方向に沿って後退し、適宜カメラ座標系の原点Ｏｃ 周りの回転を組み合わせる。

（ＴＨ５）以下、ＴＨ３の動作（前進）とＴＨ４（後退）の動作を繰り返して、スポットＦの形成位置を教示点マークＡに収束させる。この収束点は、ＴＣＰ（２ｂ）を通り、且つ、教示点マークＡを見る視線２１ａとＴＣＰ（２ｂ）を通るレーザビームの交点に他ならないから、従って、結局は教示点マークＡ、スポット位置Ｆ及びＴＣＰ（２ｂ）の３点が同じ位置に来ることになる。これはと

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りもなおさず、教示対象点たるＴＣＰ（２ｂ）が教示希望位置に到達したことを意味する。この時のフランジ位置２ａの位置を、方式１の場合と同じく、Ｐｔで表わす。

そこで、この状態におけるロボット位置を制御手段（ロボット制御装置内の不揮発性メモリ）に記憶すれば、位置Ａの位置教示が完了する。教示希望位置（教示点マーク）が複数ある場合（図示は省略するが、例えば図１中の代表ワーク３上の点Ａ１～Ａ４を参照）、２番目以降の各教示点マークに関して上記プロセスＴＨ１～ＴＨ５を適用すれば良い。

［４］方式２における教示希望位置自律移動時の処理

上記［２］で説明したプロセスに従って、自律移動開始位置Ｐｓ（フランジ位置で表現）から教示希望位置Ｐｔ（同じく、フランジ位置で表現）への移動を達成するための処理のアルゴリズムを説明する。記号＜＞は方式１の場合と同じくベクトルを表わすが、ベクトルの定義内容等は方式１とは別個である。自律的な移動は、図１５（Ｌ１～Ｌ１２）及び図１６（Ｌ１３～Ｌ１９）のフローチャートに概略を記したアルゴリズムに従った処理サイクルに基づいて実行される。以下、各ステップに分けてアルゴリズムを中心に説明する。説明中の諸記号の意味は次の通りである。

$\sigma 0$，$\sigma 1$；いずれもロボットの前進／後退を表わすフラグで±１の値をとる。＋１は前進を意味し、－１は後退を意味する。

ｌ；ロボットの前進／後退の刻み量を表わすレジスタ値

＜ｄｍ＞；図１４に示したように、カメラ座標系の原点Ｏｃから教示点マークＡを見た視線方向を表わす単位ベクトル（長さ１）で、画像データから求められる。

＜ｄｓ＞；同じく図１４に示したように、カメラ座標系の原点Ｏｃからスポット位置Ｆ（レーザビーム２４の入射位置）を見た視線方向を表わす単位ベクトル（長さ１）で、＜ｄｍ＞と同様、画像データから求められる。

Ｔ；ロボット座標系上で、ロボットの位置・姿勢を表わす行列

δr，δl；いずれも適当なしきい値で、０に近い正の定数。

Ｒ；＜ｄｍ＞と＜ｅｔ＞の方向の関係を記述する回転行列で、Ｒ＜ｅｔ＞

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＝＜ｄｍ＞となる３×３行列の内、最小の回転を表わすもの。

ｓｇｎ；符号関数で、次のように定義される。

ｓｇｎ（ｘ）＝＋１　（ｘ＞０）

ｓｇｎ（ｘ）＝０　（ｘ＝０）

ｓｇｎ（ｘ）＝－１　（ｘ＜０）

〔Ｌ１〕フラグσ０を１に初期設定する。また、１を適当な初期値（例えば３ｃｍ）に初期設定する。

〔Ｌ２〕行列Ｔのデータを表わすレジスタ値をロボットの現在位置に基づいて更新する。

〔Ｌ３〕カメラ２１を用いて撮影を行い、画像処理装置２０を用いてベクトル＜ｄｍ＞を求めることを試みる。

〔Ｌ４〕もし、ベクトル＜ｄｍ＞が求められなければ、教示点マークＡがカメラ視野で捉えられていないことが考えられるので、処理を終了する（オペレータは、ジョグ送りでロボット位置を調整し、教示点マークＡが確実にカメラ視野で捉えられる状態とする）。ベクトル＜ｄｍ＞が求められた場合には、ステップＬ５へ進む。

〔Ｌ５〕ベクトル＜ｅｔ＞とベクトル＜ｄｍ＞の外積＜ｄｒ＞を求める。＜ｄｒ＞＝＜ｅｔ＞×＜ｄｍ＞

〔Ｌ６〕ベクトル＜ｄｒ＞の絶対値をしきい値δｒと比較し、小さくなければステップＬ７へ進む。小さければステップＬ１０へ進む。

〔Ｌ７〕＜ｄｍ＞と＜ｅｔ＞の方向の関係を記述する回転行列Ｒを表記の式で算出する。なお、表記の算出式は、下記の連立方程式をＲについて解いて得られるものである。

Ｒ＜ｅｔ＞＝＜ｄｍ＞　・・・（48）

Ｒ＜ｄｒ＞＝＜ｄｒ＞　・・・（49）

〔Ｌ８〕行列Ｔのデータを表わすレジスタ値を、新しい部分行列Ｒを含む表記の行列に対するものに更新する。この行列は、下記の方程式（50）をＴｇについて解き、Ｔｇ→Ｔとしたものである。

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$$TgC = TC \begin{bmatrix} R & 0 \\ {}^{t}0 & 1 \end{bmatrix} \quad \cdots (50)$$

〔Ｌ９〕ロボットを動作させ、ステップＬ８で計算された行列Ｔの表わす位置・姿勢に移動させるための処理を行い、ステップＬ２へ戻る。

〔Ｌ１０〕ステップＬ６で、ベクトル＜ｄｒ＞の絶対値がしきい値δｒより小さいと判断されたら、初めてこのステップＬ１０が実行される。本ステップでは、カメラ座標系の原点Ｏｃからスポット位置Ｆを見た視線方向を表わす単位ベクトル＜ｄｓ＞を、画像データから求めることを試みる。

〔Ｌ１１〕ベクトル＜ｄｒ＞の絶対値がほぼ０となっているこの時点（ＴＣＰを見る視線と教示点マークを見る視線が実質一致）でスポットＦがカメラ視野に収まらないことは、システム異常や設計ミス等がない限り起こり得ないと考えられる。従って、殆どのケースでは、ベクトル＜ｄｓ＞が求められ、ステップＬ１２へ進む。しかし、万一＜ｄｓ＞が求められない場合には処理を終了する（別途、原因究明等を行なう）。

〔Ｌ１２〕＜ｄｓ＞と＜ｅｔ＞が実質同じ向きで、且つ、内積１になっているかをチェックする（δ１は非常に小さい正値であることに注意）。

〔Ｌ１３〕ロボットの前進／後退を表わすフラグσ１を、＜ｄｓ＞と＜ｅｈ＞の内積が正ならばσ１＝－１、負ならばσ１＝１、実質的に０ならばσ１＝０とする。

〔Ｌ１４〕σ１＝０であればステップＬ１５に進む。σ１＝０でなければステップＬ１６へ進む。

〔Ｌ１５〕σ１をσ０に更新し、ステップＬ１８へ進む。

〔Ｌ１６〕σ１とσ０の積が正であればステップＬ１８へ進む。負であればステップＬ１７へ進む。

〔Ｌ１７〕σ０をσ１に更新するとともに、１の値を半減する。

〔Ｌ１８〕行列Ｔのデータを表わすレジスタ値を、表記の行列に対するものに更新する。この行列は、下記の方程式（51）をＴｇについて解き、Ｔｇ→Ｔとしたものである。

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$$TgC = TC \begin{bmatrix} I & \sigma 1 I < et > \\ t_0 & 1 \end{bmatrix} \quad \cdots (51)$$

〔Ｌ１９〕ロボットを動作させ、ステップＬ１８で計算された行列Ｔの表わす位置・姿勢に移動させるための処理を行い、ステップＬ２へ戻る。

以上説明したアルゴリズムに従った処理サイクルの中で、いずれかの時点でステップＬ１２でイエスの判断出力が得られたなら、図１２の（ＴＨ５）に示したような教示希望位置到達状態が実現したと解し、ロボットを停止させて処理を終了する。

以上、方式１、方式２の実施形態についての説明から理解されるように、本発明に従えば、予め入力された教示希望位置到達状態の位置および姿勢となるように自律的にロボットの教示希望位置への移動が行なわれるので、作業効率が向上する。

更に、方式１、方式２いずれの実施形態においても、マニュアル指令入力によるジョグ送りのモードから、自律的に教示希望位置へ向かう自律移動のモードの切換を制御手段（ロボット制御装置３０及び画像処理装置２０）の内部の処理で自動化することが好ましい。

図１７は、ジョグ送りのモードから自律移動のモードへの切換をシステム内部で行なう場合について、教示操作盤の操作手順と処理の大要をフローチャートで示したものである。各ステップの処理を簡単に記すと次のようになる。本例ではモード切換のタイミングの決定に、視覚センサの出力を利用している。

〔Ｓ１〕ジョグ送りボタン４７（いずれか１つ）が押されてジョグ送りの指令がなされたか否かを判断し、なされればステップＳ２に進み、なされなければステップＳ１を繰り返す。

〔Ｓ２〕ジョグ送りボタン４７で指定された移動内容（方向、軸等）に応じて、所定の軸を制御して、ロボット１０のジョグ送り移動を開始する。例えば、Ｊ６軸＋方向の移動が指定されていれば、Ｊ６軸を＋方向へ進める移動指令を作成してサーボに渡す。

〔Ｓ３〕ジョグ送りボタン４７がオフにされたか否かを判断し、オフにされれば

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ステップＳ８に進み、されなければステップＳ４に進む。

〔Ｓ４〕画像処理装置２０から、カメラ１３の視野内に教示点マークＡ（方式２の場合、及びスポットＦ）が入ったことを知らせる信号の受信の有無を確認し、受信していればステップＳ５に進み、受信していなければステップＳ３に戻る。

〔Ｓ５〕自律移動の処理を開始する。具体的な処理内容の例については、方式１、方式２に分けて前述した通りである。

〔Ｓ６〕ジョグ送りボタン４７がオフにされたか否かを判断し、オフにされていればステップＳ８に進み、されていなければステップＳ７に進む。

〔Ｓ７〕教示希望位置へ到達したか否かを判断し、到達していればステップＳ８に進み、未到達であればステップＳ６に戻る。なお、教示希望位置到達／未到達の判断方法についても、方式１及び方式２の説明の中で述べた通りである。

〔Ｓ８〕ロボット２の各軸の動作を停止させる。

本発明によれば、教示希望位置に到達した際に観測されるところの視覚ターゲット手段の画像上の位置のデータが予め入力されているので、視覚ターゲット手段をナビゲート指標のように用い、ロボットを教示希望位置へ向けて自律的に移動させることが出来る。従って、ロボットの位置教示作業に要するオペレータの負担が大幅に軽減される。特に、ジョグ送りから自律移動への移行をシステム内の自動切換で行うことで、位置教示作業時のロボットの至便性を更に向上させることも出来る。

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請　求　の　範　囲

1．ロボットと該ロボットの手先部に取り付けられたカメラ手段並びに該カメラ手段を通して取得された画像を処理する画像処理手段を備えた視覚センサと、ロボット制御装置とを含むシステムの制御手段を用いて前記ロボットを教示希望位置へ移動させるためのロボットの移動制御方法であって、

(a) ワーク上の教示希望位置と一定の関係をもって、該ワーク上に視覚ターゲットを設けて、

(b) ロボットを手動で移動させて、ロボットのツール先端点を上記視覚ターゲットの代表点に一致させ、教示希望姿勢をとらせ、

(c) ロボットが上記(b) の位置姿勢にあるときに上記カメラ手段で撮影をし、上記画像処理手段で処理することにより、ロボットが上記教示希望位に到達したときの状態における、上記視覚ターゲットとロボット手先先端との相対位置関係を表すデータをメモリに入力し、

(d) 上記(c) のデータと、移動中の各時点で視覚センサが認識した、前記ロボット手先と前記視覚ターゲットとの相対的な位置関係を表すデータとに基づいて、ロボットを前記教示希望位置に到達させるべく自律的に移動制御する、上記の方法。

2．ロボットと該ロボットの手先部に取り付けられたカメラ手段並びに該カメラ手段を通して取得された画像を処理する画像処理手段を備えた視覚センサと、ロボット制御装置とを含むシステムの制御手段を用いて前記ロボットを教示希望位置へ移動させるためのロボットの移動制御方法において、

少なくとも一つの教示希望位置に関して教示希望位置到達状態を表現する教示希望位置到達状態表現データを前記制御手段に記憶させる教示希望位置到達状態記憶段階と、

前記制御手段による前記ロボットの移動制御によって前記ロボットを前記教示希望位置へ移動させる教示希望位置移動段階と、

教示位置データを前記制御手段に記憶させる教示位置記憶段階とを含み、

前記教示希望位置移動段階は、該教示希望位置への移動を前記教示希望位置到達状態表現データに基づいて自律的に行なわせる自律移動実行段階を含んで

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おり、

前記教示希望位置到達状態表現データは、前記視覚センサによって認識可能な視覚ターゲット手段を用いて表現された前記視覚センサから見て教示希望位置到達状態と等価な教示希望位置到達等価状態を前記視覚センサが認識することを通して取得されるものであり、

前記視覚ターゲット手段は、前記自律移動段階においては、前記視覚センサによって認識されることを通して前記ロボットを前記教示希望位置へ案内するための案内視覚ターゲット手段を提供するものであり、

前記自律移動段階における前記ロボットの移動制御は前記制御手段内のソフトウェア処理によって行なわれ、

前記ソフトウェア処理は、前記視覚センサによる前記案内視覚ターゲット手段の認識状態が、前記教示希望位置到達状態表現データに対応する認識状態と一致するように前記ロボットを誘導するための処理を含んでいる、

前記方法。

3．前記視覚ターゲット手段が、前記視覚センサによって認識可能なマーク座標系を含むマーク手段であり、

前記教示希望位置到達状態記憶段階で記憶される教示希望位置到達状態表現データが、画像上における前記マーク座標系の位置・姿勢を表わすデータを含んでおり、

前記マーク手段は、前記案内視覚ターゲット手段を提供するために、前記教示希望位置と一定の相対関係を持つ位置に前記マーク座標系を用意するものである、請求の範囲第２項に記載された、ロボットの位置教示のための移動制御方法。

4．前記マーク手段が、教示作業の対象とされる代表ワークの面上に固定可能なマーク部材であり、該マーク部材上に前記マーク座標系が描かれている、請求の範囲第３項に記載されたロボットの位置教示のための移動制御方法。

5．前記視覚ターゲット手段が、前記ロボットに支持された光ビーム投光手段によって投光面上に形成される光スポットであり、

前記教示希望位置到達状態記憶段階において、前記教示希望位置到達等価状

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態を前記視覚センサに対して用意するために、前記光スポットを前記ロボットの教示対象点に一致する位置に形成するための参照投光面が配置され、

該参照投光面上に形成された光スポットを前記視覚センサによって認識することを通して、前記光スポットの画像上の位置を表わすデータを含むように前記教示希望位置到達状態表現データが取得され、

前記自律移動段階は、前記参照投光面を除去し、且つ、前記教示希望位置到達等価状態において前記カメラから見た前記光ビーム投光方向を維持した状態で実行されるものであり、

前記自律移動実行段階における前記ロボットの移動制御は、前記教示希望位置の存在する面上に前記光ビームを投光して形成される光スポットを前記案内視覚ターゲット手段として用いて行なわれ、且つ、前記ロボットの移動制御のための前記ソフトウェア処理は、前記視覚センサによる前記光スポットの認識状態が、前記教示希望位置到達状態表現データに対応する認識状態と一致するように前記ロボットを誘導するための処理を含んでいる、請求の範囲第２項に記載されたロボットの位置教示のための移動制御方法。

６．前記教示希望位置への移動実行段階には、前記自律教示希望位置への自律移動実行段階に先立つジョグ送りの段階が含まれており、

前記ジョグ送り段階から前記自律教示希望位置への移動実行段階への移行が、前記視覚センサの出力に基づいて前記制御手段によって自動的に行なわれる、請求の範囲第２項乃至第５項のいずれか１項に記載されたロボットの位置教示のための移動制御方法。

７．前記教示希望位置への自律移動実行段階におけるソフトウェア処理が、当該時点において前記視覚センサによって認識される前記案内視覚ターゲット手段の画像上の位置を表わすデータと、前記教示希望位置到達状態表現データとを比較する処理と、前記比較結果に基づいてロボットの各軸を移動制御するための処理と、教示希望位置到達状態の完了／未完了を判定する処理を、教示希望位置到達状態完了の判定がなされるまで逐次的に繰り返すものであり、

該教示希望位置到達状態完了の判定がなされた後に、前記教示位置記憶段階が実行される、請求の範囲第２項乃至第５項のいずれか１項に記載されたロボ

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ットの位置教示のための移動制御方法。

8．ロボットの手先部に取り付けられたカメラと、該カメラを通して取得された画像を処理する画像処理手段とを備えた視覚センサと、

教示作業の対象となるワーク上に、そのワーク上の教示希望位置と一定の関係をもって与えられる視覚ターゲットと、

ロボットが上記教示希望位に到達したときの状態における、上記視覚ターゲットとロボット手先先端との相対位置関係を表すデータをロボット制御装置におけるメモリに入力するための、教示希望位置到達状態表現データ入力手段と、

ロボットを教示希望位置に向けて移動させるためのジョグ送りなどの手動送り手段と、

ロボットの移動各時点におけるそのロボットの手先と前記視覚ターゲットとの相対的な位置関係を表すデータを得るための、ロボット手先・視覚ターゲット相対位置認識手段と、

上記教示希望位置到達状態表現データ入力手段で入力されたデータと、上記ロボット手先・視覚ターゲット相対位置認識手段で認識されたデータとに基づいて、ロボットを前記教示希望位置に到達させるべく自律的に移動制御する、ロボット移動制御手段と、

から成る、位置教示のためのロボット移動制御システム。

9．上記視覚ターゲットは、ワークに貼り付けることのできるマーク部材であり、そのマーク部材には上記視覚センサによって認識可能な座標形がドットパターンで描かれている、請求の範囲第8項記載の位置教示のためのロボット移動制御システム。

10．上記ロボット移動制御手段は、

ロボットの移動各時点におけるロボットの手先の現在位置と、

カメラ座標形から見た、ロボットの移動各時点における上記マーク部材における座標形の位置・姿勢と、

カメラ座標形から見た、ロボットが上記教示希望位に到達したときの上記マーク部材における座標形の位置・姿勢と、

上記ロボットの手先から見たカメラ座標形位置・姿勢とに基づいて、ロボッ

差替え用紙（規則26）

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トを自律的に移動制御する機能を備えている、

請求の範囲第９項記載の位置教示のためのロボット移動制御システム。

１１．上記視覚ターゲットは、

ロボット手先に投光方向を調整可能に取り付けられたレーザ照射ヘッドと、

ロボット手先に取り外し可能に取り付けられる参照ツールとかなり、

しかも前記参照ツールには、ツール先端点にあたる箇所にマークが付されていて、そのため、レーザ照射ヘッドの投光方向を調整してレーザ照射ヘッドからのレーザ光がツール先端点を通過する状態を実現し確認できるようにした、

請求の範囲第８項記載の位置教示のためのロボット移動制御システム。

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FIG. 1

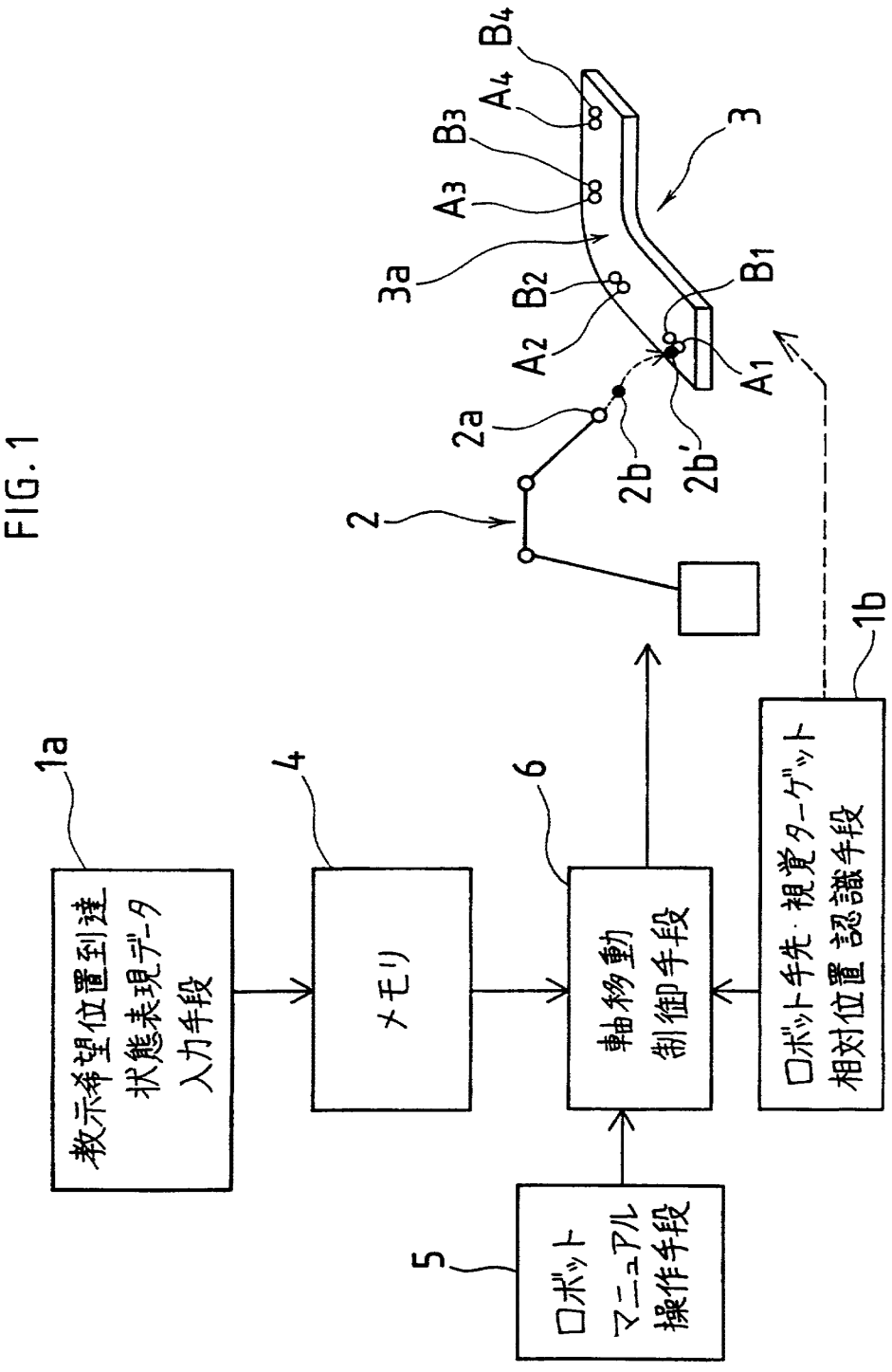
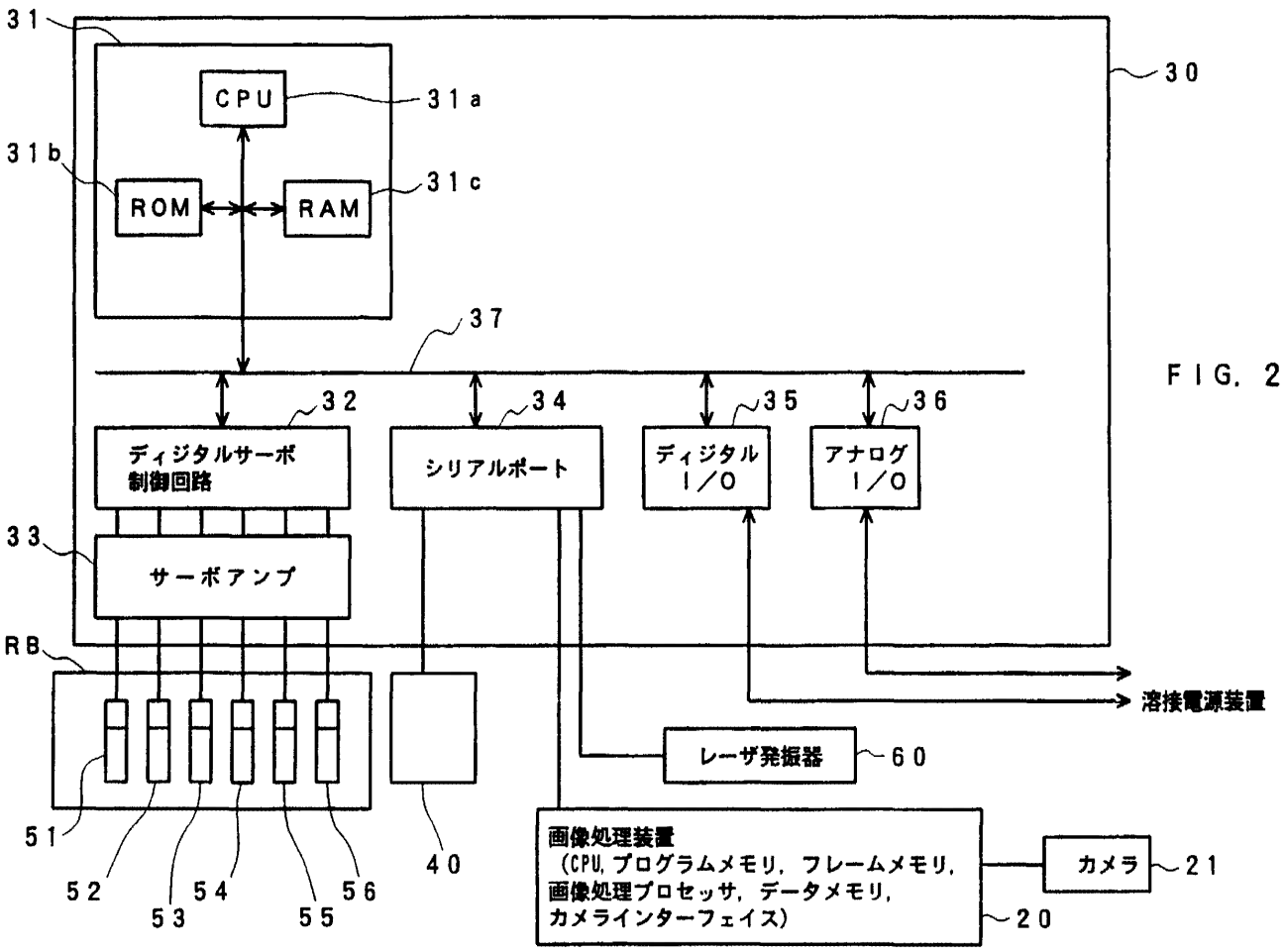


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F I G. 2

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FIG. 3

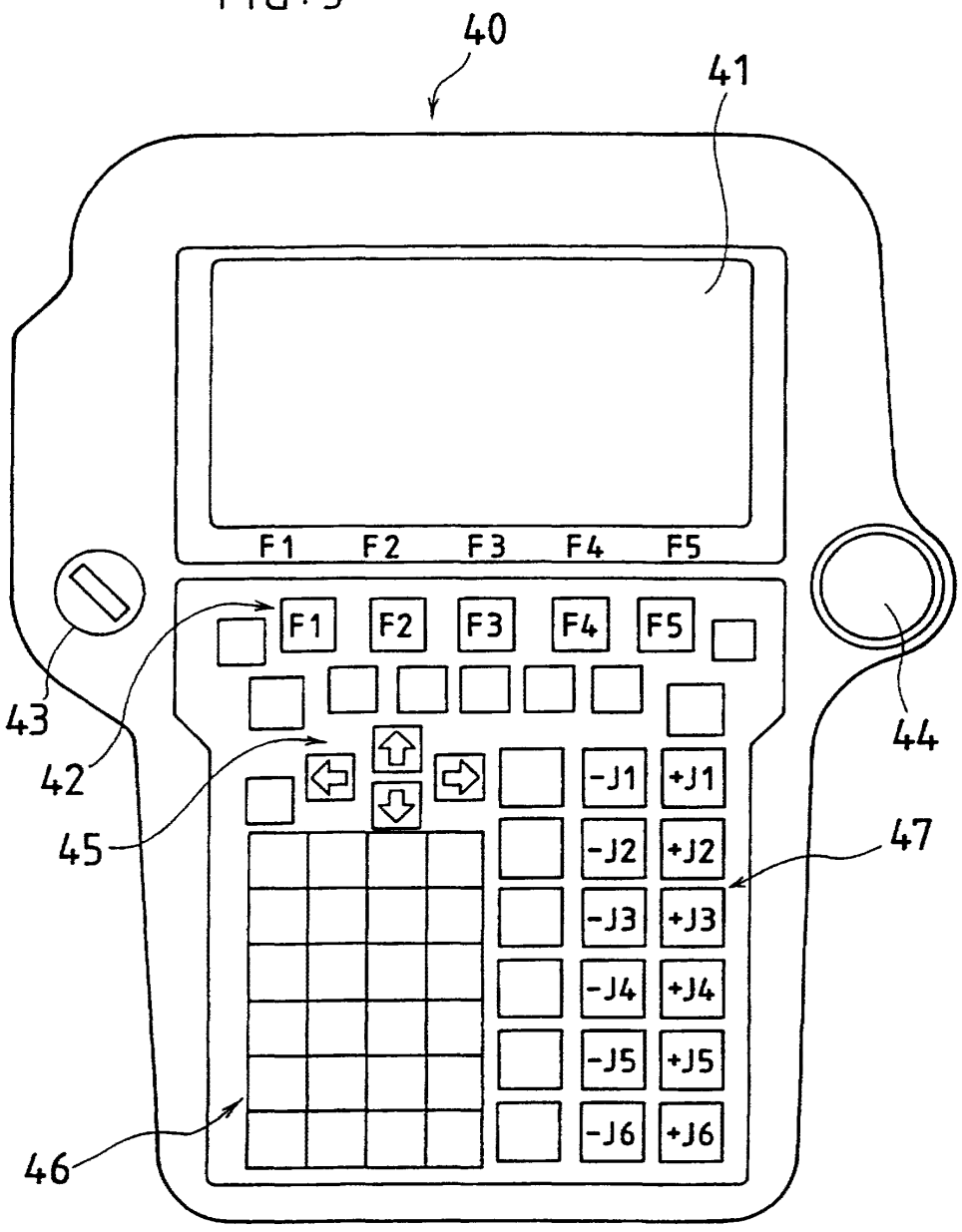


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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

FIG. 4

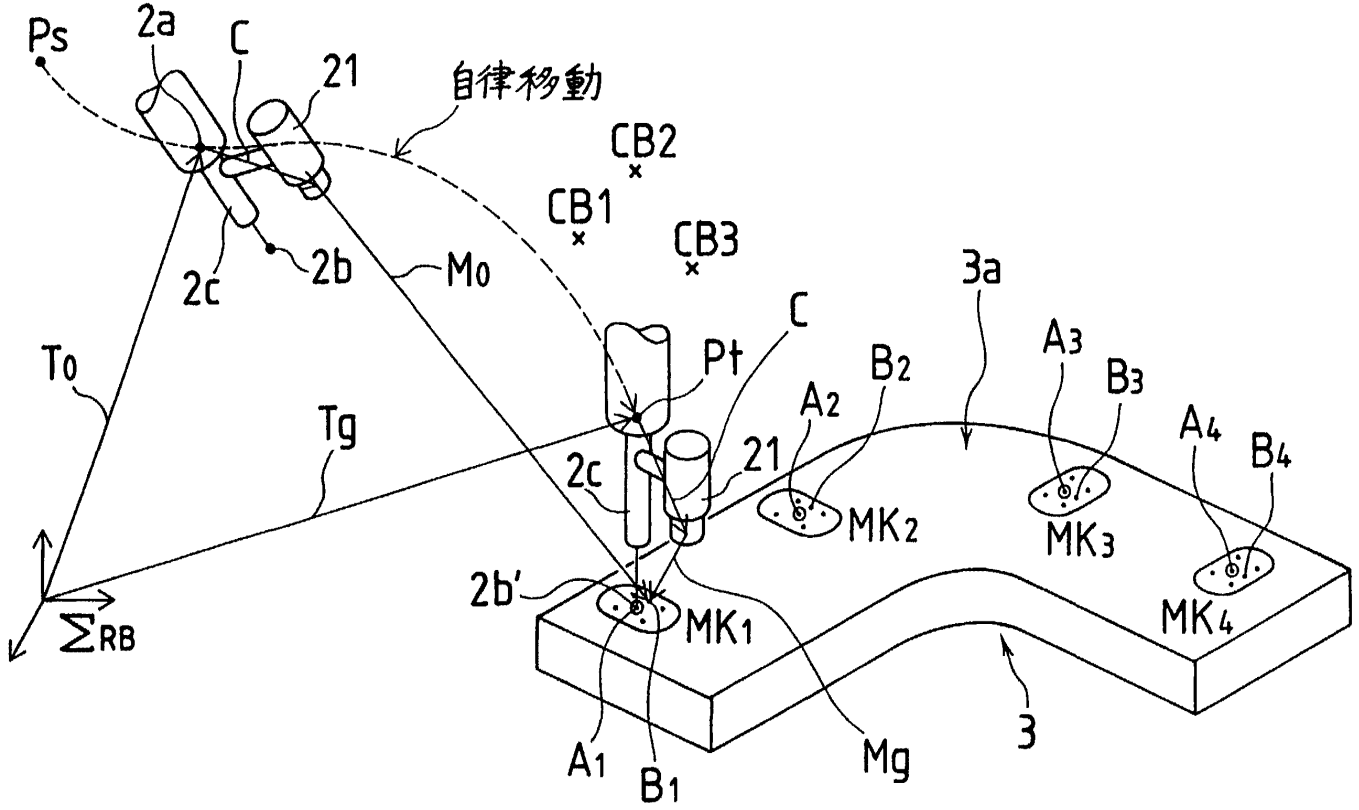

Ps
2a
C
21
自律移動
CB2
CB1
CB3
2c
2b
M0
3a
C
Pt
B2
A3
B3
A2
A4
B4
T0
Tg
2c
21
MK2
MK3
MK4
2b'
MK1
ΣRB
A1
B1
Mg
3

FIG. 5

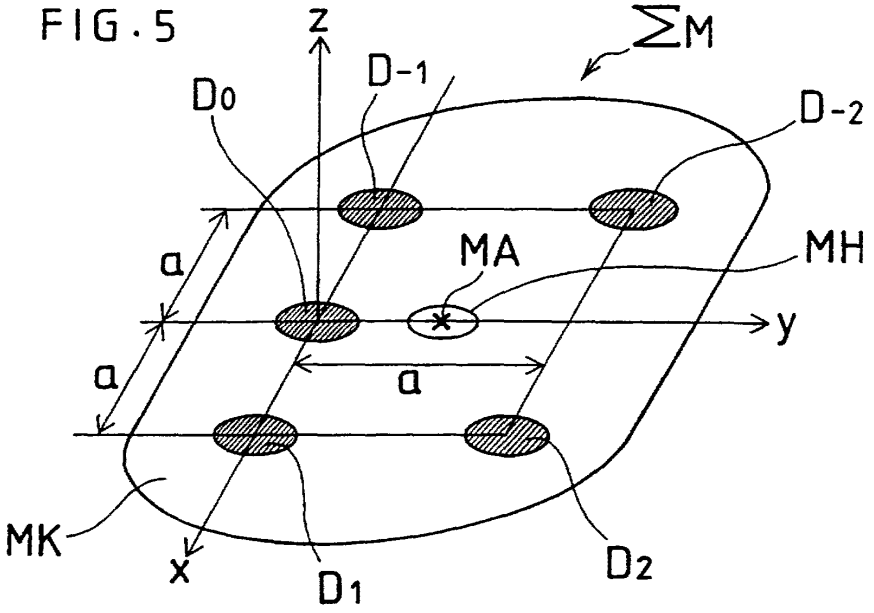


FIG. 6

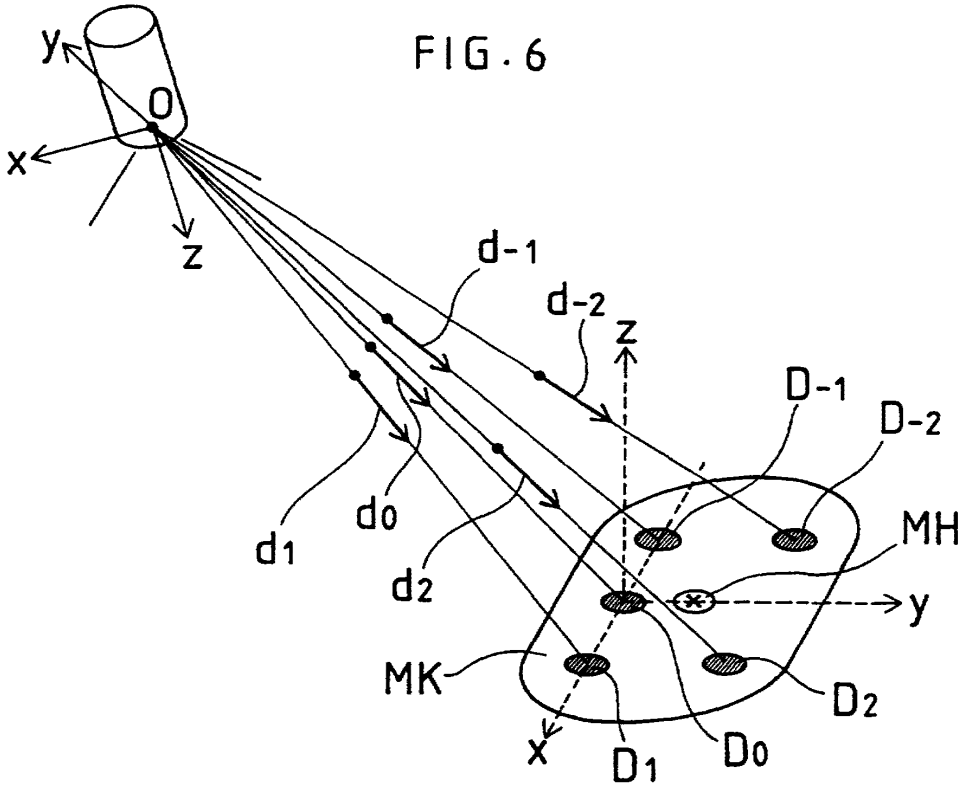


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ABB Inc. v. Roboticvisiontech, Inc.
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FIG. 7

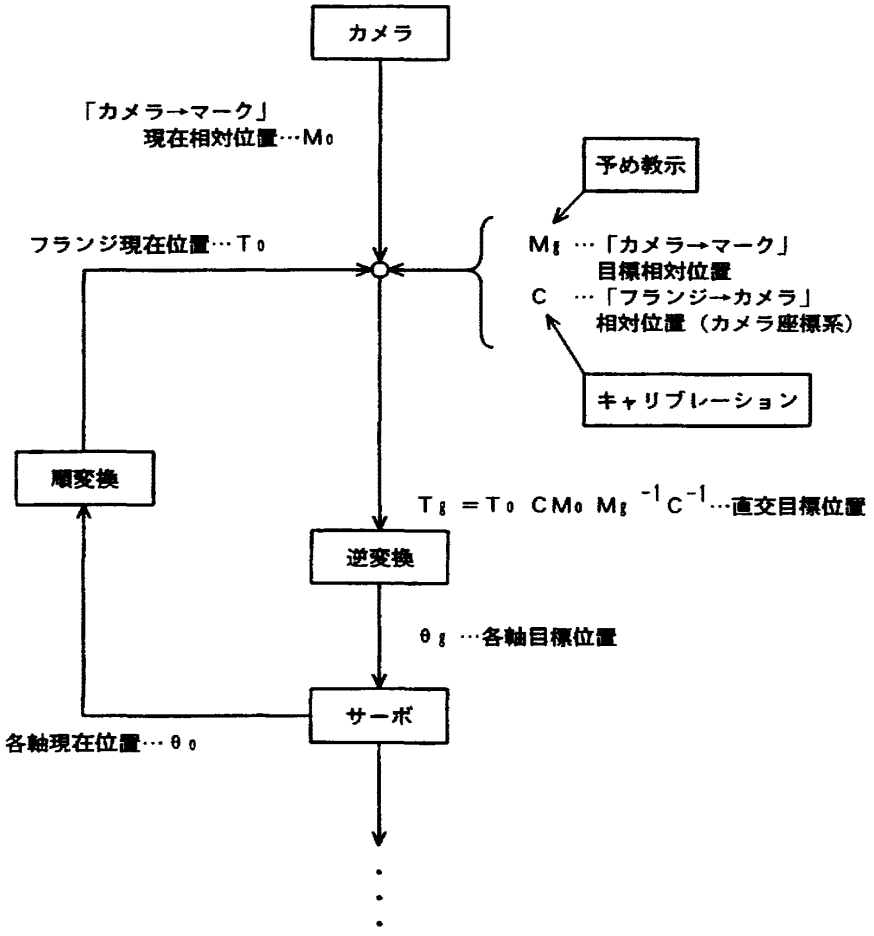


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ABB Inc. v. Roboticvisiontech, Inc.
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FIG. 8

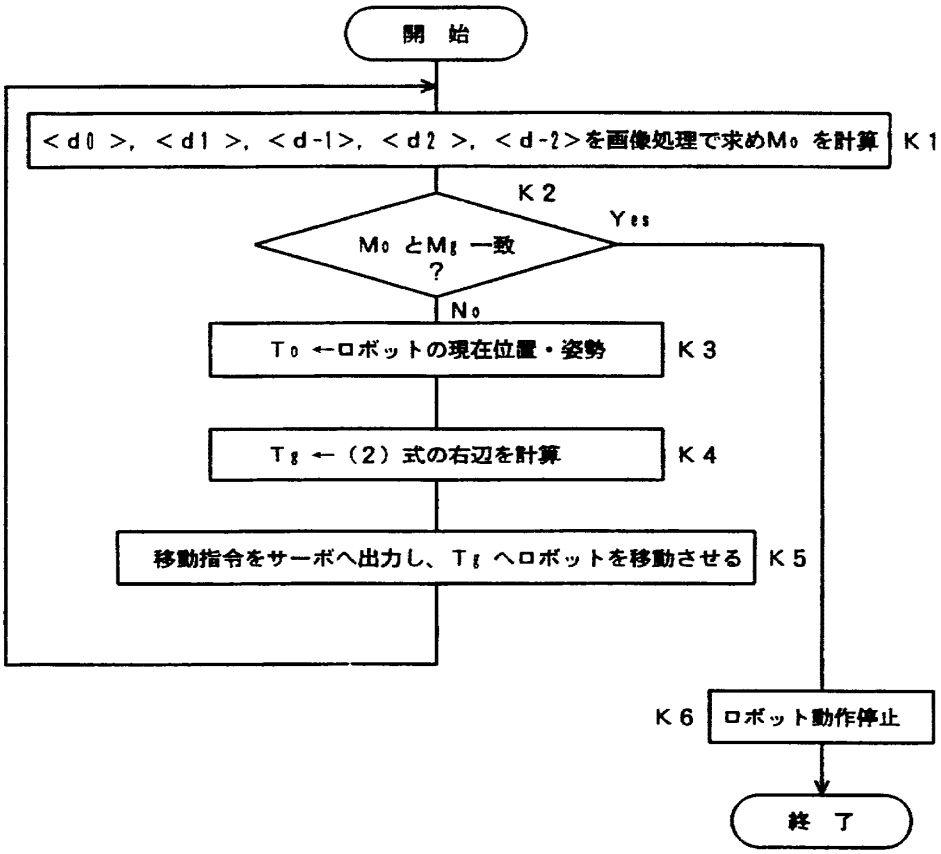


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FIG. 9

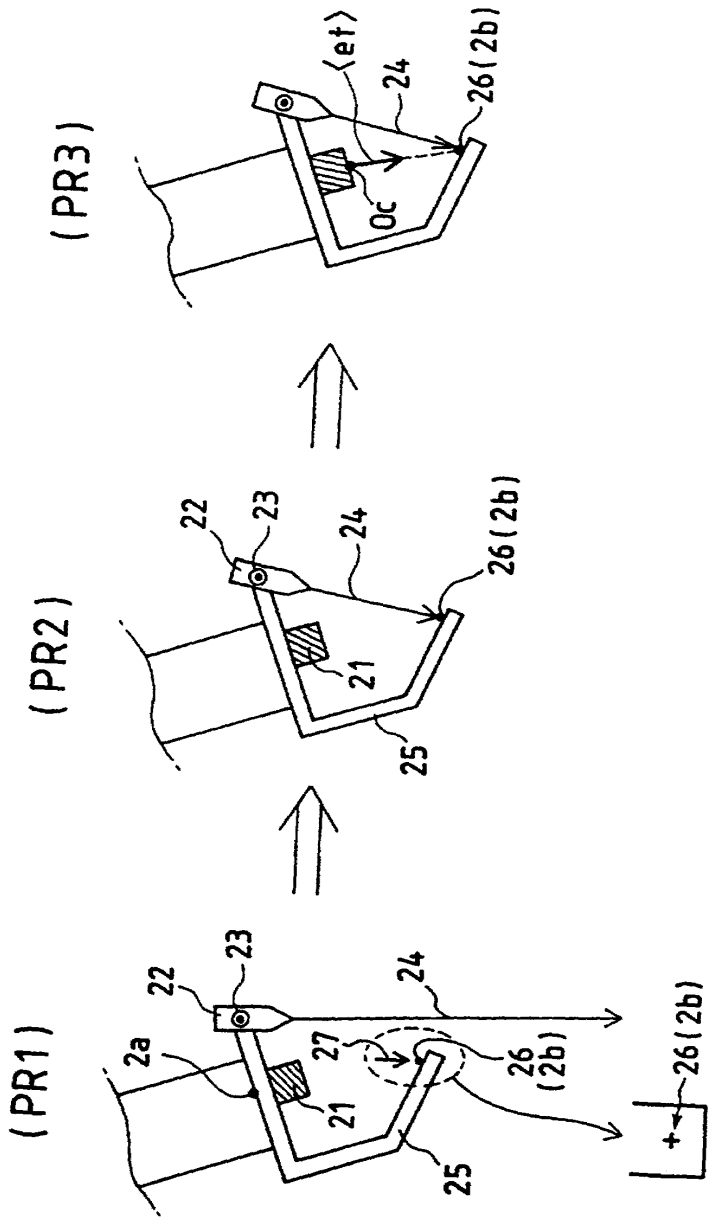


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ABB Inc. v. Roboticvisiontech, Inc.
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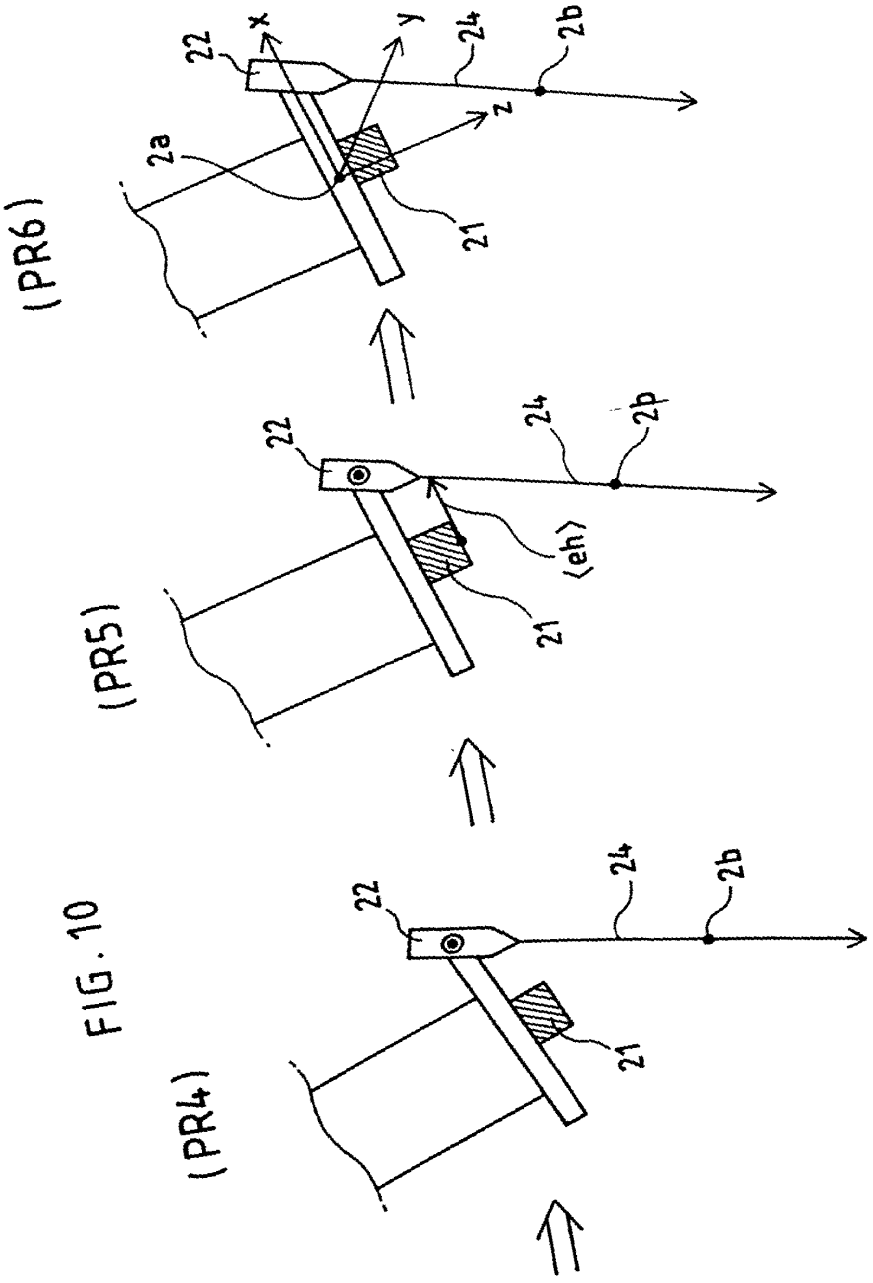


FIG. 10

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FIG. 11

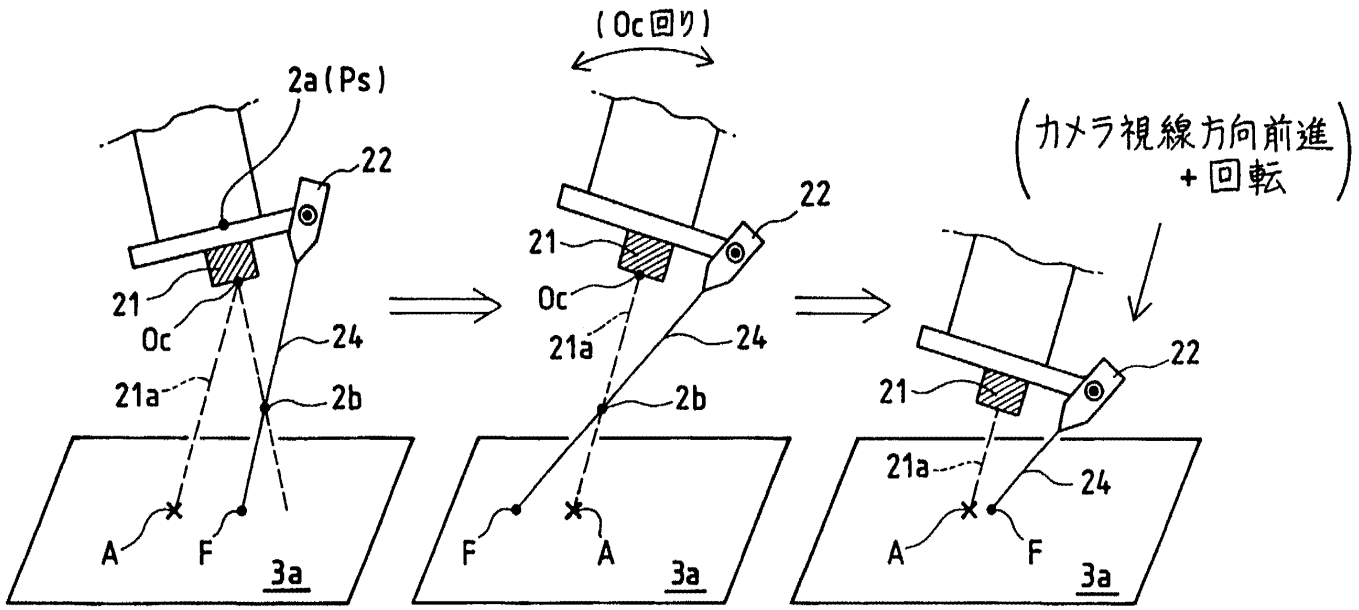


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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

FIG. 12

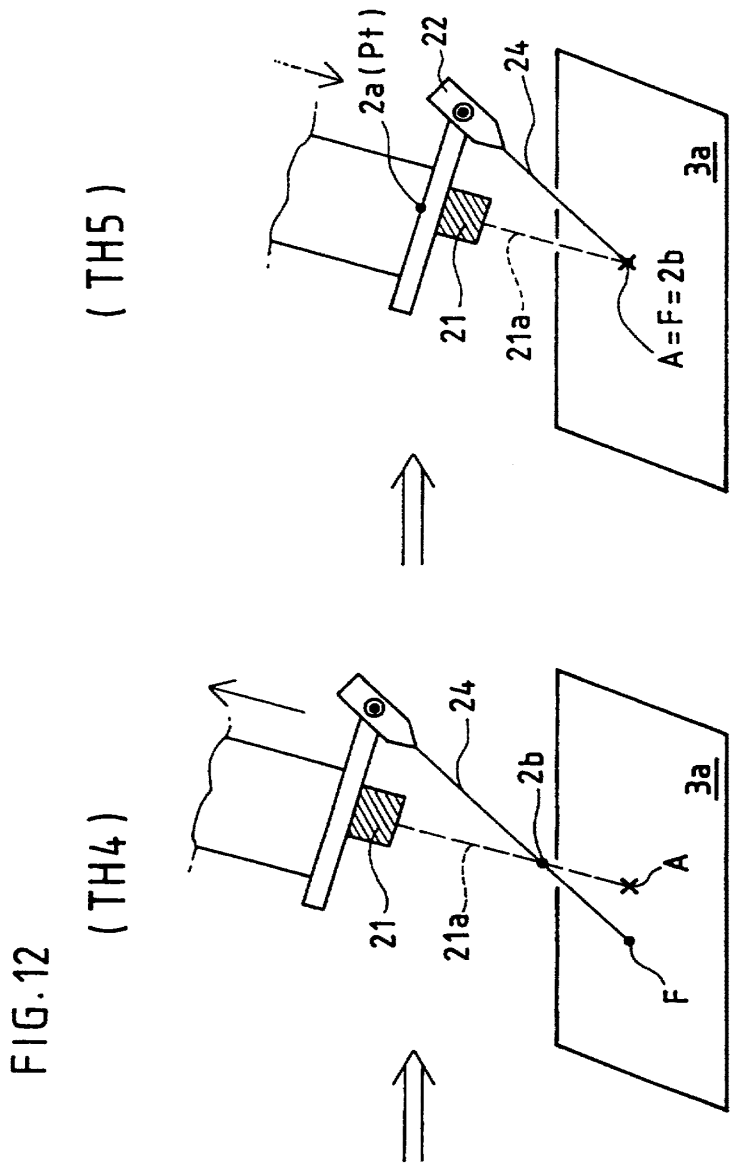


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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

FIG. 13

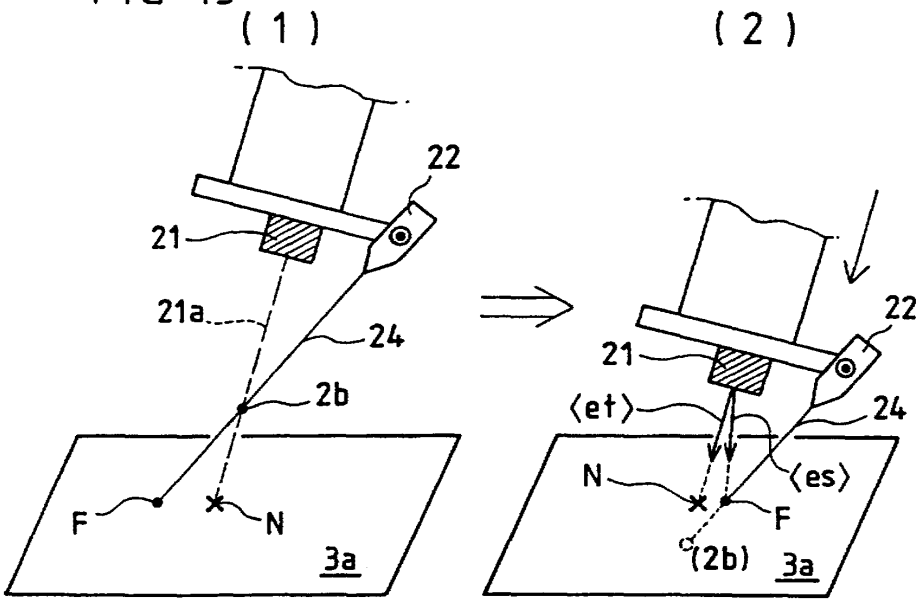


FIG. 14

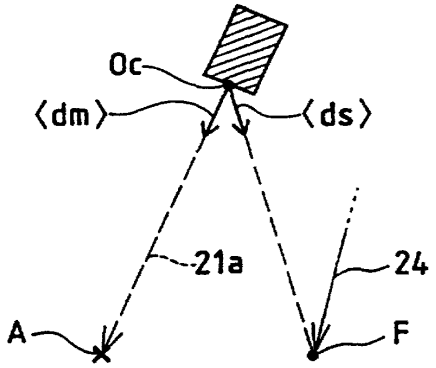


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FIG. 15

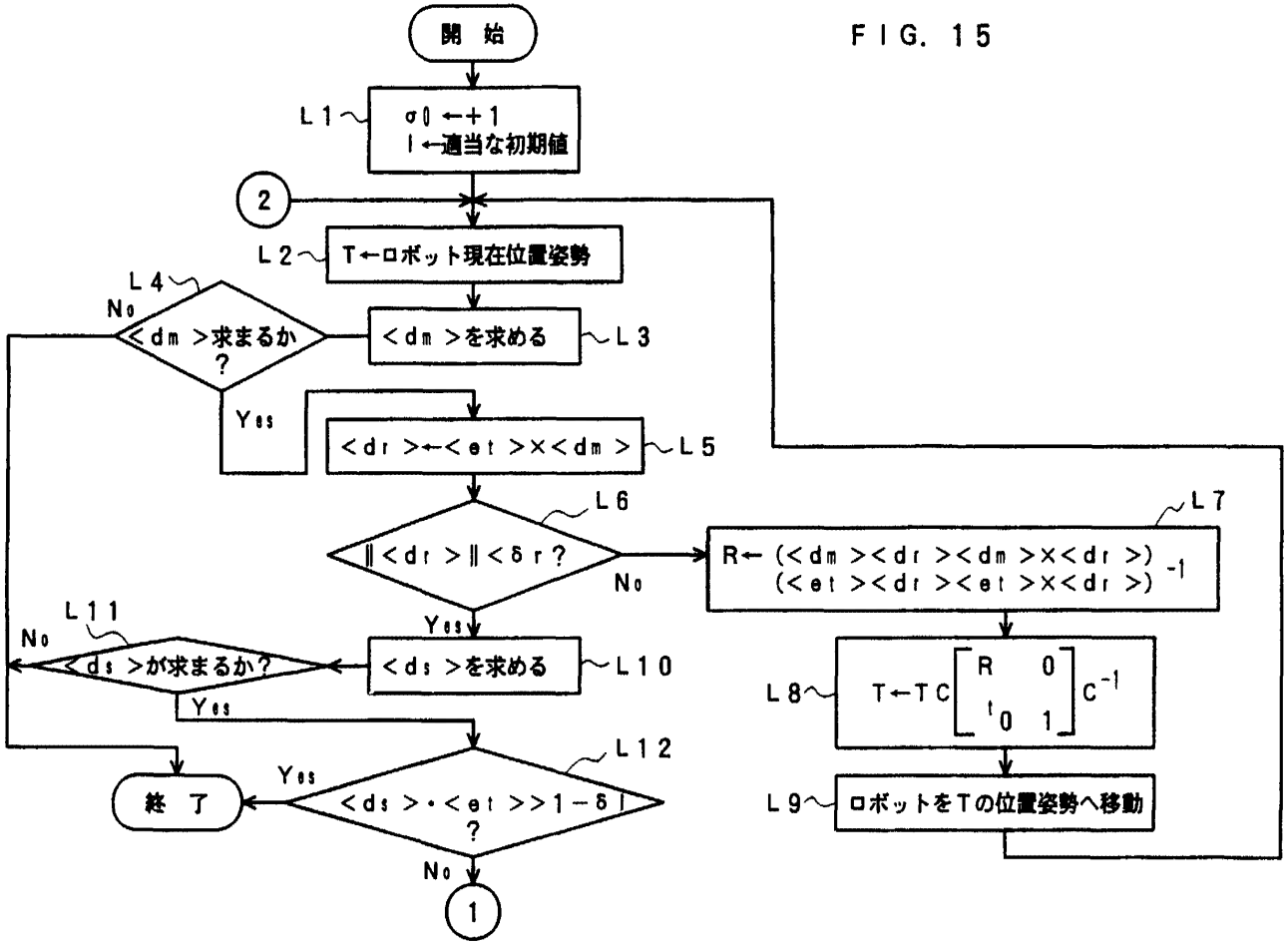

開 始
L1
σ0 ←+1
I ←適当な初期値
2
L2
T←ロボット現在位置姿勢
L4
No
<dm>求まるか?
<dm>を求める
L3
Yes
<dr>←<et>×<dm>
L5
L6
‖<dr>‖<δr?
No
L7
R← (<dm><dr><dm>×<dr>)-1
(<et><dr><et>×<dr>)
Yes
L11
No
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<ds>を求める
L10
L8
T←TC [R 0; t0 1] C-1
Yes
L12
Yes
終 了
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?
L9
ロボットをTの位置姿勢へ移動
No
1

FIG. 16

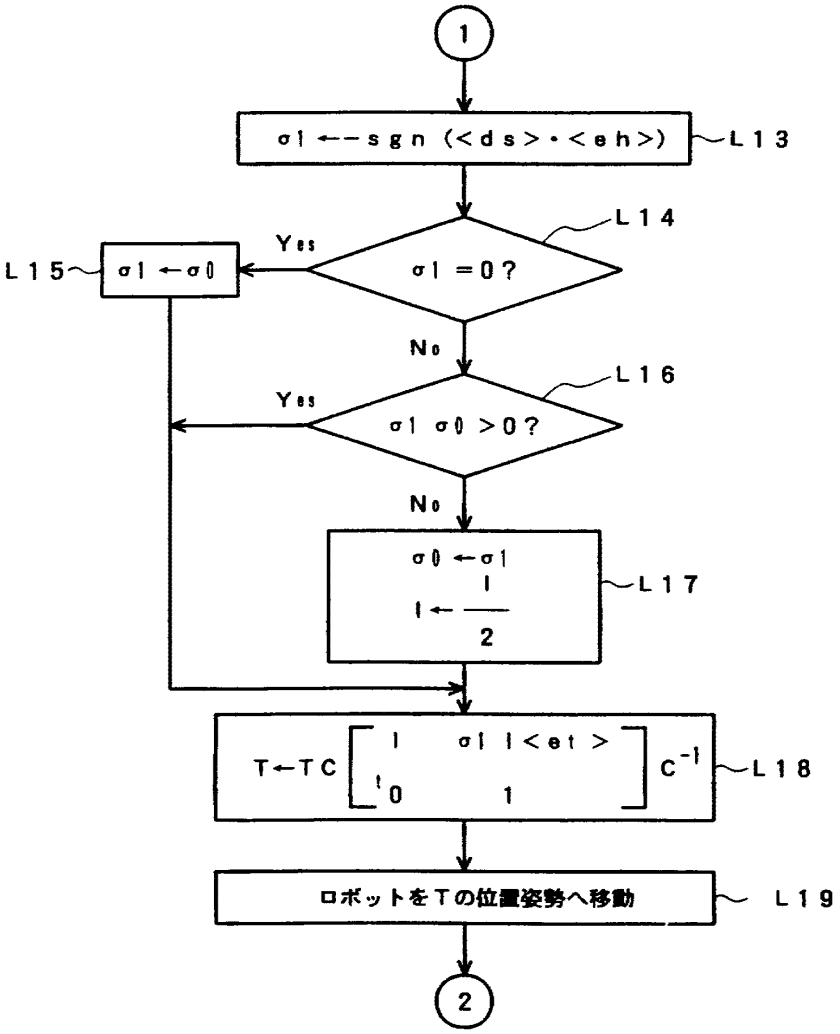


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FIG. 17

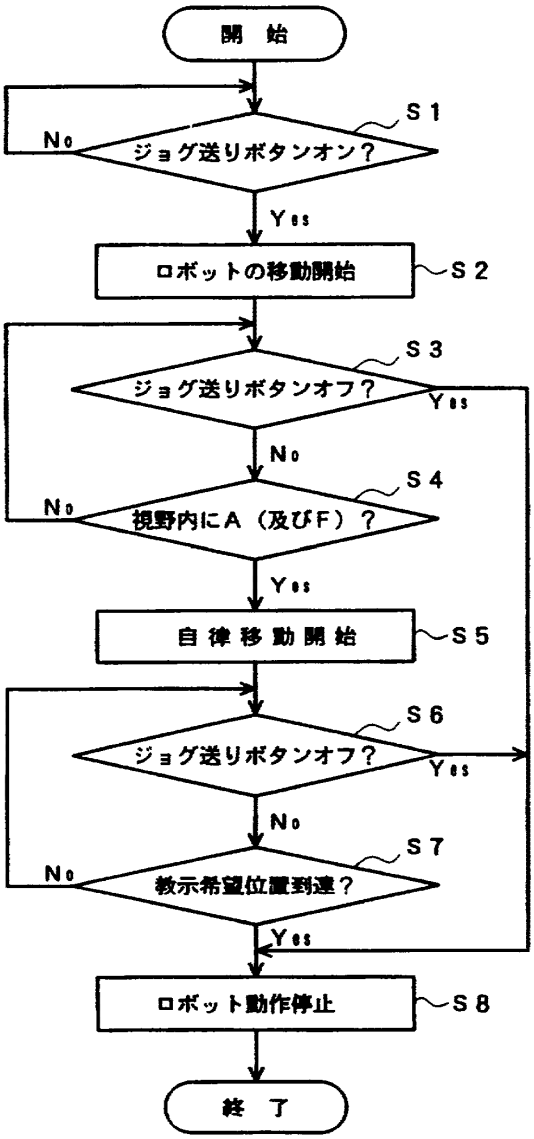


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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/02766

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 G05B19/427

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)

Int. Cl^6 G05B19/42, 19/423, 19/425, 19/427

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1965 - 1995
Kokai Jitsuyo Shinan Koho 1971 - 1994

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	JP, 63-105893, A (Hitachi, Ltd.), May 11, 1988 (11. 05. 88), Page 2, upper left column, lines 11 to 18 (Family: none)	1-4, 6-10
X Y	JP, 62-95606, A (Toshiba Corp.), May 2, 1987 (02. 05. 87), Page 2, lower right column, line 1 to page 3, upper left column, line 6 & US, A, 4879664 & WO, A1, 9007690	1 2, 5-8, 11
X Y	JP, 5-88741, A (Shin Meiwa Industry Co., Ltd.), April 9, 1993 (09. 04. 93), Page 3, left column, line 30 to right column, line 45 (Family: none)	1 2, 5-8, 11
Y	JP, 1-46804, A (Shin Meiwa Industry Co., Ltd.), February 21, 1989 (21. 02. 89), Page 2, lower right column, line 9 to page 3, upper left column, line 3 (Family: none)	2, 5-8, 11

☐ 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 document 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
October 31, 1997 (31. 10. 97)	November 11, 1997 (11. 11. 97)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

国際調査報告	国際出願番号　ＰＣＴ／ＪＰ９７／０２７６６

Ａ．　発明の属する分野の分類（国際特許分類（ＩＰＣ））

Ｉｎｔ．Ｃｌ[6]　Ｇ０５Ｂ１９／４２７

Ｂ．　調査を行った分野

調査を行った最小限資料（国際特許分類（ＩＰＣ））

Ｉｎｔ．Ｃｌ[6]　Ｇ０５Ｂ１９／４２、１９／４２３、１９／４２５、１９／４２７

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報	１９６５－１９９５年
日本国公開実用新案公報	１９７１－１９９４年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

Ｃ．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
Ｘ	ＪＰ、６３－１０５８９３、Ａ（株式会社日立製作所）、１１．５月．１９８８（１１．０５．８８）、第２頁左上欄第１１－１８行（ファミリーなし）	１－４、６－１０
Ｘ	ＪＰ、６２－９５６０６、Ａ（株式会社東芝）、	１
Ｙ	２．５月．１９８７（０２．０５．８７）、第２頁右下欄第１行－第３頁左上欄第６行＆ＵＳ、Ａ、４８７９６６４＆ＷＯ、Ａ１、９００７６９０	２、５－８、１１
Ｘ	ＪＰ、５－８８７４１、Ａ（新明和工業株式会社）、	１
Ｙ	９．４月．１９９３（０９．０４．９３）、第３頁左欄第３０行－右欄第４５行（ファミリーなし）	２、５－８、１１
Ｙ	ＪＰ、１－４６８０４、Ａ（新明和工業株式会社）、２１．２月．１９８９（２１．０２．８９）、第２頁右下欄第９行－第３頁左上欄第３行（ファミリーなし）	２、５－８、１１

☐ Ｃ欄の続きにも文献が列挙されている。　　☐ パテントファミリーに関する別紙を参照。

＊　引用文献のカテゴリー
「Ａ」特に関連のある文献ではなく、一般的技術水準を示すもの
「Ｅ」先行文献ではあるが、国際出願日以後に公表されたもの
「Ｌ」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）
「Ｏ」口頭による開示、使用、展示等に言及する文献
「Ｐ」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献
「Ｔ」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの
「Ｘ」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの
「Ｙ」特に関連のある文献であって、当該文献と他の１以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの
「＆」同一パテントファミリー文献

国際調査を完了した日	国際調査報告の発送日
３１．１０．９７	11.11.97

国際調査機関の名称及びあて先	特許庁審査官（権限のある職員）	３Ｈ	９０６４
日本国特許庁（ＩＳＡ／ＪＰ） 郵便番号１００ 東京都千代田区霞が関三丁目４番３号	牧　初　印		
	電話番号　０３－３５８１－１１０１　内線　３３１６		

様式ＰＣＴ／ＩＳＡ／２１０（第２ページ）（１９９２年７月）

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ABB Inc. v. Roboticvisiontech, Inc.
IPR2023-01426

PATENT ABSTRACTS OF JAPAN

(11)Publication number : **10-049218**
(43)Date of publication of application : **20.02.1998**

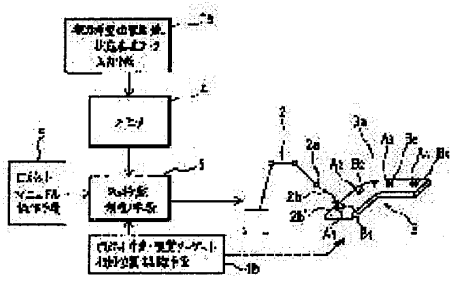
(51)Int.Cl. G05B 19/427
B25J 9/10
B25J 9/22
B25J 19/04
G05B 19/19

(21)Application number : **08-223250**
(22)Date of filing : **07.08.1996**

(71)Applicant : **FANUC LTD**
(72)Inventor : **WATANABE ATSUSHI**
KATO TETSURO
NAGAYAMA ATSURO
KUMITANI HIDETOSHI

(54) MOVEMENT CONTROL SYSTEM FOR INSTRUCTING POSITION OF ROBOT

(57)Abstract:
PROBLEM TO BE SOLVED: To make instructing operation, which makes good use of a visual sensor and a visual target, efficient.
SOLUTION: A desired instruction position arrival state representation data input means 1a which makes good use of the visual sensor previously inputs data, representing the relative position relation between the visual target B1 and a robot arm tip 2a in a state 2b' wherein the TCP 2b of the robot 2 has finished moving to a desired instruction position A1, etc., to a memory 4. An operator operates a robot manual operation means 5 such as a jog feed button to make a shaft movement control means 6 control respective shafts, thereby starting jog movement. Further, the mode is shifted from the job movement mode to an autonomous movement mode and the TCP 2b is autonomously moved to the desired instruction position A1, etc. Control over the autonomous movement is performed on the basis of the desired instruction position arrival state representation data and data obtained by a robot arm tip-visual target relative position recognizing means 1b which utilizes the visual sensor. A target means is actualized by a mark coordinate system or light spot projection means.



CLAIMS

[Claim(s)]
[Claim 1]A visual sensor provided with an image processing means which processes a picture acquired through a camera means attached to a hand part of a robot and this robot, and this camera means, In a movement control system of a robot for moving said robot to a position wishing instruction using a control means of a system containing a robot control device, A position attainment state storage step wishing instruction which makes said control means memorize position attainment state representation data wishing instruction which expresses a position attainment state wishing instruction about at least one position wishing instruction, An impaction efficiency stage wishing instruction of moving said robot to said position wishing instruction by movement controls of said robot by said control means, Instruction positional data including a teaching-positions storage step which said control means is made to memorize said impaction efficiency stage wishing instruction, Include an autonomous movement execution phase to which movement in this position wishing instruction is made to carry out autonomously based on said position attainment state representation data wishing instruction, and said position attainment state representation data wishing instruction, It is what is acquired through seeing from said visual sensor expressed using a visual target means which can be recognized with said visual sensor, and said visual sensor recognizing a position attainment equivalent state wishing instruction equivalent to a position attainment state wishing instruction, In said autonomous movement stage said visual target means, It is what provides a guidance visual target means for showing said robot to said position wishing instruction through being recognized by said visual sensor, By software processing within said control means, movement controls of said robot in said autonomous movement stage are performed, and said software processing, Said method with which a recognition state of said guidance visual target means by said visual sensor includes processing for deriving said robot so that it may be in agreement with a recognition state corresponding to said position attainment state representation data wishing instruction.
[Claim 2]Said visual target means is a mark means including a mark coordinate system which can be recognized with said visual sensor, Position attainment state representation data wishing instruction memorized by said position attainment state storage step wishing instruction, Data showing a position and a posture of said mark coordinate system on a picture is included, and said mark means, A movement control system for position instruction of a robot indicated to claim 1 which is what prepares said mark coordinate system for said position wishing instruction, and a position with fixed relative relation in order to provide said guidance visual target means.
[Claim 3]A movement control system for position instruction of a robot indicated to claim 2 with which it is a mark member which said mark means can fix on a field of a representation work made into an object of teaching work, and said mark coordinate system is drawn on this mark member.
[Claim 4]In [said visual target means is the light spot formed on a floodlighting side of an optical beam light projection means supported by said robot, and] said position attainment state storage step wishing instruction, In order to prepare said position

attainment equivalent state wishing instruction to said visual sensor, A reference floodlighting side for forming said light spot in a position which is in agreement at an instruction target point of said robot is arranged, and it lets it pass to recognize light spot formed on this reference floodlighting side with said visual sensor, It is acquired by said position attainment state representation data wishing instruction so that data showing a position on a picture of said light spot may be included, and said autonomous movement stage, It is what is performed where said optical beam floodlighting direction which removed said reference floodlighting side and was seen from said camera in said position attainment equivalent state wishing instruction is maintained, Movement controls of said robot in said autonomous movement execution phase, It is carried out, using light spot which floodlights said optical beam and is formed on a field where said position wishing instruction exists as said guidance visual target means, and a recognition state of said light spot by said visual sensor said software processing for movement controls of said robot, A movement control system for position instruction of a robot indicated to claim 1 include processing for deriving said robot so that it may be in agreement with a recognition state corresponding to said position attainment state representation data wishing instruction.

[Claim 5]A stage of jogging before an autonomous movement execution phase to said position wishing autonomous instruction is included in a move execution phase to said position wishing instruction, A movement control system for position instruction of a robot indicated in any 1 paragraph of claim 1 - claim 4 to which shift to a move execution phase from said jogging stage to said position wishing autonomous instruction is automatically performed by said control means based on an output of said visual sensor.

[Claim 6]Data showing a position on a picture of said guidance visual target means by which software processing in an autonomous movement execution phase to said position wishing instruction is recognized by said visual sensor at the time concerned, Processing which compares said position attainment state representation data wishing instruction, and processing for carrying out the movement controls of each axis of a robot based on said comparison result, It is what repeats sequentially processing which judges completion / un-completing of a position attainment state wishing instruction until a judgment of position attainment state completion wishing instruction is made, A movement control system for position instruction of a robot with which said teaching-positions storage step is performed after a judgment of this position attainment state completion wishing instruction is made and which was indicated in any 1 paragraph of claim 1 - claim 5.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]Concerning the movement control system for position instruction of a robot in more detail, this invention relates to the movement control system for moving a robot to the position wishing instruction quickly using a visual target and the visual sensor which recognizes this.

[0002]

[Description of the Prior Art]Most generally as a position teaching method of a robot, the method by jogging (robot motion by a manual input) is used. According to this teaching method, an operator operates the jogging button of a teaching control panel, and moves a robot to the position wishing instruction, and the work of teaching the position at that time to a robot is done. When off-line instruction is made and coarse position instruction has ended, or when making correction of teaching positions, fine adjustment of the teaching positions by jogging is performed.

[0003]use any -- since the work for which a robot is moved to it locating [to wish] is done by viewing with slight accuracy in relative position and posture relation of a robot hand (or end effector) and the point wishing [instruction], an operator takes skill to it. As for the number of points (a position and a posture) to be taught, since it is usually to attain to a large number, it is not new to spend great time on teaching work, either. The teaching work depending on viewing of an operator tended to produce variation for instruction accuracy, and there was a problem also in respect of reliability.

[0004]

[Problem(s) to be Solved by the Invention]This invention is made in order to conquer such a situation. That is, the purpose of this invention eases the burden which takes for an operator at the time of teaching work, and there is in providing the movement control system for position instruction of the robot which enabled improvement in the efficiency of teaching work, and reliability.

[0005]

[Means for Solving the Problem]This invention was made in view of a problem of the above-mentioned conventional technology, and an aforementioned problem is solved by enabling it to move a robot to a position wishing instruction autonomously using a visual sensor and a suitable visual target means. A position attainment state storage step wishing instruction which a control means of a system which contains a robot and a visual sensor in many stages of a method of this invention for position attainment state representation data wishing instruction expressing a position attainment state wishing instruction of a robot is made to memorize, An impaction efficiency stage wishing instruction of moving a robot to a position wishing instruction by movement controls of a robot by this control means, and a teaching-positions storage step which makes a control means memorize instruction positional data are included.

[0006]And it is the important feature of this invention that an autonomous movement execution phase made to carry out to this impaction efficiency stage wishing instruction autonomously based on position attainment state representation data wishing instruction which had movement in a position wishing instruction memorized is included.

[0007]In order to make it possible, this autonomous movement position attainment state representation data wishing instruction, It is acquired through seeing from a visual sensor expressed using a visual target means which can be recognized with a visual sensor, and said visual sensor recognizing a position attainment equivalent state wishing instruction equivalent to a position attainment state wishing instruction.

[0008]A visual target means is used in an autonomous movement stage as a guidance visual target means for showing a robot to said position wishing instruction through being recognized by a visual sensor.

[0009]Software processing performed within a control means for autonomous movement is performed so that a recognition state of a guidance visual target means by a visual

sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction and a robot may be derived. The visual target means can take a gestalt of a mark means including a mark coordinate system which can be recognized with a visual sensor. In that case, data showing a position and a posture of a mark coordinate system on a picture will be contained in position attainment state representation data wishing instruction memorized by a position attainment state storage step wishing instruction. On the other hand, this mark means is used in order to prepare a mark coordinate system for a position with fixed in order to provide a guidance visual target means for autonomous movement of a robot relative relation as a position wishing instruction. And a robot is derived so that a recognition state of a mark coordinate system by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction by movement controls based on software processing performed within a control means.

[0010]A mark member fixable on a field of a representation work made into an object of teaching work can be used for a mark means. On this mark member, a mark coordinate system is drawn by a dot pattern etc.

[0011]There is light spot formed on a floodlighting side of an optical beam light projection means supported by robot as a gestalt of another available visual target means. When using such light spot as a visual target means, in order to prepare a position attainment equivalent state wishing instruction to a visual sensor in a position attainment state storage step wishing instruction, it is an instruction target point (a point which it is going to coincide with a position wishing instruction) of a robot about light spot. Usually, it is tool point;TCP. A reference floodlighting side for forming in a position in agreement is arranged.

[0012]The optical beam floodlighting direction is adjusted and light spot is formed in an instruction target point position on this reference floodlighting side. This state is equivalent to a teaching-positions attainment equivalent state for a visual sensor. Then, light spot is recognized by a visual sensor, and position attainment state representation data wishing instruction is acquired so that data showing a position on a picture of light spot may be included.

[0013]An autonomous movement stage is performed where the optical beam floodlighting direction which removed a reference floodlighting side and was seen from a camera in a position attainment equivalent state wishing instruction is maintained. That is, movement controls of a robot in an autonomous movement execution phase are performed, using light spot which floodlights an optical beam and is formed on a field where a position wishing instruction exists as a guidance visual target means. Software processing for movement controls of a robot is performed so that a recognition state of light spot by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction and a robot may be derived.

[0014]In advance of autonomous movement to a position wishing instruction, it may be made to jog in order to perform preliminary approach to a position wishing instruction. As for shift to an autonomous movement stage from a jogging stage, in that case, it is preferred to be automatically carried out by the processing within a control means based on an output of a visual sensor.

[0015]Software processing in an autonomous movement execution phase to a position

wishing instruction, Processing which compares with position attainment state representation data wishing instruction data showing a position on a picture of a guidance visual target means recognized by a visual sensor at the time concerned, Suppose that processing for carrying out the movement controls of each axis of a robot based on a comparison result and processing which judges completion / un-completing of a position attainment state wishing instruction are repeated sequentially until a judgment of position attainment state completion wishing instruction is made.

[0016]Data of a position on a picture of a visual target means observed in this invention when a position wishing instruction is reached is inputted beforehand, and at the time of autonomous movement to a position wishing instruction. A visual target means is used like a navigation index of robot movement by observing with a visual sensor, and a robot is made to turn and derive to a position wishing instruction.

[0017]By this feature, a position attainment state wishing instruction is attained efficiently, without applying a burden to an operator. The highly convenient nature of a robot at the time of position teaching work can also be further raised by performing shift to autonomous movement from jogging with the automatic change in a system. Therefore, even when a large number [the number of positions wishing instruction], there are few burdens of teaching work and they end.

[0018]

[Embodiment of the Invention]Drawing 1 is a figure which illustrates notionally the overview of the movement control system for the position instruction of a robot according to this invention. The numerals 1a express the position attainment state representation data input means wishing instruction which inputs the data expressing the position attainment state wishing instruction. This position attainment state representation data input means 1a wishing instruction, Visual target B1 Data expressing the relative physical relationship of the visual target B1 in the state where movement in the position wishing instruction of the robot [/ else] 2 was completed, and the robot hand 2a. (it is hereafter called "the position attainment state representation data wishing instruction".) -- it has the function to input into the memory 4 beforehand.

[0019]The position wishing instruction is illustrated by the four numerals A1 on the field 3a of the representation work 3 - A4. B1 drawn A1 - near each [of A4] - B4 are given by the position A1 wishing instruction - A4 representing the position which A1 - A4 express which are visual target means and each correspond, and a fixed relation. The example of a visual target means is mentioned later. In the usual gestalt, each visual target position B1 - B4 and each position A1 wishing instruction - A4 are given so that coincidence may not be carried out, although it is close, but they can also coincide both depending on the case.

[0020]The numerals 2a and 2b express the end point position and instruction target point (usually tool point; TCP) of the robot respectively. In the following explanation, the end point position 2a of a robot shall be represented with the starting point of the coordinate system set up on the flange at the tip of a final arm.

[0021]An operator operates the robot manual operation means (robot motion instruction manual input means; teaching control panel etc.) 5, such as a jogging button, makes the shaft movement control means 6 control each axis of the robot 2, and makes movement in the position wishing instruction start in the time of actual work. The movement controls for autonomous movement in the position wishing instruction from the time of this move

start or a certain point in time after a move start are performed. The position attainment state representation data wishing instruction into which the movement controls for this autonomous movement were inputted by the position attainment state representation data input means 1a wishing instruction, It is carried out based on the relative-position-recognition data showing the relative physical relationship between the robot hand and visual target means (camera fixed to this) at each time.

[0022]The latter data is given once [at least] in the process of movement controls by the relative-position-recognition means 1b between robot hand visual targets. in the position attainment state wishing instruction -- naturally -- TCP2b -- the position wishing instruction -- one is in agreement with A1 (or A2 - A4 one) (it illustrates by numerals 2b').

[0023]The position attainment state representation data input means 1a wishing instruction and the relative-position-recognition means 1b are materialized in the form where a visual sensor is used so that it may mention later. The visual target means B1 - B4 are materialized in the form of the light spot formed of the mark coordinate system or laser beam which can be recognized with a visual sensor. In the following explanation, the gestalt which materializes a visual target means in the form of a mark coordinate system is called "the method 1", and the gestalt materialized in the form of the light spot formed of a laser beam is called "the method 2."

[0024]drawing 2 showed the outline of the hardware constitutions of the system used by this embodiment with the important section block diagram centering on a robot control device -- it is. The robot control device to which the whole was directed with the numerals 30 was equipped with the processor board 31, and this processor board 31 is provided with the central processing unit (henceforth CPU) 31a, ROM31b, and RAM31c which consist of microprocessors.

[0025]CPU31a controls the whole robot control device according to the system program stored in ROM31b. A program, a related preset value, etc. which defined the processing by the side of a robot required to perform autonomous movement to the position wishing instruction else [, such as a created operation program and various preset values,] according to the method 1 or the method 2 are stored in RAM31c. A part of RAM31c is used for temporary data storage for the computation etc. which CPU31a performs. The hard disk drive etc. which were suitably prepared as an external device are used for preservation of program data or a preset value.

[0026]The processor board 31 is combined with the bus 37, and instructions and transfer of data are performed among other portions in the robot control device 30 via this bus combination. First, the digital-servo control circuit 32 is connected to the processor board 31, and the servo motors 51-56 are driven via the servo amplifier 33 in response to the instructions from CPU31a. The servo motors 51-56 which operate each axis are built in the mechanism part of each axis of the robot 2.

[0027]The serial port 34 having a communication interface is connected to the teaching control panel 40, the image processing device 20, and the laser generator 60 with a liquid crystal display section while being combined with the bus 37. However, the laser generator 60 is used by the method 2, and is unnecessary in the method 1.

[0028]The teaching control panel 40 has the size and weight which are the grades whose carrying is possible with an operator, and the jogging button etc. which are used as a robot manual operation means are provided on the panel. In addition, the input/output

device 35 for digital signals (digital I/O) and the input/output device 36 for analog signals (analog I/O) are combined with the bus 37. When signal transfer with an end effector is required, the control section of an end effector is connected to digital I/O35 or analog I/O36. In the example mentioned later, since the arc welding robot's application is considered, the electric power unit of an arc welding torch is connected to digital I/O35.
[0029]The image processing device 20 is the usual thing which made CPU carry out bus combination of program memory, a frame memory, an image processing processor, data memory, the camera interface, etc. The camera 21 is connected to the image processing device 20 via the camera interface. This camera is used for the photography for acquiring the picture of a visual target means in the mode mentioned later. The program data for image analyses needed by the method 1 or the method 2 is stored in program memory.
[0030]Drawing 3 is a figure showing the outline composition of the panel surface of the teaching control panel 40. The display screen 41 is a liquid crystal display, and the detailed data of a movement command program, etc. change it, and it is displayed. The function key 42 is a key which selects the menu displayed on the lower end part of the display screen 41. The teaching control panel effective switch 43 is a switch which switches whether operation of the teaching control panel 40 is effective or invalid.
[0031]The emergency stop button 44 is a button to which the emergency stop of the operation of the robot 2 is carried out. The cursor key 45 is a key which moves the cursor displayed on the display screen 41. A numerical keypad and other keys are provided in the ten key part 46, and input of a numerical value and a character, deletion, etc. can be performed to it.
[0032]Although a series of jogging buttons 47 (J1-J6) are buttons which specify advancing side by side / hand of cut, and the direction of +-, and input a movement command in the normal mode which jogs a conventional system, According to this embodiment (autonomous movement mode), it is used as an autonomous movement command input means to the position wishing instruction so that it may mention later. The details of an embodiment are explained below about the method 1 and the method 2 on the assumption that the above matter.
[0033][Method 1]
[1] The schematic diagram 4 is a figure explaining operation of the autonomous movement in the embodiment by the method 1. On the field 3a of the representation work directed with the numerals 3 as well as drawing 1, a number (here four pieces) corresponding to the number of the teaching points A1 - A4 to wish of mark members MK1-MK4 are stuck. On each mark member, the same mark coordinate system is drawn by the dot pattern so that it may mention later. Mark member MK1 is stuck by the position and the posture in which it corresponds to the position and posture of the point A1 wishing [instruction] correctly. Similarly, the mark members MK2-MK4 are stuck by the position and the posture in which it corresponds to the point A2 wishing [instruction] - the position and posture of A4 correctly respectively.
[0034]The robot which carried out representation only of the hand part circumference carries the welding torch 2c and the camera 21 in the hand part, and TCP2b is set up at the tip of welding torch 2c. By this embodiment, a robot is left from the move starting position Ps, autonomous movement of the TCP2b set up at the tip of the welding torch 2c is carried out to the point A1 wishing [instruction] - A4 one by one, and the case where position instruction is performed in each position wishing instruction is considered.

Generally the starting position Ps of autonomous movement is arbitrary, if mark MK1 of the beginning is a position included in the view of the camera 21.
[0035]Drawing 5 is a figure explaining the composition of the mark member used by the embodiment by the method 1. Reference of the figure constitutes mark coordinate system sigmaM from the five circular dots D0 arranged in the shape of a lattice by the interval a on the mark member MK, D1, D-1, D2, and D-2. Dot space a is positive constant value. Therefore, the center position of each dot is set to D0 (0, 0, 0), D1 (a, 0, 0), D-1 (- a, 0, 0), D2 (a, a, 0), and D-2 (- a, a, 0). As long as it can express a three-dimensional rectangular coordinate system, a mark coordinate system may consist of other patterns.
[0036]Hole MH is provided in the regular position where the mark member MK is suitable. This hole MH points to the position wishing instruction, and when sticking on the field 3a of the representation work 3, a sticking position is chosen so that that representative point (for example, center) may be in agreement with the position wishing instruction. A pasting posture is chosen with reference to direction of mark coordinate system sigmaM. That is, if pasting postures differ, the postures taught later also differ. For example, since the pasting posture of MK1 and MK4 in drawing 4 is different 90 degrees, it becomes what differed also in the posture taught later 90 degrees.
[0037][2] Preparation (the calibration of a camera, and acquisition of the position attainment state representation data wishing instruction)
1. Perform the calibration of the camera with the application of suitable calibration method in advance of working starting. Although various techniques are known by the calibration of the camera, the mark member shown here can also be used. The outline is described on the convenience of explanation, and in the back.
[0038]2. Perform acquisition of the position attainment state representation data wishing instruction. First, the mark member MK is fixed to a suitable position. Of course, one of the mark members stuck on the representation work 3 can also be used as it is. First, by jog operation of the normal mode (conventional system), a robot is moved, tool point 2b is coincided with representative point MA of hole MH of the mark member MK, and it is made to take the posture wishing instruction. It means that the position attainment state wishing instruction was realized about the mark member MK by this.
[0039]3. If the position attainment state wishing instruction is realized about the mark member MK, photography with the camera 21 will be made to perform via the robot control device 30, and the picture for creating the position attainment state representation data wishing instruction will be acquired.
4. Image processing of the acquired picture is carried out within the image processing device 20, and the data showing the relative positional attitude of mark coordinate system sigmaM to the camera coordinate system of the camera 21 is created (it mentions later for details).
[0040][3] Start movement in the position wishing autonomous instruction from the approach starting position Ps (it expresses in a flange position) shown in processing drawing 4 at the time of the position autonomous movement wishing instruction in the method 1, and explain the algorithm of the processing for attaining movement in the position Pt (it expresses in a flange position) wishing instruction. In the following explanation, since a vector is expressed, sign <> is used.
1. Skeleton drawing 7 of an algorithm describes the skeleton of an algorithm required for movement in the autonomous position wishing instruction. The current position (position

at each [under movement in the position wishing instruction] time) T0 of a flange, and the present relative position (relative position at each [in the moving process to the position wishing instruction] time) M0 of a camera coordinate system and a mark coordinate system, As [describe / the geometric relation with the flange position Tg and relative-position (target relative position) Mg of a camera coordinate system and a mark coordinate system in the position attainment state wishing instruction in the position attainment state wishing instruction / into drawing 4]

[0041]And Mg is equivalent to the position attainment state representation data wishing instruction acquired by the above-mentioned preparatory work. C is taught by a camera calibration. The fundamental equation which specifies the relation between these [T0], M0, Tg, and Mg is as follows.

T0 CM0 =Tg CMg ... (1), therefore the following formula (2) which solved this about Tg turn into a basic equation showing the moving-target position on the rectangular coordinate system of a robot.

$Tg = T0\ CM0\ Mg^{-1}C^{-1}$ ... (2)

If the position instruction which makes this Tg a final moving-target point is given to a servo, a robot can be turned to the position wishing instruction and can be moved autonomously. Therefore, defining the algorithm of the autonomous movement to the position wishing instruction results in the problem which asks for the right-hand side of (2) types concretely.

[0042](2) Among the right-hand side of a formula, T0 expresses the present position data of the robot, and is data of the character obtained within a robot control device at any time. The data of C is separately gained by a suitable camera calibration (the example of a calibration is mentioned later). Then, it explains from how to calculate M0 and Mg.

[0043]2. Each of equations M0 of M0 and Mg and Mg expresses the position and the posture of mark coordinate system sigmaM seen from the camera coordinate system (at the time of the completion of the present and approach).

[0044]Since it is positive constant value, the arrangement interval a of the circular dots D0 which constitute mark coordinate system sigmaM (refer to drawing 5) used by this embodiment, D1, D-1, D2, and D-2 is a> 0... It is (3). M0 and Mg are the homogeneous transformation processions of 4x4 expressing the relation between the position and posture between three-dimensional rectangular coordinate systems, and can be placed like a following formula (4).

[0045]

[Equation 1]

$$M = \begin{bmatrix} RM & lM \\ {}^{t}0 & 1 \end{bmatrix} \quad \cdots (4)$$

Here, 3x3 processions for which RM expresses rotation, and lM are 3x1 processions (vector) showing a position. It considers asking for the equation which RM and lM fill hereafter as an equation which M0 and Mg fill. First, the following formula (5) and (6) defines a vector <e1> and <e2>.

[0046]

[Equation 2]

$$<e1>=\begin{bmatrix}1\\0\\0\end{bmatrix} \quad \cdots (5)$$

$$<e2>=\begin{bmatrix}0\\1\\0\end{bmatrix} \quad \cdots (6)$$

As for the information acquired from a visual sensor about mark coordinate system sigmaM, the center of each circular dots D0, D1, D-1, D2, and D-2 aims (sight line direction) to be in sight from the starting point of a camera coordinate system. These directions can be expressed with five unit vectors <d0>, <d1>, <d-1>, <d2>, and <d-2> as shown in drawing 6.

[0047]deltaij defined by the following formula (7) is introduced about the inner product of these vectors.

deltaij=<di>- <dj> (i, j=-2, -1, 0, 1, 2) ... (7) -- here, since all the length of <d0>, <d1>, <d-1>, <d2>, and <d-2> is 1, the absolute value of deltaij does not exceed 1.

| deltaij|<=1 (a necessary and sufficient condition for equal mark formation is i=j) ... (8)

Although distance from the camera coordinate system starting point to each dot center is unknown, this is placed with ti (i=-2, -1, 0, 1, 2). Naturally these take a positive value.

[0048]

ti >0 (i=-2, -1, 0, 1, 2) ... If (9) is carried out, following equation (10) - (12) will be obtained.

t0 <d0> =lM ... (10) t1 <d1> =lM+aRM <e1> ... (11a)

t-1<d-1> =lM -aRM <e1> ... (11b)

t2 <d2> =t1 <d1>+aRM <e2> ... (12a)

t-2<d-2> =t-1<d-1>+aRM <e2> ... (12b)

Therefore, if an equation of these is solved about RM and lM and it goes, calculating ti, M0 and Mg can be defined. A concrete solution will be explained by a paragraph of how to calculate 4.M0 and Mg, and C showing a position and a posture of a camera coordinate system is described briefly.

[0049]3. The equation C of C is a procession expressing a position and a posture of a camera coordinate system seen from a flange, and the data is obtained by calibration of the camera 21. Although various techniques are publicly known about a calibration and they can be used, even if it uses mark coordinate system sigmaM, a calibration of the camera 21 can also be performed. Here, only the main point is described briefly.

[0050]In three different points as shown with the numerals CB1-CB3 in drawing 4, photography with the camera 21 is performed respectively, image processing is performed and the data Pi (i= 1, 2, 3) about a relative position between the starting points of mark coordinate system sigmaM and a camera coordinate system is obtained. If data Ti (i= 1, 2, 3) of a robot position at the time of they and each photography is combined, the following 3 sets of equations will be obtained. The point which calculates Pi (i= 1, 2, 3) is the same as that of M0 or Mg.

T1 CP1 =T2 CP2 =T3 CP3 ... (13)

Under conditions from which three postures of a robot of CB1-CB3 differ mutually, it is possible to solve this equation about C. This condition is set to (14).

Conditions: T1 and T2 differ from each posture ingredient of T3 mutually. ... Data of C

(14) Called for is memorized by a robot control device or image processing device. About a solution of an equation, it explains supplementarily depending on how to ask for 5.C.

[0051]4. In M0 and Mg asking, and solving equation (10) - (12) here and there, and calculating RM and lM, consider calculating ti (i=-2, -1, 0, 1, 2) first. Therefore, a following formula (15) is replaced.

[0052]

[Equation 3]

$$<rM>=\begin{bmatrix} rMx \\ rMy \\ rMz \end{bmatrix} = RM^{-1} <lM> \quad \cdots (15)$$

And equation (10) - (11) is transformed like following formula (16) - (18) using this. <rM> =t0 RM^{-1} <d0> ... <rM>+a<e1 >=t1 RM^{-1} <d1> ... <rM>-a<e1 >=t-1RM^{-1} <d-1> ... (18) -- here, (17) (16) If RM^{-1} is cautious of it being a procession showing rotation, a following formula (19) will be materialized.

(RM^{-1} <di>) -(RM^{-1} <dj>) =<di> - <dj> (i, j=-2, -1, 0, 1, 2) ... If this (19) (19) type, and (5) - (8) type and (16) - (18) type are used, following expression-of-relations (20) - (23) will be obtained.

[0053]

$||<rM>||^2=t0^2$ ... (20) $||<rM>||^2+2$ arMx+$a^2=t1^2$ ... (21a)

$||||[<rM>]^2-2$ arMx+$a^2=t-1^2$ ... (21b)

$||<rM>||^2$+arMx=t 0t1delta0 and 1 --- (22a)

$||<rM>||^2$-arMx=t0 t-1delta0 and -1 --- (22b)

delta 0, $1^2<1$, delta 0, and $-1^2<1$ --- (23)

If it arranges carefully from these formulas for $||<rM>||^2$+arMx, adelta0, 1 and $||<rM>||^2$-arMx, and adelta0 and -1 to become a same sign from conditions (3), (9), a formula (22a), and (22b) respectively, following formula (24a) - (25b) will be obtained.

[0054]

[Equation 4]

$$\|<rM>\|^2 + arMx = a\alpha + \sqrt{rMy^2 + rMz^2} \quad \cdots (24a)$$

$$\|<rM>\|^2 - arMx = a\alpha - \sqrt{rMy^2 + rMz^2} \quad \cdots (24b)$$

(但し、

$$\alpha + \overset{def}{=} \frac{\delta 0,1}{\sqrt{1-\delta 0,1^2}} \quad \cdots (25a)$$

$$\alpha - \overset{def}{=} \frac{\delta 0,-1}{\sqrt{1-\delta 0,-1^2}} \quad \cdots (25b)$$

If a formula (24a) and (24b) change further, the following formula (26) and (27) will be obtained.

$||<rM>||^2=(a^2$beta+$^2)/(1+$beta-$^2)$ ... (26) rMx=(abeta+beta-)/(1+beta-^{2}) ... (27) however beta+, and beta- shall be defined by a following formula (28a) and (28b).

beta+ = (alpha++alpha-) / 2 ... (28a)

beta- = (alpha+-alpha-) / 2 ... (28b)
And if the formula (26) and (27) is substituted for the formula (20), (21a), and (21 b) and the conditions (3) and (9) are used, t0, t1, and t-1 can be found with the following formula (29), (30a), and (30b).
[0055]
[Equation 5]

$$t0 = a\sqrt{\frac{\beta+^2}{1+\beta-^2}} \quad \cdots (29)$$

$$t1 = a\sqrt{\frac{1+\alpha+^2}{1+\beta-^2}} \quad \cdots (30a)$$

$$t-1 = a\sqrt{\frac{1+\alpha-^2}{1+\beta-^2}} \quad \cdots (30b)$$

t2, t-2, <lM>, and RM are further calculated as follows using these.
[0056]
[Equation 6]

$$t2 = \frac{t1 - t-1\delta1,-1}{t1\delta1,2 - t-1\delta-1,2}\, t1 \quad \cdots (30c1)$$

(t1δ1,2 − t-1δ-1,2 ≠ 0の場合)

$$t-2 = \frac{t-1 - t1\delta1,-1}{t-1\delta-1,-2 - t1\delta1,-2}\, t-1 \quad \cdots (30c2)$$

(t1δ1,2 − t-1δ-1,2 = 0の場合)

$$<IM> = t0<d0> \quad \cdots (30d)$$

$$<RM> = (<f1><f2><f3>) \quad \cdots (30e)$$

但し、 $$<f1> = \frac{1}{2a}(t1<d1> - t-1<d-1>) \quad \cdots (30f)$$

$$<f2> = \begin{cases} \frac{1}{a}(t2<d2> - t1<d1>) & (t1\delta1,2 - t-1\delta-1,2 \neq 0の場合) \\ \frac{1}{a}(t-2<d-2> - t-1<d-1>) & (t1\delta1,2 - t-1\delta-1,2 = 0の場合) \end{cases} \quad \cdots (30g)$$

$$<f3> = <f1> \times <f2> \quad \cdots (30h)$$

5. Solve the above-mentioned equation (13) under the conditions (14) of the how [to ask for C] above-mentioned. Modification of an equation (13) will obtain the following (31) and (32).
$C^{-1}T1^{-1}T3\ C=P1\ P3^{-1}$ ... $C^{-1}T2^{-1}T3\ C=P2\ P3^{-1}$ ... (32) -- replacement which followed

following formula (33) - (37) here is performed. (31)

[0057]

[Equation 7]

$$\begin{bmatrix} Rc & lc \\ t_0 & 1 \end{bmatrix} \overset{def}{=} C \quad \cdots (33)$$

$$\begin{bmatrix} R1 & l1 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} T1^{-1}T3 \quad \cdots (34)$$

$$\begin{bmatrix} R2 & l2 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} P1P3^{-1} \quad \cdots (35)$$

$$\begin{bmatrix} R3 & l3 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} T2^{-1}T3 \quad \cdots (36)$$

$$\begin{bmatrix} R4 & l4 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} P2P3^{-1} \quad \cdots (37)$$

Then, the equation (31) and (32) is decomposed into following equation (38) - (41).
$RC^{-1}R1\ RC = R2$ ... (38) $RC^{-1}R3\ RC = R4$ ... (39) $<(I-R1)\ lC> = <l1> - RC <l2>$ ... (40) $<(I-R3)\ lC> = <l3> - RC <l4>$ ... (41)
Therefore, it becomes a target to calculate RC and <lC>. Here, a form of an equation (38) and (39) shows that both similar transformation processions expressing the similarity R1 during a rotation procession - R2, R3 - R4, and those similarity relations are RC. Then, the following formula (42) and (43) is obtained considering a vector showing a hand of cut of Ri (i= 1, 2, 3, 4) as <vi> (i= 1, 2, 3, 4). Here, <vi> (i= 1, 2, 3, 4) can be uniquely defined from conditions (14), a definitional equation (34), and (36).
<v1> =RC <v2 > ... (42) <v3> =RC <v4> ... (43)
RC can be calculated if a relation of a following formula (44) is used.
(<v1>, <v3>, and <v1> x <v3>) =RC (<v2>, <v4>, and <v2> x <v4>) ... About (44) equations (40) and (41), a form of a following formula (45) is used at a bundle, and if a least-squares method is applied, <lC> will be calculated.

[0058]

[Equation 8]

$$\begin{bmatrix} I & -R1 \\ I & -R3 \end{bmatrix} <lC> = \begin{bmatrix} <l1> \\ <l3> \end{bmatrix} - RC \begin{bmatrix} <l2> \\ <l4> \end{bmatrix} \quad \cdots (45)$$

6. Explain the outline of the process flow for movement in the preparatory work and the position wishing autonomous instruction in the method 1 on the assumption that the explanation item of beyond outline of process flow of movement controls by method 1 1.

- 5. First, it is as follows if supplemented about a preparatory work.
(1) preceding working starting -- the above 3 -- as it came out and explained, move a robot to the three positions CB1-CB3 one by one.
(2) In each positions CB1-CB3, acquire the picture of mark coordinate system sigmaM (one piece) of mark member MK1 on the representation work 3, and acquire the data which expresses the sight line direction based on [each] dots by image processing in the image processing device 20.
(3) Perform processing according to the algorithm explained by above-mentioned 5. within the image processing device 20, and compute and memorize the data (data of RC and <lC>) of camera coordinate system C.
[0059](4) When a camera calibration is completed, move a robot to the position Pt shown in drawing 4, and make the position attainment state wishing instruction over mark MK1 appear.
[0060](5) Acquire a picture of mark coordinate system sigmaM and acquire data which expresses a sight line direction based on [each] dots by image processing in the image processing device 20.
(6) Perform processing according to an algorithm explained by above-mentioned 1.2.4. within the image processing device 20, and compute and memorize position attainment state representation data wishing instruction (data of Mg).
[0061]Autonomous movement in a position wishing instruction is performed by a processing cycle containing many following steps, as shown in a flow chart of drawing 8.
[K1] <d0>, <d1>, <d-1>, <d2>, and <d-2> are calculated by image processing, and M0 is calculated.
[K2] M0 calculated from <d0> calculated at data and Step K1 of Mg memorized, <d1>, <d-1>, <d2>, and <d-2> is compared, and both coincidence/disagreement are judged. If in agreement, since an attainment state to a position wishing instruction is meant, it progresses to Step K6. If inharmonious, since it means not having reached a position wishing instruction, it returns to Step K1 via Step K3 - K5. Various algorithms can be used for evaluation of the degree of coincidence of Mg and M0. for example, what is necessary is to compute the deciding index delta with a following formula (46), and just to suppose approach un-completing, if it is delta<epsilon (epsilon -- enough -- smallness -- a positive value) and is the completion of approach, and delta>=epsilon
[0062]
[Equation 9]

$$\Delta \overset{def}{=} \left\| (Mo-Mg) \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \right\|^2 \quad \cdots (46)$$

[K3] The four-line procession T0 of four rows showing the position and posture of the hand (starting point of the coordinate system set up on the flange) of a robot is calculated and memorized.
[K4] Using the algorithm which explained [above-mentioned] with the data (data of C and Mg) acquired by the preparatory work, the right-hand side of (2) types is calculated

and it asks for the perpendicular slip target position Tg.
[0063][K5] The movement command for going to the perpendicular slip target position Tg is created, a servo is passed, and a robot is moved. If the non-error of a system is perfect, it should result in the position attainment state wishing instruction in the above step K1 - one cycle of K5, but the position attainment state wishing instruction is actually attained in successive approximations for the error of a visual sensor, the error of calculation, etc.
[0064][K6] A robot is stopped and processing is ended.
[Method 2]
[1] In the embodiment by the outline method 2, the light spot formed of a laser beam is used as a visual target means. First, drawing 9 - drawing 14 are added to a reference figure, and the outline of a preparatory work and teaching work is explained. Drawing 9 is a figure for explaining inner-1--3 of many stages of a preparatory work, and drawing 10 is a figure for explaining the remaining stages PR4-PR6. A figure for drawing 11 to explain inner TH1-TH3 of many stages of teaching work and drawing 12 are the figures for explaining stage TH4 and PR5.
[0065][2] Preparatory work (acquisition of position attainment state representation data wishing instruction, and calibration of a camera)
(PR1) a hand of a robot first represented with the flange position 2a -- the camera 21 -- in addition, the laser head 22 (irradiation head of the laser generator 60 shown in drawing 2) and the reference tool 25 are attached. The laser head 22 is attached via the suitable adjustment mechanism 23, and can adjust now the floodlighting direction of the laser beam 24. The mark 26 which expresses TCP (2b) with a portion shown by the arrow 27 near the tip of the reference tool 25 is formed. However, it needs to be cautious of this mark 26 being for viewing. Where the laser head 22 is attached, generally the laser beam 24 does not enter into the mark 26 on the reference tool 25, as illustrated.
[0066](PR2) Direction of the laser head 22 is adjusted and it is made for the laser beam 24 to enter into the mark 26 on the reference tool 25. Thereby, light spot is formed in a position of the mark 26, i.e., position 2b of TCP. The laser head 22 is henceforth fixed in this state.
[0067](PR3) Photography with the camera 21 is made to perform via the robot control device 30 in this state, and a picture for creating position attainment state representation data wishing instruction is acquired. Image processing of the picture of acquired light spot is carried out within the image processing device 20, and data showing the direction of light spot (it is in TCP position 2b.) seen from a camera coordinate system (starting point Oc) of the camera 21 of a vector <et> is created and memorized. This data is behind used as position attainment state representation data wishing instruction.
[0068](PR4) If data of <et> is acquired, the reference tool 25 will be removed. Since the laser head 22 is fixed, the laser beam 24 will pass along TCP (2b) in the air as illustrated.
[0069](PR5) Data of a vector <eh> is created and memorized as a vector showing the laser beam's 24 seen from the starting point Oc of camera coordinate system existence direction. <eh> is a vector by which the following two conditions are fulfilled.
Conditions 1; it is in a flat surface which a vector <et> and the laser beam 24 stretch.
It is a vector of a direction near a direction which looked at the laser head 22 from the camera 21 among <eh(s)> which fill condition 2;<eh> ** <et>. <eh> can be calculated by a method shown, for example in drawing 13.

[0070]That is, a robot is moved by jogging above the suitable flat surface (here, the representation work surface 3a is used.), and the spot F of the laser beam 24 is formed. And by approach to the field 3a of a robot from a state which has TCP position 2b above the field 3a as shown in (1), as shown in (2), TCP position 2b makes the state of the field 3a of coming caudad. If it puts in another way, it will be made for a position of the spot F to come to an opposite hand from a state of (1) across the look 21a of the camera 21 and the intersection N of the field 3a which look at a TCP position (2b).
[0071]In this state, photography with the camera 21 is performed and a picture of the spot F is acquired. And image processing is performed within the image processing device 20, and it asks for data showing the direction of the spot F seen from a camera coordinate system of a vector <es>. A vector <eh> is computed with a following formula (47) using this <es>.
[0072]
[Equation 10]

$$<eh> = \frac{<et> \times <es>}{\| <et> \times <es> \|} \quad \cdots (47)$$

(PR6) The calibration of the camera 21 is performed. This is for asking for the relation of the flange coordinate system (2a is the starting point) and camera coordinate system which are set up on a robot hand's flange face. Various things are available as explanation of the method 1 described the technique of the KIKYA rib ration of a camera (the technique by a mark member may be used).
[0073][3] teaching work (TH1) by the method 2 -- move a robot first above the representation work surface 3a where the first position wishing instruction exists by jogging, and form the spot F of the laser beam 24 on the representation work surface 3a. Marking of the position A wishing instruction shall be beforehand carried out by the suitable teaching point mark A which can be recognized with a visual sensor. The flange position 2a in the state where it illustrated shall be set to Ps, and autonomous movement shall be started from the position Ps. Shift to autonomous movement from jogging can be considered as an automatic change which used a visual-sensor output, for example so that it may mention later.
[0074]TCP position 2b is above the field 3a, and the laser beam 24 forms the spot F on the field 3a through this point as illustrated. Generally in this stage TH1, three points are in another position mutually [the teaching point mark A and the spot positions F and TCP (2b)]. The look 21a which looked at the teaching point mark A from the camera 21 does not pass along TCP (2b).
[0075](TH2) A robot is operated by processing of autonomous movement and the look 21a which looked at the teaching point mark A from the camera 21 passes along TCP (2b). As operation of a robot, rotation of a circumference of the starting point Oc of a camera coordinate system is rational.
[0076](TH3) A robot is operated by processing of autonomous movement, and a formation position of the spot F is made to approach the teaching point mark A, keeping conditions by which the look 21a passes along TCP (2b) as much as possible. As operation of a robot, rotation of a circumference of Oc should be suitably combined with advance of the direction of look 21a.
[0077](TH4) If advance of the direction of look 21a becomes superfluous, while the look 21a will keep conditions which pass along TCP (2b) as much as possible, in accordance

with the direction of look 21a, it retreats suitably, and rotation of a circumference of Oc is combined suitably.
[0078](TH5) Hereafter, operation (advance) of TH3 and operation of TH4 (retreat) are repeated, and a formation position of the spot F is completed as the teaching point mark A. Since it is exactly an intersection of the look 21a which this convergent point passes along TCP (2b), and looks at the teaching point mark A, and a laser beam which passes along TCP (2b) therefore, it will come to the teaching point mark A and the position in which three points are the same as for the spot positions F and TCP (2b) after all. This means namely that instruction target point slack TCP (2b) reached a position wishing instruction. A position of flange position 2b at this time is expressed with Pt as well as a case of the method 1.
[0079]Then, if a robot position in this state is memorized to a control means (nonvolatile memory in a robot control device), position instruction of the position A will be completed. What is necessary is just to apply the above-mentioned processes TH1-TH5 about each teaching point mark of the 2nd henceforth, when there are two or more positions wishing instruction (teaching point mark) (see the point A1 - A4 on the representation work 3 in drawing 1, for example although a graphic display is omitted).
[0080][4] Explain an algorithm of processing for attaining movement in the position Pt (similarly it expresses in a flange position) wishing instruction from the autonomous movement starting position Ps (it expresses in a flange position) according to a process explained by the processing above at the time of position autonomous movement wishing instruction in the method 2 [2]. Although sign <> expresses a vector as well as a case of the method 1, a definition content of a vector is separate from the method 1. Autonomous movement is performed based on a processing cycle according to an algorithm which described an outline in a flow chart of drawing 15 (L1-L12) and drawing 16 (L13-L19). Hereafter, it divides into each step and explains focusing on an algorithm. The meaning of many signs under explanation is as follows.
[0081]sigma0, sigma1 ; A value of 1 [**] is taken with a flag with which all express advance/retreat of a robot. +1 means advance and -1 means retreat.
l; register value [showing the amount of units of advance/retreat of a robot] <dm>; -- to have been shown in drawing 14 is asked from image data by a unit vector (length 1) showing a sight line direction which looked at the teaching point mark A from the starting point Oc of a camera coordinate system.
<ds>; to have been shown in drawing 14 similarly is asked from image data like <dm> by a unit vector (length 1) showing a sight line direction which looked at spot position F (incidence position of the laser beam 24) from the starting point Oc of a camera coordinate system.
[0082]T; procession deltar which expresses a position and a posture of a robot on a robot-coordinates system, deltal ; Positive constant near [in a threshold with suitable all] 0. What expresses the minimum rotation with a rotation procession which describes a relation of the direction of R;<dm > and <et > among 3x3 processions used as R<et >= <dm>.
sgn; it defines as signum as follows.
sgn(x)=+1 (x>0)
sgn(x)=0 (x=0)
sgn(x)=-1 (x<0)

[L1] Flag sigma0 is initialized to 1. l is initialized to a suitable initial value (for example, 3 cm).
[L2] A register value showing data of the procession T is updated based on a current position of a robot.
[L3] A photograph is taken using the camera 21 and it tries to search for a vector <dm> using the image processing device 20.
[L4] Since it is possible that the teaching point mark A is not caught with a camera view if a vector <dm> is not searched for, processing is ended (an operator is changed into the state where adjust a robot position by jogging and the teaching point mark A is certainly caught with a camera view). When a vector <dm> is searched for, it progresses to Step L5.
[0083][L5] It asks for an outer product of a vector <et> and a vector <dm>, and <dr =[>] <et> x <dm>.
[L6] As compared with threshold deltar, if not small, he follows an absolute value of a vector <dr> to Step L7. If small, it will progress to Step L10.
[0084][L7] The rotation procession R which describes a relation of the direction of <dm> and <et> is computed by a declared formula. A declared formula is obtained by solving the following simultaneous equations about R.
R<et >= <dm> ... (48)
R<dr >= <dr> ... (49)
[L8] A register value showing data of the procession T is updated to a thing to a procession of a notation containing the new submatrix R. This procession solves the following equation (50) about Tg, and is set to Tg ->T.
[0085]
[Equation 11]

$$TgC = TC \begin{bmatrix} R & 0 \\ t_0 & 1 \end{bmatrix} \quad \cdots (50)$$

[L9] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L8 expresses is performed, and it returns to Step L2.
[L10] By step L6, if it is judged that the absolute value of a vector <dr> is smaller than threshold deltar, this step L10 will be performed for the first time. It tries to search for the unit vector <ds> which expresses with this step the sight line direction which looked at spot position F from the starting point Oc of the camera coordinate system from image data.
[0086][L11] It is thought that it cannot happen that the spot F is not settled in a camera view when [this] an absolute value of a vector <dr> is about 0 (a look which looks at TCP, and a look which looks at a teaching point mark are real coincidence) unless there are a system abnormality, a design error, etc. Therefore, in almost all cases, a vector <ds> is searched for and it progresses to Step L12. However, processing is ended if <ds> should not be calculated (a cause inquiry etc. are performed separately).
[0087][L12] <ds> and <et> are the real same directions, and it confirms whether to be the inner product 1 (it is cautious of deltal being a very small positive value).
[L13] Flag sigma1 showing advance/retreat of a robot will be set to sigma1 =0, if an inner product of <ds> and <eh> is positive, it is sigma1 =-1 and negative and it will become sigma1 =1 and a real target zero.

[L14] If it is sigma1 =0, it will progress to Step L15. If it is not sigma1 =0, it will progress to Step L16.
[L15] sigma1 is updated to sigma0 and it progresses to Step L18.
[L16] If a product of sigma1 and sigma0 is positive, it will progress to Step L18. If it is negative, it will progress to Step L17.
[0088][L17] A value of l is reduced by half while updating sigma0 to sigma1.
[L18] A register value showing data of the procession T is updated to a thing to a declared procession. This procession solves the following equation (51) about Tg, and is set to Tg ->T.
[0089]
[Equation 12]

$$TgC = TC \begin{bmatrix} I & \sigma 1 I < et > \\ t_0 & 1 \end{bmatrix} \quad \cdots (51)$$

[L19] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L18 expresses is performed, and it returns to Step L2.
In the processing cycle according to the algorithm explained above, if the judgment output of yes is obtained at Step L12 at one of the times, it will be understood as the position attainment state wishing instruction as shown in (TH5) of drawing 12 having been realized, a robot will be stopped, and processing will be ended.
[0090]As mentioned above, since movement in the position wishing instruction of a robot will be autonomously performed so that it may become the position of a position attainment state wishing instruction and the posture which it was inputted beforehand if this invention is followed so that I may be understood from the explanation about the embodiment of the method 1 and the method 2, working efficiency improves.
[0091]the method 1 and the method 2 -- also in which embodiment, it is preferred to automate a change in the mode of autonomous movement in which it tends toward a position wishing instruction autonomously, from the mode of jogging by a manual command input by processing inside a control means (the robot control device 30 and the image processing device 20).
[0092]Drawing 17 shows an operating procedure of a teaching control panel, and outline of processing with a flow chart about a case where a change in the mode of autonomous movement of jogging from the mode is performed inside a system. It is as follows when processing of each step is described briefly. An output of a visual sensor is used for determination of timing of a mode change in this example.
[S1] If it judges whether the jogging button 47 (any one) was pushed and instructions of jogging were made, and are made, will progress to Step S2 and it will not be made, Step S1 is repeated.
[S2] According to movement contents (a direction, an axis, etc.) specified with the jogging button 47, a predetermined axis is controlled and jogging movement of the robot 10 is started. For example, if movement of the direction of J6 axis + is specified, a movement command which advances J6 axis in the direction of + will be created, and a servo will be passed.
[S3] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 will not be progressed and used, it progresses to step S4.

[S4] If existence of reception of a signal which tells that the teaching point mark A (a case of the method 2 and the spot F) entered in a view of the camera 13 was checked, it has received and it will not have progressed and received to Step S5, it returns from the image processing device 20 to Step S3.
[S5] Processing of autonomous movement is started. It is as having divided into the method 1 and the method 2 and having mentioned above about an example of the concrete contents of processing.
[S6] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 is not progressed and used, it progresses to Step S7.
[S7] It judges whether it reached to a position wishing instruction, if it has reached, it will progress to Step S8, and if it has not reached, it will return to Step S6. It is as having also described a judgment method which is not reached [the position attainment wishing instruction /] in explanation of the method 1 and the method 2.
[S8] Operation of each axis of the robot 2 is stopped.
[0093]
[Effect of the Invention]According to this invention, since the data of the position on the picture of the visual target means observed when the position wishing instruction is reached is inputted beforehand, using a visual target means like a navigation index, a robot can be turned to the position wishing instruction and can be moved autonomously. Therefore, the burden of the operator which the position teaching work of a robot takes is eased substantially. The highly convenient nature of the robot at the time of position teaching work can also be further raised by performing the shift to autonomous movement from jogging with the automatic change in a system especially.

TECHNICAL FIELD

[Field of the Invention]Concerning the movement control system for position instruction of a robot in more detail, this invention relates to the movement control system for moving a robot to the position wishing instruction quickly using a visual target and the visual sensor which recognizes this.

PRIOR ART

[Description of the Prior Art]Most generally as a position teaching method of a robot, the method by jogging (robot motion by a manual input) is used. According to this teaching method, an operator operates the jogging button of a teaching control panel, and moves a robot to the position wishing instruction, and the work of teaching the position at that time to a robot is done. When off-line instruction is made and coarse position instruction has ended, or when making correction of teaching positions, fine adjustment of the teaching positions by jogging is performed.
[0003]use any -- since the work for which a robot is moved to it locating [to wish] is done by viewing with slight accuracy in relative position and posture relation of a robot hand (or end effector) and the point wishing [instruction], an operator takes skill to it. As for the number of points (a position and a posture) to be taught, since it is usually to

attain to a large number, it is not new to spend great time on teaching work, either. The teaching work depending on viewing of an operator tended to produce variation for instruction accuracy, and there was a problem also in respect of reliability.

EFFECT OF THE INVENTION

[Effect of the Invention]In this invention, the data of the position on the picture of the visual target means observed when the position wishing instruction is reached is inputted beforehand.
Therefore, using a visual target means like a navigation index, a robot can be turned to the position wishing instruction and can be moved autonomously.
Therefore, the burden of the operator which the position teaching work of a robot takes is eased substantially. The highly convenient nature of the robot at the time of position teaching work can also be further raised by performing the shift to autonomous movement from jogging with the automatic change in a system especially.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]This invention is made in order to conquer such a situation. That is, the purpose of this invention eases the burden which takes for an operator at the time of teaching work, and there is in providing the movement control system for position instruction of the robot which enabled improvement in the efficiency of teaching work, and reliability.

MEANS

[Means for Solving the Problem]This invention was made in view of a problem of the above-mentioned conventional technology, and an aforementioned problem is solved by enabling it to move a robot to a position wishing instruction autonomously using a visual sensor and a suitable visual target means. A position attainment state storage step wishing instruction which a control means of a system which contains a robot and a visual sensor in many stages of a method of this invention for position attainment state representation data wishing instruction expressing a position attainment state wishing instruction of a robot is made to memorize, An impaction efficiency stage wishing instruction of moving a robot to a position wishing instruction by movement controls of a robot by this control means, and a teaching-positions storage step which makes a control means memorize instruction positional data are included.
[0006]And it is the important feature of this invention that an autonomous movement execution phase made to carry out to this impaction efficiency stage wishing instruction autonomously based on position attainment state representation data wishing instruction which had movement in a position wishing instruction memorized is included.
[0007]In order to make it possible, this autonomous movement position attainment state representation data wishing instruction, It is acquired through seeing from a visual sensor

expressed using a visual target means which can be recognized with a visual sensor, and said visual sensor recognizing a position attainment equivalent state wishing instruction equivalent to a position attainment state wishing instruction.

[0008]A visual target means is used in an autonomous movement stage as a guidance visual target means for showing a robot to said position wishing instruction through being recognized by a visual sensor.

[0009]Software processing performed within a control means for autonomous movement is performed so that a recognition state of a guidance visual target means by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction and a robot may be derived. The visual target means can take a gestalt of a mark means including a mark coordinate system which can be recognized with a visual sensor. In that case, data showing a position and a posture of a mark coordinate system on a picture will be contained in position attainment state representation data wishing instruction memorized by a position attainment state storage step wishing instruction. On the other hand, this mark means is used in order to prepare a mark coordinate system for a position with fixed in order to provide a guidance visual target means for autonomous movement of a robot relative relation as a position wishing instruction. And a robot is derived so that a recognition state of a mark coordinate system by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction by movement controls based on software processing performed within a control means.

[0010]A mark member fixable on a field of a representation work made into an object of teaching work can be used for a mark means. On this mark member, a mark coordinate system is drawn by a dot pattern etc.

[0011]There is light spot formed on a floodlighting side of an optical beam light projection means supported by robot as a gestalt of another available visual target means. When using such light spot as a visual target means, in order to prepare a position attainment equivalent state wishing instruction to a visual sensor in a position attainment state storage step wishing instruction, it is an instruction target point (a point which it is going to coincide with a position wishing instruction) of a robot about light spot. Usually, it is tool point;TCP. A reference floodlighting side for forming in a position in agreement is arranged.

[0012]The optical beam floodlighting direction is adjusted and light spot is formed in an instruction target point position on this reference floodlighting side. This state is equivalent to a teaching-positions attainment equivalent state for a visual sensor. Then, light spot is recognized by a visual sensor, and position attainment state representation data wishing instruction is acquired so that data showing a position on a picture of light spot may be included.

[0013]An autonomous movement stage is performed where the optical beam floodlighting direction which removed a reference floodlighting side and was seen from a camera in a position attainment equivalent state wishing instruction is maintained. That is, movement controls of a robot in an autonomous movement execution phase are performed, using light spot which floodlights an optical beam and is formed on a field where a position wishing instruction exists as a guidance visual target means. Software processing for movement controls of a robot is performed so that a recognition state of light spot by a visual sensor may be in agreement with a recognition state corresponding

to position attainment state representation data wishing instruction and a robot may be derived.
[0014]In advance of autonomous movement to a position wishing instruction, it may be made to jog in order to perform preliminary approach to a position wishing instruction. As for shift to an autonomous movement stage from a jogging stage, in that case, it is preferred to be automatically carried out by the processing within a control means based on an output of a visual sensor.
[0015]Software processing in an autonomous movement execution phase to a position wishing instruction, Processing which compares with position attainment state representation data wishing instruction data showing a position on a picture of a guidance visual target means recognized by a visual sensor at the time concerned, Suppose that processing for carrying out the movement controls of each axis of a robot based on a comparison result and processing which judges completion / un-completing of a position attainment state wishing instruction are repeated sequentially until a judgment of position attainment state completion wishing instruction is made.
[0016]Data of a position on a picture of a visual target means observed in this invention when a position wishing instruction is reached is inputted beforehand, and at the time of autonomous movement to a position wishing instruction. A visual target means is used like a navigation index of robot movement by observing with a visual sensor, and a robot is made to turn and derive to a position wishing instruction.
[0017]By this feature, a position attainment state wishing instruction is attained efficiently, without applying a burden to an operator. The highly convenient nature of a robot at the time of position teaching work can also be further raised by performing shift to autonomous movement from jogging with the automatic change in a system. Therefore, even when a large number [the number of positions wishing instruction], there are few burdens of teaching work and they end.
[0018]
[Embodiment of the Invention]Drawing 1 is a figure which illustrates notionally the overview of the movement control system for the position instruction of a robot according to this invention. The numerals 1a express the position attainment state representation data input means wishing instruction which inputs the data expressing the position attainment state wishing instruction. This position attainment state representation data input means 1a wishing instruction, Visual target B1 Data expressing the relative physical relationship of the visual target B1 in the state where movement in the position wishing instruction of the robot [/ else] 2 was completed, and the robot hand 2a. (it is hereafter called "the position attainment state representation data wishing instruction".) -- it has the function to input into the memory 4 beforehand.
[0019]The position wishing instruction is illustrated by the four numerals A1 on the field 3a of the representation work 3 - A4. B1 drawn A1 - near each [of A4] - B4 are given by the position A1 wishing instruction - A4 representing the position which A1 - A4 express which are visual target means and each correspond, and a fixed relation. The example of a visual target means is mentioned later. In the usual gestalt, each visual target position B1 - B4 and each position A1 wishing instruction - A4 are given so that coincidence may not be carried out, although it is close, but they can also coincide both depending on the case.
[0020]The numerals 2a and 2b express the end point position and instruction target point

(usually tool point; TCP) of the robot respectively. In the following explanation, the end point position 2a of a robot shall be represented with the starting point of the coordinate system set up on the flange at the tip of a final arm.

[0021]An operator operates the robot manual operation means (robot motion instruction manual input means; teaching control panel etc.) 5, such as a jogging button, makes the shaft movement control means 6 control each axis of the robot 2, and makes movement in the position wishing instruction start in the time of actual work. The movement controls for autonomous movement in the position wishing instruction from the time of this move start or a certain point in time after a move start are performed. The position attainment state representation data wishing instruction into which the movement controls for this autonomous movement were inputted by the position attainment state representation data input means 1a wishing instruction, It is carried out based on the relative-position-recognition data showing the relative physical relationship between the robot hand and visual target means (camera fixed to this) at each time.

[0022]The latter data is given once [at least] in the process of movement controls by the relative-position-recognition means 1b between robot hand visual targets. in the position attainment state wishing instruction -- naturally -- TCP2b -- the position wishing instruction -- one is in agreement with A1 (or A2 - A4 one) (it illustrates by numerals 2b').

[0023]The position attainment state representation data input means 1a wishing instruction and the relative-position-recognition means 1b are materialized in the form where a visual sensor is used so that it may mention later. The visual target means B1 - B4 are materialized in the form of the light spot formed of the mark coordinate system or laser beam which can be recognized with a visual sensor. In the following explanation, the gestalt which materializes a visual target means in the form of a mark coordinate system is called "the method 1", and the gestalt materialized in the form of the light spot formed of a laser beam is called "the method 2."

[0024]drawing 2 showed the outline of the hardware constitutions of the system used by this embodiment with the important section block diagram centering on a robot control device -- it is. The robot control device to which the whole was directed with the numerals 30 was equipped with the processor board 31, and this processor board 31 is provided with the central processing unit (henceforth CPU) 31a, ROM31b, and RAM31c which consist of microprocessors.

[0025]CPU31a controls the whole robot control device according to the system program stored in ROM31b. A program, a related preset value, etc. which defined the processing by the side of a robot required to perform autonomous movement to the position wishing instruction else [, such as a created operation program and various preset values,] according to the method 1 or the method 2 are stored in RAM31c. A part of RAM31c is used for temporary data storage for the computation etc. which CPU31a performs. The hard disk drive etc. which were suitably prepared as an external device are used for preservation of program data or a preset value.

[0026]The processor board 31 is combined with the bus 37, and instructions and transfer of data are performed among other portions in the robot control device 30 via this bus combination. First, the digital-servo control circuit 32 is connected to the processor board 31, and the servo motors 51-56 are driven via the servo amplifier 33 in response to the instructions from CPU31a. The servo motors 51-56 which operate each axis are built in

the mechanism part of each axis of the robot 2.
[0027]The serial port 34 having a communication interface is connected to the teaching control panel 40, the image processing device 20, and the laser generator 60 with a liquid crystal display section while being combined with the bus 37. However, the laser generator 60 is used by the method 2, and is unnecessary in the method 1.
[0028]The teaching control panel 40 has the size and weight which are the grades whose carrying is possible with an operator, and the jogging button etc. which are used as a robot manual operation means are provided on the panel. In addition, the input/output device 35 for digital signals (digital I/O) and the input/output device 36 for analog signals (analog I/O) are combined with the bus 37. When signal transfer with an end effector is required, the control section of an end effector is connected to digital I/O35 or analog I/O36. In the example mentioned later, since the arc welding robot's application is considered, the electric power unit of an arc welding torch is connected to digital I/O35.
[0029]The image processing device 20 is the usual thing which made CPU carry out bus combination of program memory, a frame memory, an image processing processor, data memory, the camera interface, etc. The camera 21 is connected to the image processing device 20 via the camera interface. This camera is used for the photography for acquiring the picture of a visual target means in the mode mentioned later. The program data for image analyses needed by the method 1 or the method 2 is stored in program memory.
[0030]Drawing 3 is a figure showing the outline composition of the panel surface of the teaching control panel 40. The display screen 41 is a liquid crystal display, and the detailed data of a movement command program, etc. change it, and it is displayed. The function key 42 is a key which selects the menu displayed on the lower end part of the display screen 41. The teaching control panel effective switch 43 is a switch which switches whether operation of the teaching control panel 40 is effective or invalid.
[0031]The emergency stop button 44 is a button to which the emergency stop of the operation of the robot 2 is carried out. The cursor key 45 is a key which moves the cursor displayed on the display screen 41. A numerical keypad and other keys are provided in the ten key part 46, and input of a numerical value and a character, deletion, etc. can be performed to it.
[0032]Although a series of jogging buttons 47 (J1-J6) are buttons which specify advancing side by side / hand of cut, and the direction of +-, and input a movement command in the normal mode which jogs a conventional system, According to this embodiment (autonomous movement mode), it is used as an autonomous movement command input means to the position wishing instruction so that it may mention later. The details of an embodiment are explained below about the method 1 and the method 2 on the assumption that the above matter.
[0033][Method 1]
[1] The schematic diagram 4 is a figure explaining operation of the autonomous movement in the embodiment by the method 1. On the field 3a of the representation work directed with the numerals 3 as well as drawing 1, a number (here four pieces) corresponding to the number of the teaching points A1 - A4 to wish of mark members MK1-MK4 are stuck. On each mark member, the same mark coordinate system is drawn by the dot pattern so that it may mention later. Mark member MK1 is stuck by the position and the posture in which it corresponds to the position and posture of the point A1 wishing [instruction] correctly. Similarly, the mark members MK2-MK4 are stuck

by the position and the posture in which it corresponds to the point A2 wishing [instruction] - the position and posture of A4 correctly respectively.
[0034]The robot which carried out representation only of the hand part circumference carries the welding torch 2c and the camera 21 in the hand part, and TCP2b is set up at the tip of welding torch 2c. By this embodiment, a robot is left from the move starting position Ps, autonomous movement of the TCP2b set up at the tip of the welding torch 2c is carried out to the point A1 wishing [instruction] - A4 one by one, and the case where position instruction is performed in each position wishing instruction is considered. Generally the starting position Ps of autonomous movement is arbitrary, if mark MK1 of the beginning is a position included in the view of the camera 21.
[0035]Drawing 5 is a figure explaining the composition of the mark member used by the embodiment by the method 1. Reference of the figure constitutes mark coordinate system sigmaM from the five circular dots D0 arranged in the shape of a lattice by the interval a on the mark member MK, D1, D-1, D2, and D-2. Dot space a is positive constant value. Therefore, the center position of each dot is set to D0 (0, 0, 0), D1 (a, 0, 0), D-1 (- a, 0, 0), D2 (a, a, 0), and D-2 (- a, a, 0). As long as it can express a three-dimensional rectangular coordinate system, a mark coordinate system may consist of other patterns.
[0036]Hole MH is provided in the regular position where the mark member MK is suitable. This hole MH points to the position wishing instruction, and when sticking on the field 3a of the representation work 3, a sticking position is chosen so that that representative point (for example, center) may be in agreement with the position wishing instruction. A pasting posture is chosen with reference to direction of mark coordinate system sigmaM. That is, if pasting postures differ, the postures taught later also differ. For example, since the pasting posture of MK1 and MK4 in drawing 4 is different 90 degrees, it becomes what differed also in the posture taught later 90 degrees.
[0037][2] Preparation (the calibration of a camera, and acquisition of the position attainment state representation data wishing instruction)
1. Perform the calibration of the camera with the application of suitable calibration method in advance of working starting. Although various techniques are known by the calibration of the camera, the mark member shown here can also be used. The outline is described on the convenience of explanation, and in the back.
[0038]2. Perform acquisition of the position attainment state representation data wishing instruction. First, the mark member MK is fixed to a suitable position. Of course, one of the mark members stuck on the representation work 3 can also be used as it is. First, by jog operation of the normal mode (conventional system), a robot is moved, tool point 2b is coincided with representative point MA of hole MH of the mark member MK, and it is made to take the posture wishing instruction. It means that the position attainment state wishing instruction was realized about the mark member MK by this.
[0039]3. If the position attainment state wishing instruction is realized about the mark member MK, photography with the camera 21 will be made to perform via the robot control device 30, and the picture for creating the position attainment state representation data wishing instruction will be acquired.
4. Image processing of the acquired picture is carried out within the image processing device 20, and the data showing the relative positional attitude of mark coordinate system sigmaM to the camera coordinate system of the camera 21 is created (it mentions later for details).

[0040][3] Start movement in the position wishing autonomous instruction from the approach starting position Ps (it expresses in a flange position) shown in processing drawing 4 at the time of the position autonomous movement wishing instruction in the method 1, and explain the algorithm of the processing for attaining movement in the position Pt (it expresses in a flange position) wishing instruction. In the following explanation, since a vector is expressed, sign <> is used.
1. Skeleton drawing 7 of an algorithm describes the skeleton of an algorithm required for movement in the autonomous position wishing instruction. The current position (position at each [under movement in the position wishing instruction] time) T0 of a flange, and the present relative position (relative position at each [in the moving process to the position wishing instruction] time) M0 of a camera coordinate system and a mark coordinate system, As [describe / the geometric relation with the flange position Tg and relative-position (target relative position) Mg of a camera coordinate system and a mark coordinate system in the position attainment state wishing instruction in the position attainment state wishing instruction / into drawing 4]
[0041]And Mg is equivalent to the position attainment state representation data wishing instruction acquired by the above-mentioned preparatory work. C is taught by a camera calibration. The fundamental equation which specifies the relation between these [T0], M0, Tg, and Mg is as follows.
T0 CM0 =Tg CMg ... (1), therefore the following formula (2) which solved this about Tg turn into a basic equation showing the moving-target position on the rectangular coordinate system of a robot.
$Tg = T0\ CM0\ Mg^{-1}C^{-1}$ ... (2)
If the position instruction which makes this Tg a final moving-target point is given to a servo, a robot can be turned to the position wishing instruction and can be moved autonomously. Therefore, defining the algorithm of the autonomous movement to the position wishing instruction results in the problem which asks for the right-hand side of (2) types concretely.
[0042](2) Among the right-hand side of a formula, T0 expresses the present position data of the robot, and is data of the character obtained within a robot control device at any time. The data of C is separately gained by a suitable camera calibration (the example of a calibration is mentioned later). Then, it explains from how to calculate M0 and Mg.
[0043]2. Each of equations M0 of M0 and Mg and Mg expresses the position and the posture of mark coordinate system sigmaM seen from the camera coordinate system (at the time of the completion of the present and approach).
[0044]Since it is positive constant value, the arrangement interval a of the circular dots D0 which constitute mark coordinate system sigmaM (refer to drawing 5) used by this embodiment, D1, D-1, D2, and D-2 is a> 0... It is (3). M0 and Mg are the homogeneous transformation processions of 4x4 expressing the relation between the position and posture between three-dimensional rectangular coordinate systems, and can be placed like a following formula (4).
[0045]
[Equation 1]

$$M = \begin{bmatrix} R_M & l_M \\ {}^{t}0 & 1 \end{bmatrix} \quad \cdots (4)$$

Here, 3x3 processions for which RM expresses rotation, and lM are 3x1 processions (vector) showing a position. It considers asking for the equation which RM and lM fill hereafter as an equation which M0 and Mg fill. First, the following formula (5) and (6) defines a vector <e1> and <e2>.

[0046]

[Equation 2]

$$<e1>=\begin{bmatrix}1\\0\\0\end{bmatrix} \quad \cdots (5)$$

$$<e2>=\begin{bmatrix}0\\1\\0\end{bmatrix} \quad \cdots (6)$$

As for the information acquired from a visual sensor about mark coordinate system sigmaM, the center of each circular dots D0, D1, D-1, D2, and D-2 aims (sight line direction) to be in sight from the starting point of a camera coordinate system. These directions can be expressed with five unit vectors <d0>, <d1>, <d-1>, <d2>, and <d-2> as shown in drawing 6.

[0047]deltaij defined by the following formula (7) is introduced about the inner product of these vectors.

deltaij=<di>- <dj> (i, j=-2, -1, 0, 1, 2) ... (7) -- here, since all the length of <d0>, <d1>, <d-1>, <d2>, and <d-2> is 1, the absolute value of deltaij does not exceed 1.

| deltaij|<=1 (a necessary and sufficient condition for equal mark formation is i=j) --- (8)

Although distance from the camera coordinate system starting point to each dot center is unknown, this is placed with ti (i=-2, -1, 0, 1, 2). Naturally these take a positive value.

[0048]

ti >0 (i=-2, -1, 0, 1, 2) ... If (9) is carried out, following equation (10) - (12) will be obtained.

t0 <d0> =lM ... (10) t1 <d1> =lM+aRM <e1> ... (11a)

t-1<d-1> =lM -aRM <e1> ... (11b)

t2 <d2> =t1 <d1>+aRM <e2> ... (12a)

t-2<d-2> =t-1<d-1>+aRM <e2> ... (12b)

Therefore, if an equation of these is solved about RM and lM and it goes, calculating ti, M0 and Mg can be defined. A concrete solution will be explained by a paragraph of how to calculate 4.M0 and Mg, and C showing a position and a posture of a camera coordinate system is described briefly.

[0049]3. The equation C of C is a procession expressing a position and a posture of a camera coordinate system seen from a flange, and the data is obtained by calibration of the camera 21. Although various techniques are publicly known about a calibration and they can be used, even if it uses mark coordinate system sigmaM, a calibration of the camera 21 can also be performed. Here, only the main point is described briefly.

[0050]In three different points as shown with the numerals CB1-CB3 in drawing 4, photography with the camera 21 is performed respectively, image processing is performed and the data Pi (i= 1, 2, 3) about a relative position between the starting points of mark coordinate system sigmaM and a camera coordinate system is obtained. If data Ti (i= 1, 2, 3) of a robot position at the time of they and each photography is combined,

the following 3 sets of equations will be obtained. The point which calculates Pi (i= 1, 2, 3) is the same as that of M0 or Mg.
T1 CP1 =T2 CP2 =T3 CP3 ... (13)
Under conditions from which three postures of a robot of CB1-CB3 differ mutually, it is possible to solve this equation about C. This condition is set to (14).
Conditions: T1 and T2 differ from each posture ingredient of T3 mutually. ... Data of C (14) Called for is memorized by a robot control device or image processing device.
About a solution of an equation, it explains supplementarily depending on how to ask for 5.C.
[0051]4. In M0 and Mg asking, and solving equation (10) - (12) here and there, and calculating RM and lM, consider calculating ti (i=-2, -1, 0, 1, 2) first. Therefore, a following formula (15) is replaced.
[0052]
[Equation 3]

$$<rM>=\begin{bmatrix} rMx \\ rMy \\ rMz \end{bmatrix} = RM^{-1} <lM> \qquad \cdots (15)$$

And equation (10) - (11) is transformed like following formula (16) - (18) using this.
<rM> =t0 RM^{-1} <d0> ... <rM>+a<e1 >=t1 RM^{-1} <d1> ... <rM>-a<e1 >=t-1RM^{-1} <d-1> ... (18) -- here, (17) (16) If RM^{-1} is cautious of it being a procession showing rotation, a following formula (19) will be materialized.
(RM^{-1} <di>) -(RM^{-1} <dj>) =<di> - <dj> (i, j=-2, -1, 0, 1, 2) ... If this (19) (19) type, and (5) - (8) type and (16) - (18) type are used, following expression-of-relations (20) - (23) will be obtained.
[0053]
$||<rM>||^2$=t0 ^{2} ... (20) $||<rM>||^2$+2 arMx+a^2=t1 ^{2} ... (21a)
||||[<rM>] ^{2}-2 arMx+a^2=t-1 ^{2} ... (21b)
$||<rM>||^2$+arMx=t 0t1delta0 and 1 --- (22a)
$||<rM>||^2$-arMx=t0 t-1delta0 and -1 --- (22b)
delta 0, 1^2<1, delta 0, and -1 ^{2}<1 --- (23)
If it arranges carefully from these formulas for $||<rM>||^2$+arMx, adelta0, 1 and $||<rM>||^2$-arMx, and adelta0 and -1 to become a same sign from conditions (3), (9), a formula (22a), and (22b) respectively, following formula (24a) - (25b) will be obtained.
[0054]
[Equation 4]

$$\|<rM>\|^2 + arMx = a\alpha + \sqrt{rMy^2 + rMz^2} \qquad \cdots (24a)$$

$$\|<rM>\|^2 - arMx = a\alpha - \sqrt{rMy^2 + rMz^2} \qquad \cdots (24b)$$

但し、

$$\alpha+ \overset{def}{=} \frac{\delta 0,1}{\sqrt{1-\delta 0,1^2}} \qquad \cdots (25a)$$

$$\alpha- \overset{def}{=} \frac{\delta 0,-1}{\sqrt{1-\delta 0,-1^2}} \qquad \cdots (25b)$$

If a formula (24a) and (24b) change further, the following formula (26) and (27) will be obtained.
$||\langle rM\rangle||^2=(a^2\text{beta}+^2)/(1+\text{beta}-^2)$ ... (26) rMx=(abeta+beta-)/(1+beta-^{2}) ... (27) however beta+, and beta- shall be defined by a following formula (28a) and (28b).
beta+ = (alpha++alpha-) / 2 ... (28a)
beta- = (alpha+-alpha-) / 2 ... (28b)
And if the formula (26) and (27) is substituted for the formula (20), (21a), and (21 b) and the conditions (3) and (9) are used, t0, t1, and t-1 can be found with the following formula (29), (30a), and (30b).
[0055]
[Equation 5]

$$t0 = a\sqrt{\frac{\beta+^2}{1+\beta-^2}} \quad \cdots (29)$$

$$t1 = a\sqrt{\frac{1+\alpha+^2}{1+\beta-^2}} \quad \cdots (30a)$$

$$t-1 = a\sqrt{\frac{1+\alpha-^2}{1+\beta-^2}} \quad \cdots (30b)$$

t2, t-2, <lM>, and RM are further calculated as follows using these.
[0056]
[Equation 6]

$$t2 = \frac{t1 - t{-}1\delta 1,-1}{t1\delta 1,2 - t{-}1\delta{-}1,2}\, t1 \quad (t1\delta 1,2 - t{-}1\delta{-}1,2 \neq 0 \text{の場合}) \qquad \cdots (30c1)$$

$$t{-}2 = \frac{t{-}1 - t1\delta 1,-1}{t{-}1\delta{-}1,-2 - t1\delta 1,-2}\, t{-}1 \quad (t1\delta 1,2 - t{-}1\delta{-}1,2 = 0 \text{の場合}) \qquad \cdots (30c2)$$

$$<IM> = t0<d0> \qquad \cdots (30d)$$

$$<RM> = (<f1><f2><f3>) \qquad \cdots (30e)$$

但し、 $$<f1> = \frac{1}{2a}(t1<d1> - t{-}1<d{-}1>) \qquad \cdots (30f)$$

$$<f2> = \begin{cases} \frac{1}{a}(t2<d2> - t1<d1>) & (t1\delta 1,2 - t{-}1\delta{-}1,2 \neq 0 \text{の場合}) \\ \frac{1}{a}(t{-}2<d{-}2> - t{-}1<d{-}1>) & (t1\delta 1,2 - t{-}1\delta{-}1,2 = 0 \text{の場合}) \end{cases} \qquad \cdots (30g)$$

$$<f3> = <f1> \times <f2> \qquad \cdots (30h)$$

5. Solve the above-mentioned equation (13) under the conditions (14) of the how [to ask for C] above-mentioned. Modification of an equation (13) will obtain the following (31) and (32).

$C^{-1}T1^{-1}T3\ C=P1\ P3^{-1}$ ... $C^{-1}T2^{-1}T3\ C=P2\ P3^{-1}$ ... (32) -- replacement which followed following formula (33) - (37) here is performed. (31)

[0057]

[Equation 7]

$$\begin{bmatrix} Rc & lc \\ t_0 & 1 \end{bmatrix} \overset{def}{=} C \quad \cdots (33)$$

$$\begin{bmatrix} R1 & l1 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} T1^{-1}T3 \quad \cdots (34)$$

$$\begin{bmatrix} R2 & l2 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} P1P3^{-1} \quad \cdots (35)$$

$$\begin{bmatrix} R3 & l3 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} T2^{-1}T3 \quad \cdots (36)$$

$$\begin{bmatrix} R4 & l4 \\ t_0 & 1 \end{bmatrix} \overset{def}{=} P2P3^{-1} \quad \cdots (37)$$

Then, the equation (31) and (32) is decomposed into following equation (38) - (41).
$RC^{-1}R1\ RC = R2$ ... (38) $RC^{-1}R3\ RC = R4$ ... (39) <(I-R1) lC> =<l1>-RC <l2 > ... (40) <(I-R3) lC> =<l3>-RC <l4> ... (41)
Therefore, it becomes a target to calculate RC and <lC>. Here, a form of an equation (38) and (39) shows that both similar transformation processions expressing the similarity R1 during a rotation procession - R2, R3 - R4, and those similarity relations are RC. Then, the following formula (42) and (43) is obtained considering a vector showing a hand of cut of Ri (i= 1, 2, 3, 4) as <vi> (i= 1, 2, 3, 4). Here, <vi> (i= 1, 2, 3, 4) can be uniquely defined from conditions (14), a definitional equation (34), and (36).
<v1> =RC <v2 > ... (42) <v3> =RC <v4> ... (43)
RC can be calculated if a relation of a following formula (44) is used.
(<v1>, <v3>, and <v1> x <v3>) =RC (<v2>, <v4>, and <v2> x <v4>) ... About (44)
equations (40) and (41), a form of a following formula (45) is used at a bundle, and if a least-squares method is applied, <lC> will be calculated.
[0058]
[Equation 8]

$$\begin{bmatrix} I & -R1 \\ I & -R3 \end{bmatrix} <lC> = \begin{bmatrix} <l1> \\ <l3> \end{bmatrix} - RC \begin{bmatrix} <l2> \\ <l4> \end{bmatrix} \quad \cdots (45)$$

6. Explain the outline of the process flow for movement in the preparatory work and the position wishing autonomous instruction in the method 1 on the assumption that the explanation item of beyond outline of process flow of movement controls by method 1 1. - 5. First, it is as follows if supplemented about a preparatory work.
(1) preceding working starting -- the above 3 -- as it came out and explained, move a robot to the three positions CB1-CB3 one by one.

(2) In each positions CB1-CB3, acquire the picture of mark coordinate system sigmaM (one piece) of mark member MK1 on the representation work 3, and acquire the data which expresses the sight line direction based on [each] dots by image processing in the image processing device 20.
(3) Perform processing according to the algorithm explained by above-mentioned 5. within the image processing device 20, and compute and memorize the data (data of RC and <lC>) of camera coordinate system C.
[0059](4) When a camera calibration is completed, move a robot to the position Pt shown in drawing 4, and make the position attainment state wishing instruction over mark MK1 appear.
[0060](5) Acquire a picture of mark coordinate system sigmaM and acquire data which expresses a sight line direction based on [each] dots by image processing in the image processing device 20.
(6) Perform processing according to an algorithm explained by above-mentioned 1.2.4. within the image processing device 20, and compute and memorize position attainment state representation data wishing instruction (data of Mg).
[0061]Autonomous movement in a position wishing instruction is performed by a processing cycle containing many following steps, as shown in a flow chart of drawing 8.
[K1] <d0>, <d1>, <d-1>, <d2>, and <d-2> are calculated by image processing, and M0 is calculated.
[K2] M0 calculated from <d0> calculated at data and Step K1 of Mg memorized, <d1>, <d-1>, <d2>, and <d-2> is compared, and both coincidence/disagreement are judged. If in agreement, since an attainment state to a position wishing instruction is meant, it progresses to Step K6. If inharmonious, since it means not having reached a position wishing instruction, it returns to Step K1 via Step K3 - K5. Various algorithms can be used for evaluation of the degree of coincidence of Mg and M0. for example, what is necessary is to compute the deciding index delta with a following formula (46), and just to suppose approach un-completing, if it is delta<epsilon (epsilon -- enough -- smallness -- a positive value) and is the completion of approach, and delta>=epsilon
[0062]
[Equation 9]

$$\Delta \overset{\text{def}}{=} \left\| (Mo-Mg) \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \right\|^2$$

$$+ \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} \right\|^2 + \left\| (Mo-Mg) \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \right\|^2 \quad \cdots (46)$$

[K3] The four-line procession T0 of four rows showing the position and posture of the hand (starting point of the coordinate system set up on the flange) of a robot is calculated and memorized.
[K4] Using the algorithm which explained [above-mentioned] with the data (data of C and Mg) acquired by the preparatory work, the right-hand side of (2) types is calculated and it asks for the perpendicular slip target position Tg.
[0063][K5] The movement command for going to the perpendicular slip target position Tg is created, a servo is passed, and a robot is moved. If the non-error of a system is

perfect, it should result in the position attainment state wishing instruction in the above step K1 - one cycle of K5, but the position attainment state wishing instruction is actually attained in successive approximations for the error of a visual sensor, the error of calculation, etc.

[0064][K6] A robot is stopped and processing is ended.

[Method 2]

[1] In the embodiment by the outline method 2, the light spot formed of a laser beam is used as a visual target means. First, drawing 9 - drawing 14 are added to a reference figure, and the outline of a preparatory work and teaching work is explained. Drawing 9 is a figure for explaining inner-1--3 of many stages of a preparatory work, and drawing 10 is a figure for explaining the remaining stages PR4-PR6. A figure for drawing 11 to explain inner TH1-TH3 of many stages of teaching work and drawing 12 are the figures for explaining stage TH4 and PR5.

[0065][2] Preparatory work (acquisition of position attainment state representation data wishing instruction, and calibration of a camera)

(PR1) a hand of a robot first represented with the flange position 2a -- the camera 21 -- in addition, the laser head 22 (irradiation head of the laser generator 60 shown in drawing 2) and the reference tool 25 are attached. The laser head 22 is attached via the suitable adjustment mechanism 23, and can adjust now the floodlighting direction of the laser beam 24. The mark 26 which expresses TCP (2b) with a portion shown by the arrow 27 near the tip of the reference tool 25 is formed. However, it needs to be cautious of this mark 26 being for viewing. Where the laser head 22 is attached, generally the laser beam 24 does not enter into the mark 26 on the reference tool 25, as illustrated.

[0066](PR2) Direction of the laser head 22 is adjusted and it is made for the laser beam 24 to enter into the mark 26 on the reference tool 25. Thereby, light spot is formed in a position of the mark 26, i.e., position 2b of TCP. The laser head 22 is henceforth fixed in this state.

[0067](PR3) Photography with the camera 21 is made to perform via the robot control device 30 in this state, and a picture for creating position attainment state representation data wishing instruction is acquired. Image processing of the picture of acquired light spot is carried out within the image processing device 20, and data showing the direction of light spot (it is in TCP position 2b.) seen from a camera coordinate system (starting point Oc) of the camera 21 of a vector <et> is created and memorized. This data is behind used as position attainment state representation data wishing instruction.

[0068](PR4) If data of <et> is acquired, the reference tool 25 will be removed. Since the laser head 22 is fixed, the laser beam 24 will pass along TCP (2b) in the air as illustrated.

[0069](PR5) Data of a vector <eh> is created and memorized as a vector showing the laser beam's 24 seen from the starting point Oc of camera coordinate system existence direction. <eh> is a vector by which the following two conditions are fulfilled.
Conditions 1; it is in a flat surface which a vector <et> and the laser beam 24 stretch.
It is a vector of a direction near a direction which looked at the laser head 22 from the camera 21 among <eh(s)> which fill condition 2;<eh> ** <et>. <eh> can be calculated by a method shown, for example in drawing 13.

[0070]That is, a robot is moved by jogging above the suitable flat surface (here, the representation work surface 3a is used.), and the spot F of the laser beam 24 is formed. And by approach to the field 3a of a robot from a state which has TCP position 2b above

the field 3a as shown in (1), as shown in (2), TCP position 2b makes the state of the field 3a of coming caudad. If it puts in another way, it will be made for a position of the spot F to come to an opposite hand from a state of (1) across the look 21a of the camera 21 and the intersection N of the field 3a which look at a TCP position (2b).

[0071]In this state, photography with the camera 21 is performed and a picture of the spot F is acquired. And image processing is performed within the image processing device 20, and it asks for data showing the direction of the spot F seen from a camera coordinate system of a vector <es>. A vector <eh> is computed with a following formula (47) using this <es>.

[0072]

[Equation 10]

$$<eh> = \frac{<et> \times <es>}{\| <et> \times <es> \|} \quad \cdots (47)$$

(PR6) The calibration of the camera 21 is performed. This is for asking for the relation of the flange coordinate system (2a is the starting point) and camera coordinate system which are set up on a robot hand's flange face. Various things are available as explanation of the method 1 described the technique of the KIKYA rib ration of a camera (the technique by a mark member may be used).

[0073][3] teaching work (TH1) by the method 2 -- move a robot first above the representation work surface 3a where the first position wishing instruction exists by jogging, and form the spot F of the laser beam 24 on the representation work surface 3a. Marking of the position A wishing instruction shall be beforehand carried out by the suitable teaching point mark A which can be recognized with a visual sensor. The flange position 2a in the state where it illustrated shall be set to Ps, and autonomous movement shall be started from the position Ps. Shift to autonomous movement from jogging can be considered as an automatic change which used a visual-sensor output, for example so that it may mention later.

[0074]TCP position 2b is above the field 3a, and the laser beam 24 forms the spot F on the field 3a through this point as illustrated. Generally in this stage TH1, three points are in another position mutually [the teaching point mark A and the spot positions F and TCP (2b)]. The look 21a which looked at the teaching point mark A from the camera 21 does not pass along TCP (2b).

[0075](TH2) A robot is operated by processing of autonomous movement and the look 21a which looked at the teaching point mark A from the camera 21 passes along TCP (2b). As operation of a robot, rotation of a circumference of the starting point Oc of a camera coordinate system is rational.

[0076](TH3) A robot is operated by processing of autonomous movement, and a formation position of the spot F is made to approach the teaching point mark A, keeping conditions by which the look 21a passes along TCP (2b) as much as possible. As operation of a robot, rotation of a circumference of Oc should be suitably combined with advance of the direction of look 21a.

[0077](TH4) If advance of the direction of look 21a becomes superfluous, while the look 21a will keep conditions which pass along TCP (2b) as much as possible, in accordance with the direction of look 21a, it retreats suitably, and rotation of a circumference of Oc is combined suitably.

[0078](TH5) Hereafter, operation (advance) of TH3 and operation of TH4 (retreat) are

repeated, and a formation position of the spot F is completed as the teaching point mark A. Since it is exactly an intersection of the look 21a which this convergent point passes along TCP (2b), and looks at the teaching point mark A, and a laser beam which passes along TCP (2b) therefore, it will come to the teaching point mark A and the position in which three points are the same as for the spot positions F and TCP (2b) after all. This means namely that instruction target point slack TCP (2b) reached a position wishing instruction. A position of flange position 2b at this time is expressed with Pt as well as a case of the method 1.

[0079]Then, if a robot position in this state is memorized to a control means (nonvolatile memory in a robot control device), position instruction of the position A will be completed. What is necessary is just to apply the above-mentioned processes TH1-TH5 about each teaching point mark of the 2nd henceforth, when there are two or more positions wishing instruction (teaching point mark) (see the point A1 - A4 on the representation work 3 in drawing 1, for example although a graphic display is omitted).

[0080][4] Explain an algorithm of processing for attaining movement in the position Pt (similarly it expresses in a flange position) wishing instruction from the autonomous movement starting position Ps (it expresses in a flange position) according to a process explained by the processing above at the time of position autonomous movement wishing instruction in the method 2 [2]. Although sign <> expresses a vector as well as a case of the method 1, a definition content of a vector is separate from the method 1. Autonomous movement is performed based on a processing cycle according to an algorithm which described an outline in a flow chart of drawing 15 (L1-L12) and drawing 16 (L13-L19). Hereafter, it divides into each step and explains focusing on an algorithm. The meaning of many signs under explanation is as follows.

[0081]sigma0, sigma1 ; A value of 1 [**] is taken with a flag with which all express advance/retreat of a robot. +1 means advance and -1 means retreat.

l; register value [showing the amount of units of advance/retreat of a robot] <dm>; -- to have been shown in drawing 14 is asked from image data by a unit vector (length 1) showing a sight line direction which looked at the teaching point mark A from the starting point Oc of a camera coordinate system.

<ds>; to have been shown in drawing 14 similarly is asked from image data like <dm> by a unit vector (length 1) showing a sight line direction which looked at spot position F (incidence position of the laser beam 24) from the starting point Oc of a camera coordinate system.

[0082]T; procession deltar which expresses a position and a posture of a robot on a robot-coordinates system, deltal ; Positive constant near [in a threshold with suitable all] 0. What expresses the minimum rotation with a rotation procession which describes a relation of the direction of R;<dm > and <et > among 3x3 processions used as R<et >= <dm>.

sgn; it defines as signum as follows.

sgn(x)=+1 (x>0)

sgn(x)=0 (x=0)

sgn(x)=-1 (x<0)

[L1] Flag sigma0 is initialized to 1. l is initialized to a suitable initial value (for example, 3 cm).

[L2] A register value showing data of the procession T is updated based on a current

position of a robot.
[L3] A photograph is taken using the camera 21 and it tries to search for a vector <dm> using the image processing device 20.
[L4] Since it is possible that the teaching point mark A is not caught with a camera view if a vector <dm> is not searched for, processing is ended (an operator is changed into the state where adjust a robot position by jogging and the teaching point mark A is certainly caught with a camera view). When a vector <dm> is searched for, it progresses to Step L5.
[0083][L5] It asks for an outer product of a vector <et> and a vector <dm>, and <dr =[>] <et> x <dm>.
[L6] As compared with threshold deltar, if not small, he follows an absolute value of a vector <dr> to Step L7. If small, it will progress to Step L10.
[0084][L7] The rotation procession R which describes a relation of the direction of <dm> and <et> is computed by a declared formula. A declared formula is obtained by solving the following simultaneous equations about R.
R<et = [>] <dm> ... (48)
R<dr = [>] <dr> ... (49)
[L8] A register value showing data of the procession T is updated to a thing to a procession of a notation containing the new submatrix R. This procession solves the following equation (50) about Tg, and is set to Tg ->T.
[0085]
[Equation 11]

$$TgC = TC \begin{bmatrix} R & 0 \\ t_0 & 1 \end{bmatrix} \quad \cdots (50)$$

[L9] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L8 expresses is performed, and it returns to Step L2.
[L10] By step L6, if it is judged that the absolute value of a vector <dr> is smaller than threshold deltar, this step L10 will be performed for the first time. It tries to search for the unit vector <ds> which expresses with this step the sight line direction which looked at spot position F from the starting point Oc of the camera coordinate system from image data.
[0086][L11] It is thought that it cannot happen that the spot F is not settled in a camera view when [this] an absolute value of a vector <dr> is about 0 (a look which looks at TCP, and a look which looks at a teaching point mark are real coincidence) unless there are a system abnormality, a design error, etc. Therefore, in almost all cases, a vector <ds> is searched for and it progresses to Step L12. However, processing is ended if <ds> should not be calculated (a cause inquiry etc. are performed separately).
[0087][L12] <ds> and <et> are the real same directions, and it confirms whether to be the inner product 1 (it is cautious of deltal being a very small positive value).
[L13] Flag sigma1 showing advance/retreat of a robot will be set to sigma1 =0, if an inner product of <ds> and <eh> is positive, it is sigma1 =-1 and negative and it will become sigma1 =1 and a real target zero.
[L14] If it is sigma1 =0, it will progress to Step L15. If it is not sigma1 =0, it will progress to Step L16.
[L15] sigma1 is updated to sigma0 and it progresses to Step L18.

[L16] If a product of sigma1 and sigma0 is positive, it will progress to Step L18. If it is negative, it will progress to Step L17.
[0088][L17] A value of l is reduced by half while updating sigma0 to sigma1.
[L18] A register value showing data of the procession T is updated to a thing to a declared procession. This procession solves the following equation (51) about Tg, and is set to Tg ->T.
[0089]
[Equation 12]

$$TgC = TC \begin{bmatrix} 1 & \sigma 1 \mid < et > \\ t_0 & 1 \end{bmatrix} \quad \cdots (51)$$

[L19] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L18 expresses is performed, and it returns to Step L2.
In the processing cycle according to the algorithm explained above, if the judgment output of yes is obtained at Step L12 at one of the times, it will be understood as the position attainment state wishing instruction as shown in (TH5) of drawing 12 having been realized, a robot will be stopped, and processing will be ended.
[0090]As mentioned above, since movement in the position wishing instruction of a robot will be autonomously performed so that it may become the position of a position attainment state wishing instruction and the posture which it was inputted beforehand if this invention is followed so that I may be understood from the explanation about the embodiment of the method 1 and the method 2, working efficiency improves.
[0091]the method 1 and the method 2 -- also in which embodiment, it is preferred to automate a change in the mode of autonomous movement in which it tends toward a position wishing instruction autonomously, from the mode of jogging by a manual command input by processing inside a control means (the robot control device 30 and the image processing device 20).
[0092]Drawing 17 shows an operating procedure of a teaching control panel, and outline of processing with a flow chart about a case where a change in the mode of autonomous movement of jogging from the mode is performed inside a system. It is as follows when processing of each step is described briefly. An output of a visual sensor is used for determination of timing of a mode change in this example.
[S1] If it judges whether the jogging button 47 (any one) was pushed and instructions of jogging were made, and are made, will progress to Step S2 and it will not be made, Step S1 is repeated.
[S2] According to movement contents (a direction, an axis, etc.) specified with the jogging button 47, a predetermined axis is controlled and jogging movement of the robot 10 is started. For example, if movement of the direction of J6 axis + is specified, a movement command which advances J6 axis in the direction of + will be created, and a servo will be passed.
[S3] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 will not be progressed and used, it progresses to step S4.
[S4] If existence of reception of a signal which tells that the teaching point mark A (a case of the method 2 and the spot F) entered in a view of the camera 13 was checked, it has received and it will not have progressed and received to Step S5, it returns from the

image processing device 20 to Step S3.
[S5] Processing of autonomous movement is started. It is as having divided into the method 1 and the method 2 and having mentioned above about an example of the concrete contents of processing.
[S6] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 is not progressed and used, it progresses to Step S7.
[S7] It judges whether it reached to a position wishing instruction, if it has reached, it will progress to Step S8, and if it has not reached, it will return to Step S6. It is as having also described a judgment method which is not reached [the position attainment wishing instruction /] in explanation of the method 1 and the method 2.
[S8] Operation of each axis of the robot 2 is stopped.

DESCRIPTION OF DRAWINGS

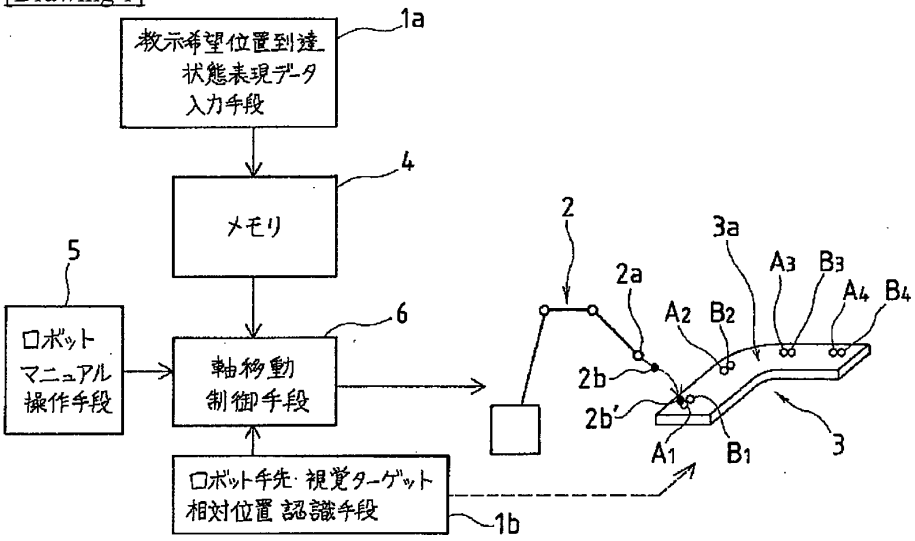
[Brief Description of the Drawings]
[Drawing 1]It is a figure which illustrates notionally the overview of the movement control system for the position instruction of a robot according to this invention.
[Drawing 2]the important section block diagram centering on a robot control device showed the outline of the hardware constitutions of the system used by this embodiment -- it is.
[Drawing 3]It is a figure showing the outline composition of the panel surface of the teaching control panel 40.
[Drawing 4]It is a figure explaining operation of the autonomous movement in the embodiment by the method 1.
[Drawing 5]It is a figure explaining the composition of the mark member used by the embodiment by the method 1.
[Drawing 6]In the embodiment by the method 1, a camera is a figure explaining the vector which describes the sight line direction which looks at a mark coordinate system.
[Drawing 7]It is a figure explaining the outline of an algorithm required for the position autonomous movement wishing instruction in the embodiment by the method 1.
[Drawing 8]It is the flow chart which described the outline of processing of the position autonomous movement wishing instruction in the embodiment by the method 1.
[Drawing 9]It is a figure for explaining inner-1--3 of many stages of the preparatory work in the embodiment by the method 2.
[Drawing 10]It is a figure for explaining inner-4--6 of many stages of the preparatory work in the embodiment by the method 2.
[Drawing 11]It is a figure for explaining inner TH1-TH3 of many stages of the teaching work in the embodiment by the method 2.
[Drawing 12]It is a figure for explaining inner TH4 of many stages of the teaching work in the embodiment by the method 2, and TH5.
[Drawing 13]In the embodiment by the method 2, it is a figure explaining how to search for a vector <eh>.
[Drawing 14]It is a figure which illustrates a vector <dm> and <ds> about the embodiment by the method 2.
[Drawing 15]It is the first half (L1-L12) of a flow chart in which the outline of the

algorithm of processing for control of the autonomous movement in the embodiment by the method 2 was described.
[Drawing 16]It is the latter half (L13-L19) of the flow chart which described the outline of the algorithm of processing for control of the autonomous movement in the embodiment by the method 2.
[Drawing 17]In the embodiment by the method 1 or the method 2, a flow chart shows the operating procedure of a teaching control panel, and the outline of processing about the case where the change in the mode of autonomous movement of jogging from the mode is performed inside a system.
[Description of Notations]
1a The position attainment status input means wishing instruction
1b The relative-position-recognition means between robot hand visual targets
2 Robot
2a Flange representative point (flange coordinate system starting point)
2b Instruction target point (TCP; tool point)
The instruction target point (TCP) which reached the position wishing 2b' instruction
3 Representation work
4 Memory
5 Robot manual operation means
6 Shaft movement control means
20 Image processing device
21 Camera
22 Laser head (irradiation part of a laser generator)
23 The floodlighting direction control function of a laser head
24 Laser beam
30 Robot control device
31 Processor board
31a Processor
31b ROM
31c RAM
35 Digital I/O
36 Analog I/O
37 Bus
40 Teaching control panel
41 Display screen
42 Function key
44 Emergency stop button
45 Cursor key
46 Ten key part
47 (J1-J6) jogging button
51-56 Servo motor
60 Laser generator
A Teaching point mark (position wishing instruction)
A1 - A4 Position wishing instruction
B1 - B4 visual target means
CB1-3 Position which performs the calibration of a camera

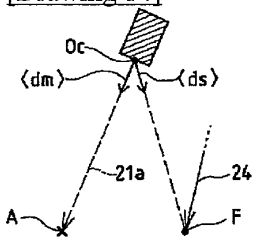
The dot of D0, D1, D-1, D2, and D-2 mark coordinate system
F Spot
MK1-MK4 Mark member
sigmaM mark coordinate system

DRAWINGS

[Drawing 1]

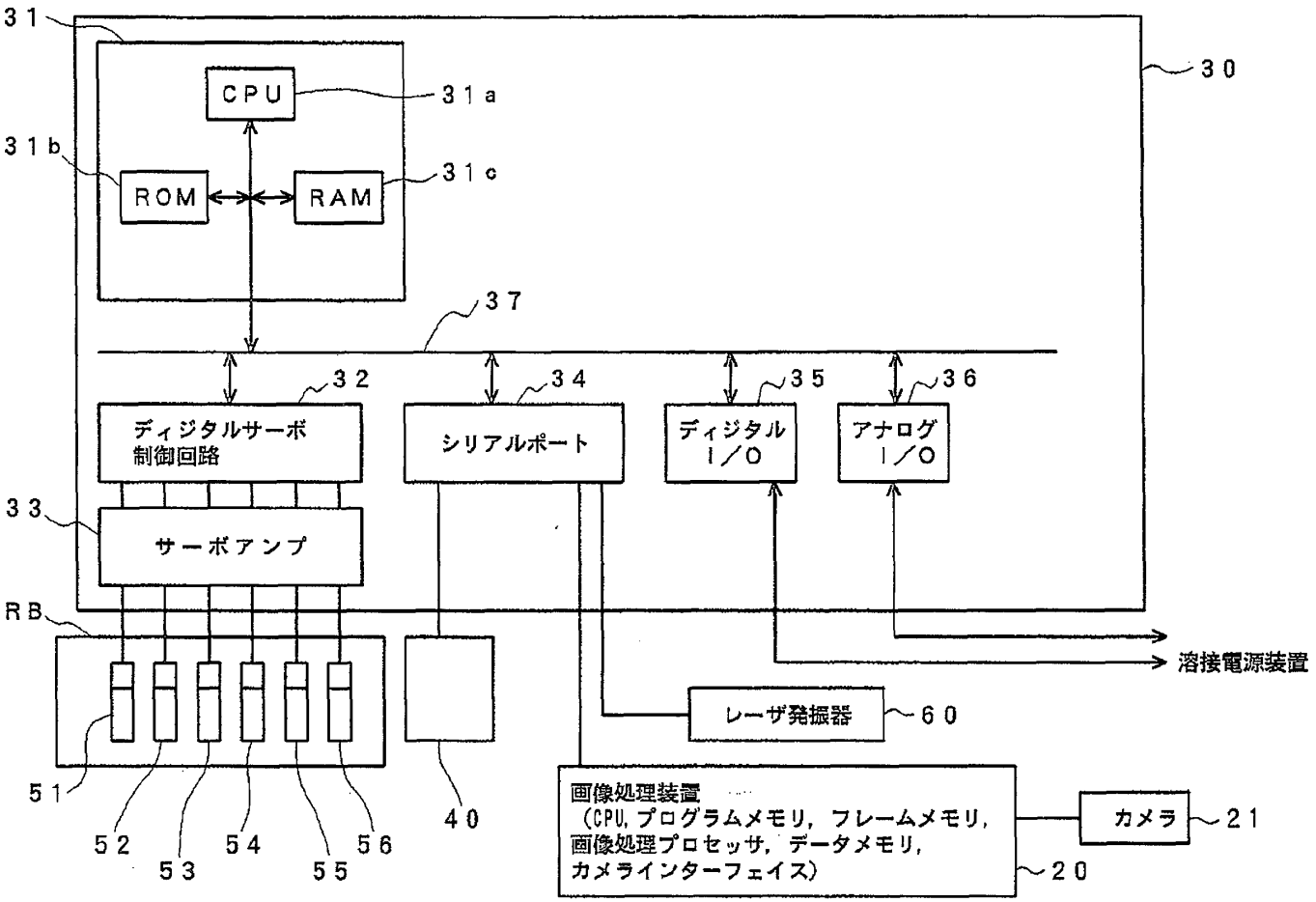


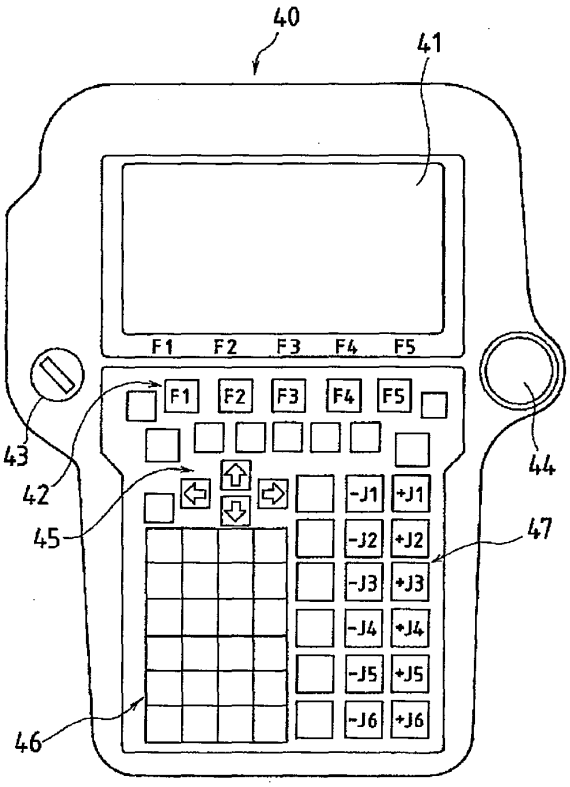
[Drawing 14]



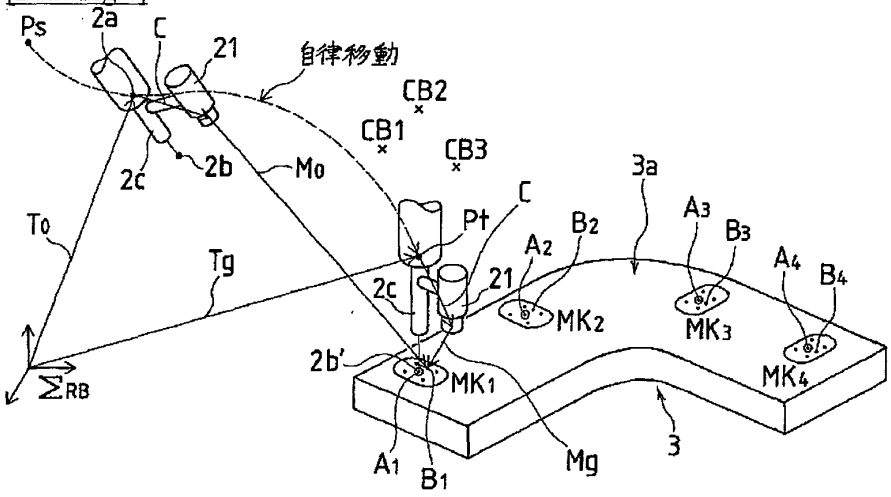
[Drawing 2]

[Drawing 3]

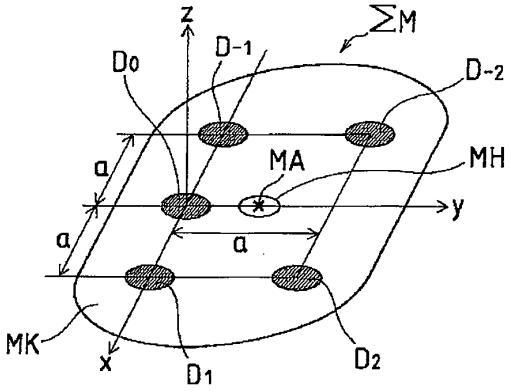

31
CPU
31a
31b
ROM
RAM
31c
30
37
32
34
35
36
ディジタルサーボ
制御回路
シリアルポート
ディジタル
I／O
アナログ
I／O
33
サーボアンプ
RB
溶接電源装置
レーザ発振器
60
51
52
53
54
55
56
40
画像処理装置
（CPU，プログラムメモリ，フレームメモリ，
画像処理プロセッサ，データメモリ，
カメラインターフェイス）
20
カメラ
21



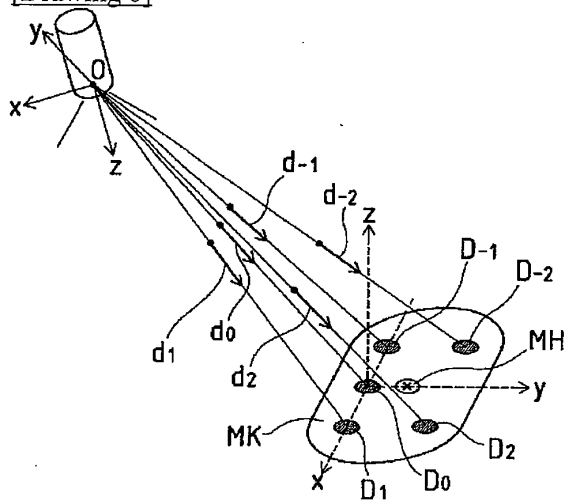
[Drawing 4]



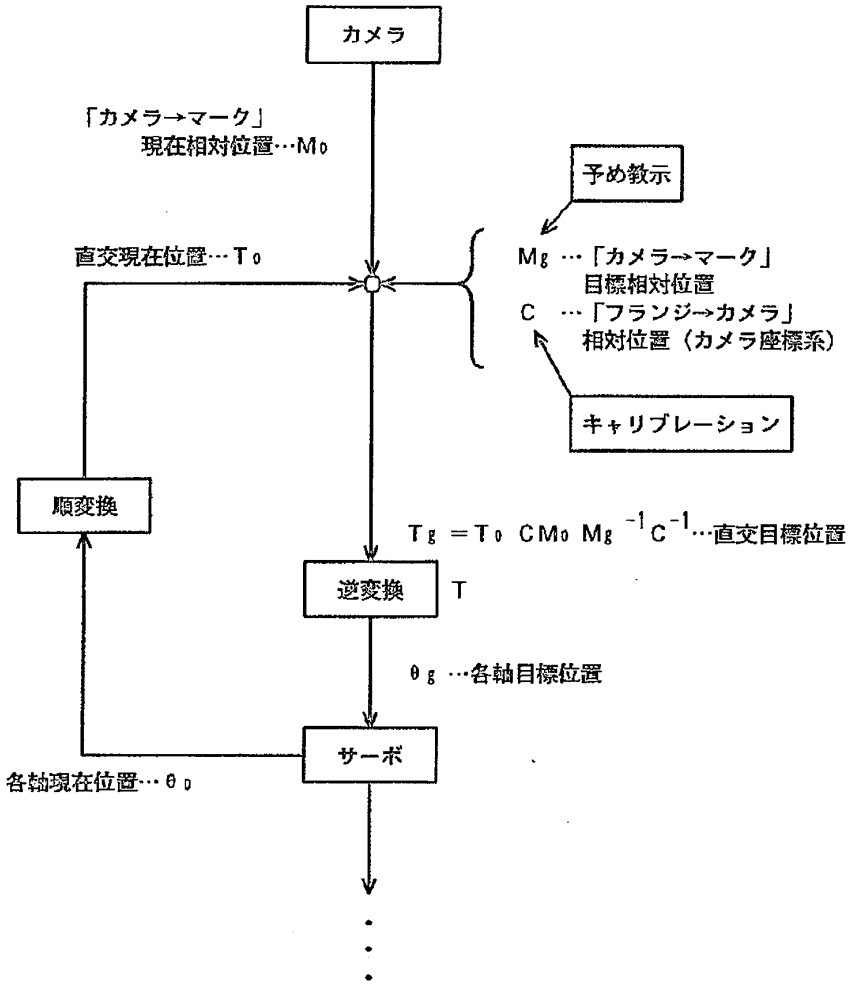
[Drawing 5]



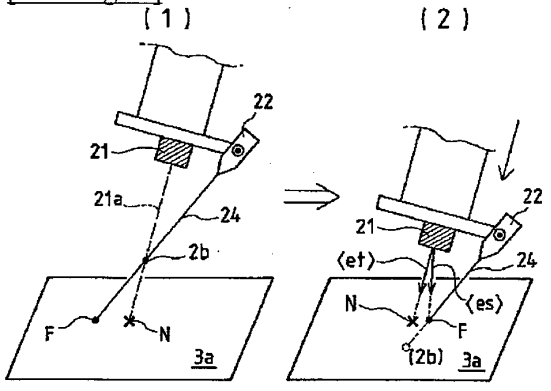
[Drawing 6]



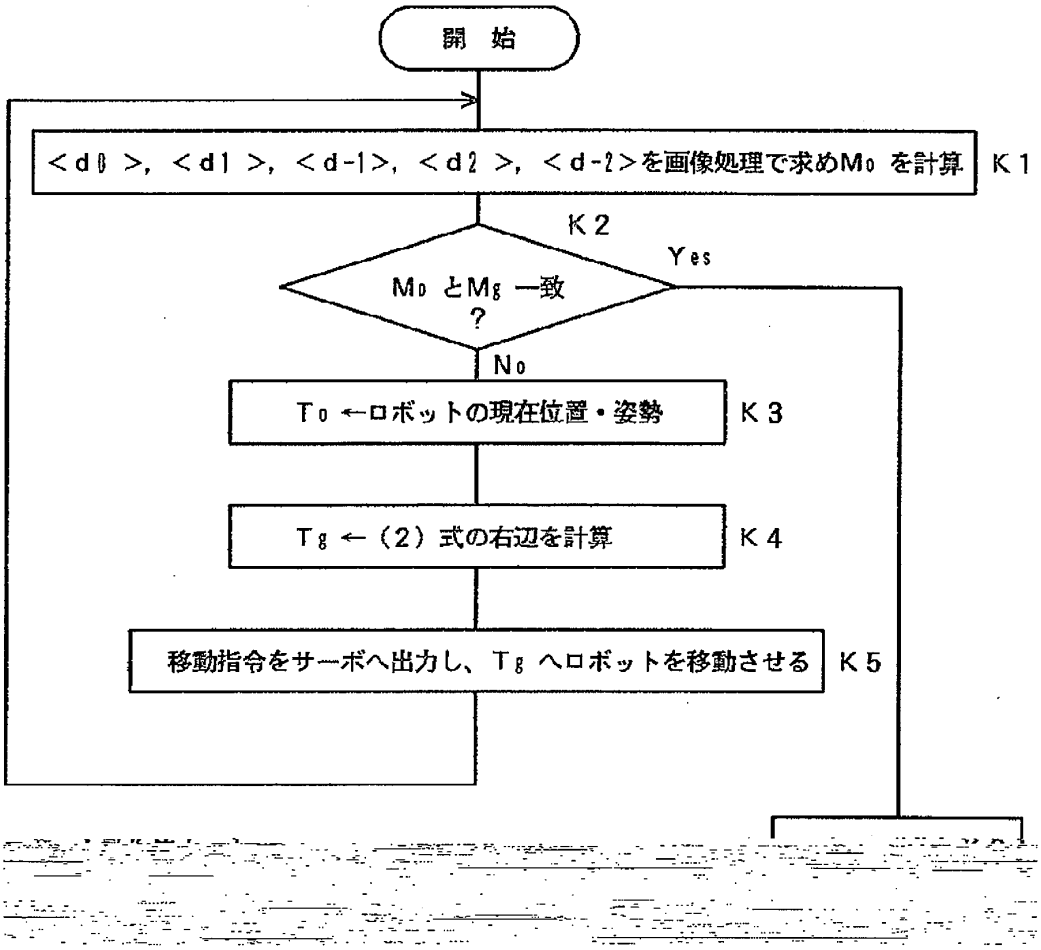
[Drawing 7]



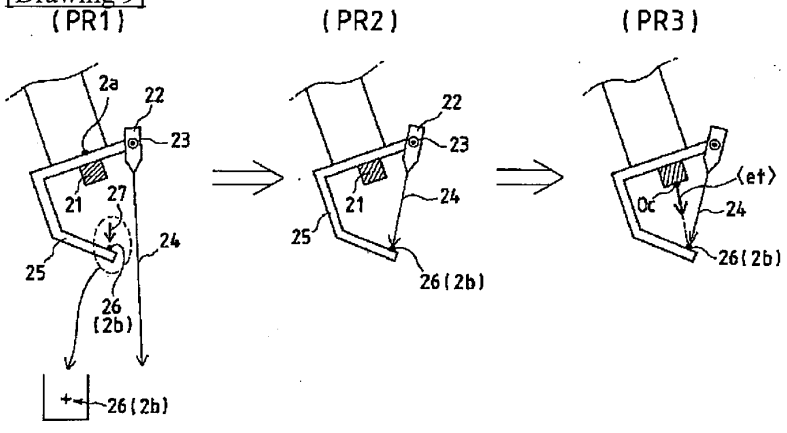
[Drawing 13]



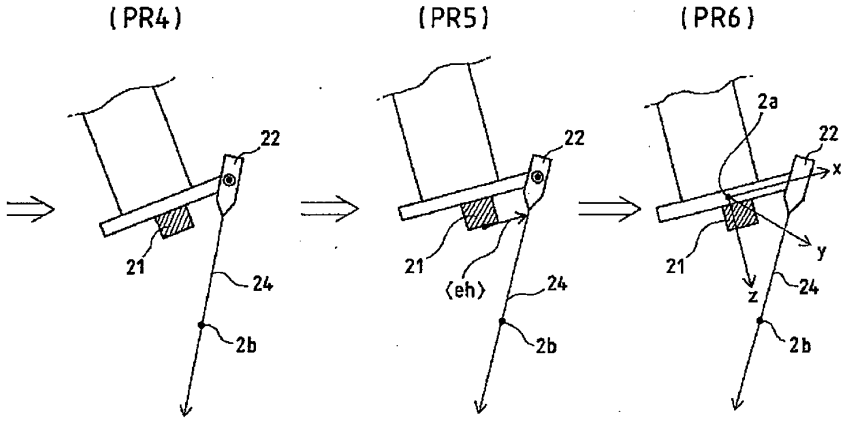
[Drawing 8]



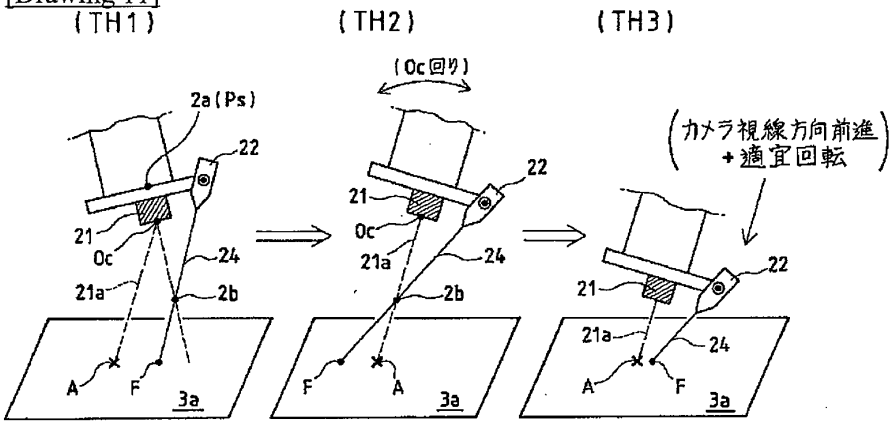
[Drawing 9]



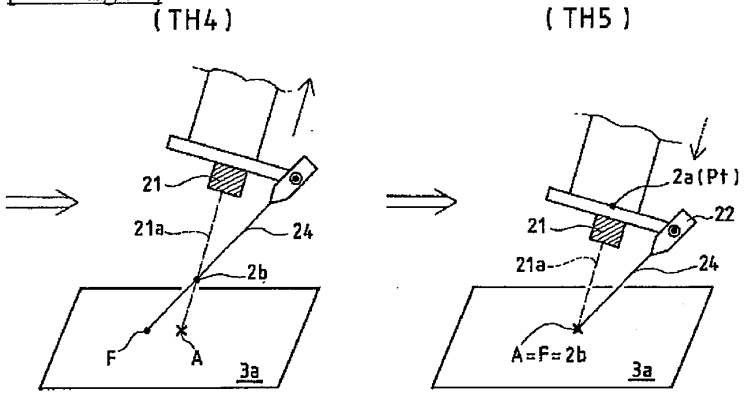
[Drawing 10]



[Drawing 11]

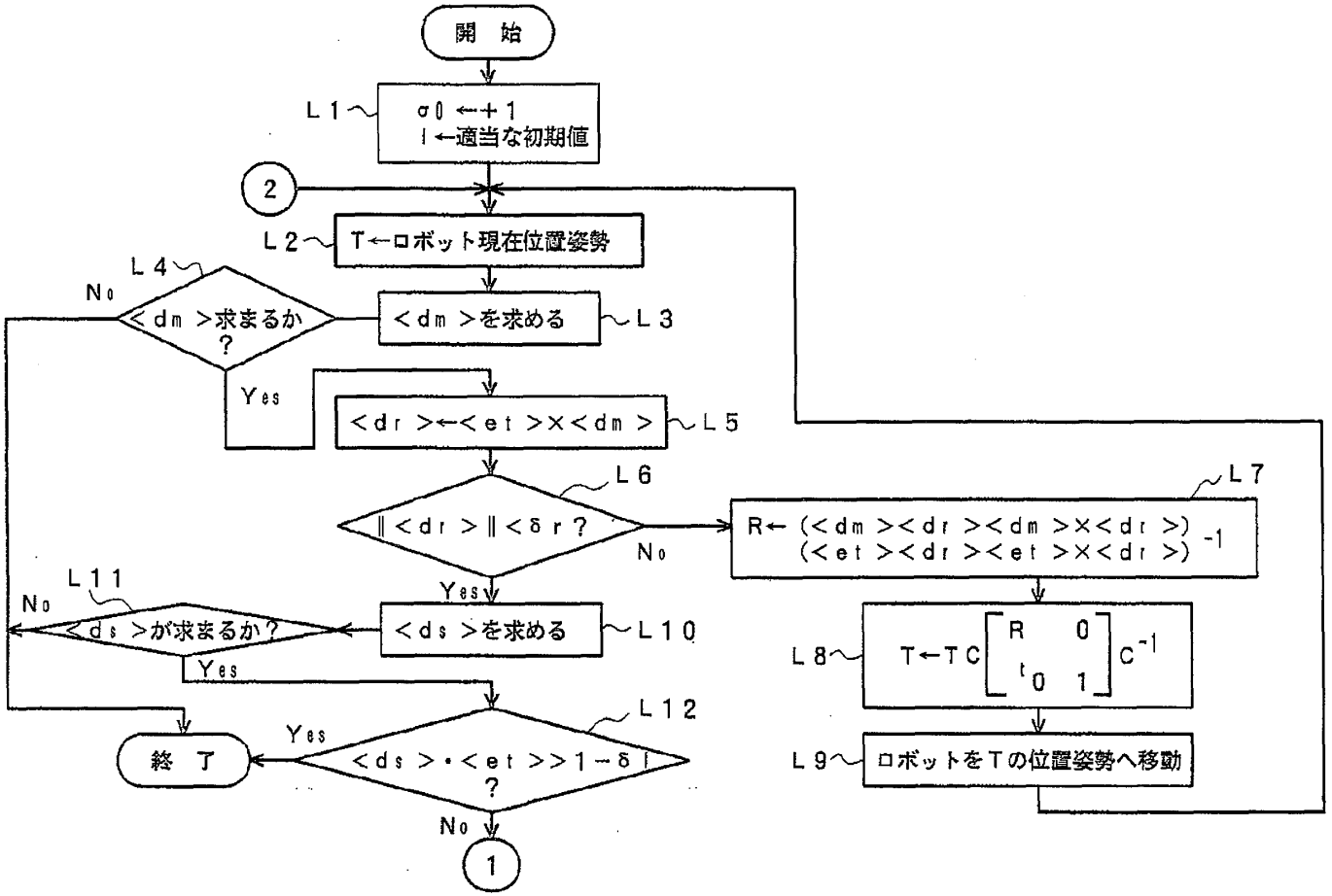


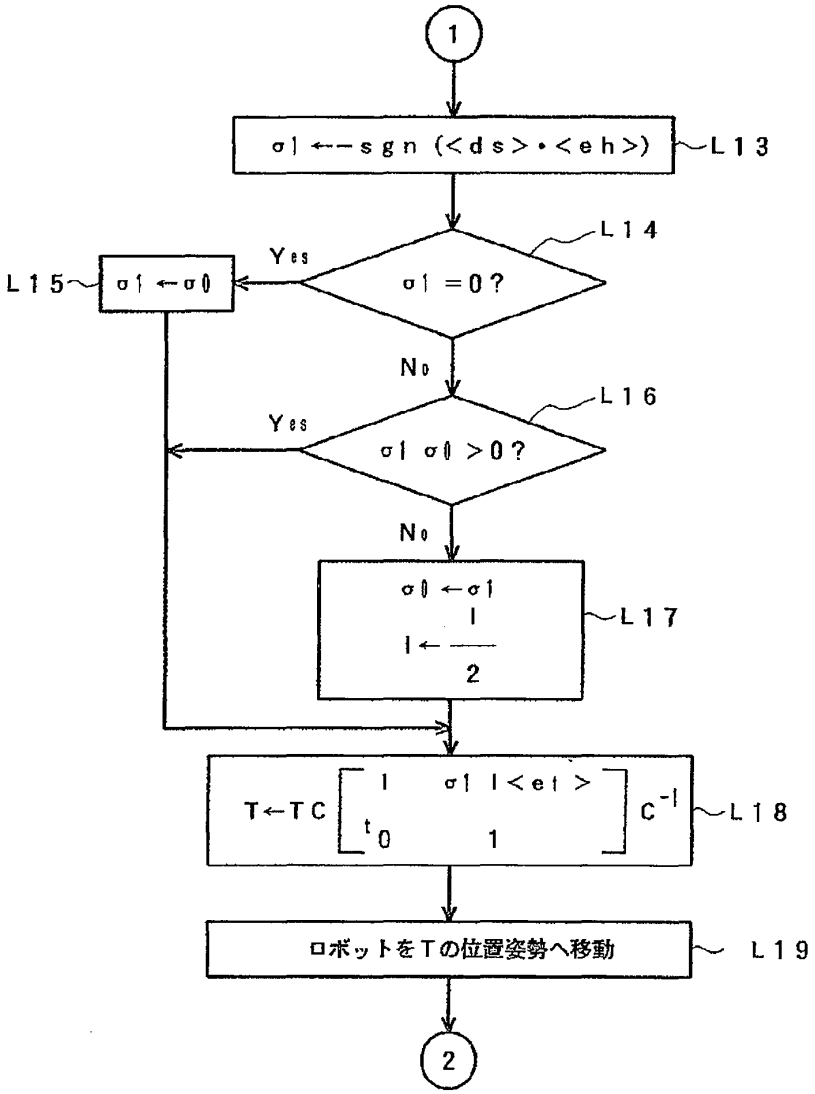
[Drawing 12]



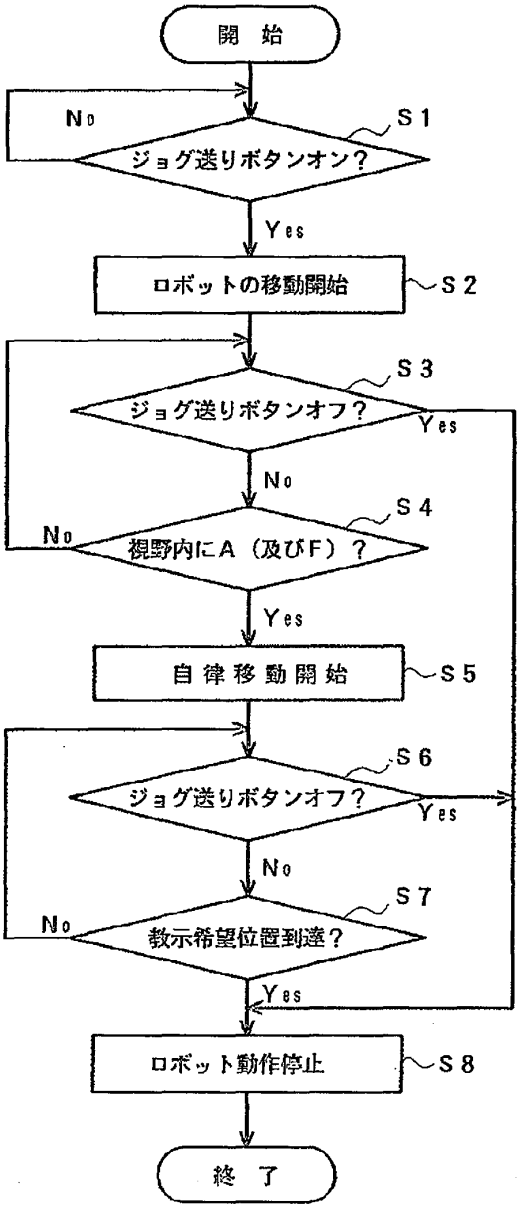
[Drawing 15]

[Drawing 16]


開 始
L 1
σ0 ←+1
l ←適当な初期値
2
L 2
T←ロボット現在位置姿勢
L 4
No
＜dm＞求まるか？
＜dm＞を求める
L 3
Yes
＜dr＞←＜et＞×＜dm＞
L 5
L 6
‖＜dr＞‖＜δr？
No
L 7
R← (＜dm＞＜dr＞＜dm＞×＜dr＞) -1
(＜et＞＜dr＞＜et＞×＜dr＞)
Yes
L 11
No
＜ds＞が求まるか？
＜ds＞を求める
L 10
Yes
L 8
T←TC [R 0; t 0 1] C-1
L 12
Yes
終 了
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[Drawing 17]



[Translation done.]

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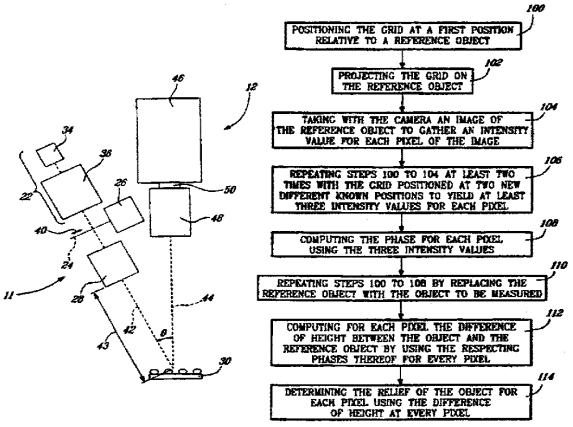
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(54) Title: METHOD AND SYSTEM FOR MEASURING THE RELIEF OF AN OBJECT



(57) **Abstract:** A method and a system for measuring the relief of an object are described herein. The system includes a grid projecting for projecting a grid, an image acquisition apparatus that includes a camera, and a computer. Providing a reference object having common elements with the object to measure, the method includes the steps of a) positioning the grid at three different known positions relative to the camera and the common elements; b) for each position of the grid, projecting the grid unto the reference object and, with the camera, taking an image of the reference object to yield three images having values for each pixel of the camera and c) computing the reference object phase for each pixel using the three reference object intensity values for the corresponding pixel. Steps a), b) and c) are repeated by replacing the reference object by the object to be measured. The difference of height between the object to be measured and the reference object for each pixel are then computed by subtracting the reference object phase and the object phase for the corresponding pixel.

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TITLE OF THE INVENTION

METHOD AND SYSTEM FOR MEASURING THE RELIEF OF AN OBJECT

FIELD OF THE INVENTION

The present invention generally relates to methods for measuring the relief of an object. More specifically, the present invention is concerned with the use of such systems and methods to inspect the lead coplanarity on circuit board.

BACKGROUND OF THE INVENTION

The use of interferometric methods to inspect the surface of an object for defects or to measure the relief of an object is well known. Generally stated, these methods consist in generating an interferometric pattern on the surface of the object and then analyzing the resulting interferometric image (or interferogram) to obtain the relief of the object. The interferometric image generally includes a series of black and white fringes.

Interferometric methods that require the use of a laser to generate the interferometric pattern are called "classic interferometric methods". In such classic methods, the wavelength of the laser and the configuration of the measuring assembly generally determine the period of the resulting interferogram. Classic interferometry methods are

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generally used in the visible spectrum to measure height variations in the order of micron.

However, it has been found difficult to use such method to measure height variations (relief) on a surface showing variations beyond 0.5 – 1 μm when they are implemented in the visible spectrum. Indeed, the density of the black and white fringes of the resulting interferogram increases, causing its analysis to be tedious.

Another drawback of classic interferometric methods is that they require measuring assemblies that are particularly sensitive to noise and vibrations.

Surface inspection methods based on Moiré interferometry allow measuring the relief of an object in the visible spectrum with accuracy much more than the accuracy of classic interferometric methods. These methods are based on the analysis of the frequency beats obtained between 1) a grid positioned over the object to be measured and its shadow on the object ("Shadow Moiré Techniques") or 2) the projection of a grid on the object and another grid positioned between the object and the camera that is used to take a picture of the resulting interferogram ("Projected Moiré Techniques"). In both cases, the frequency beats between two grids produce the fringes of the resulting interferogram.

More specifically, the Shadow Moiré technique includes the steps of positioning a grid near the object to be measured, providing

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illumination from a first angle from the plane of the object (for example 45 degrees) and using a camera, positioned at a second angle (for example 90 degrees from the plane of the object), to take pictures of the interferogram.

Since the distance between the grid and the object varies, this variation of height produces a variation in the pattern of the interferogram. This variation in the pattern can then be analysed to obtain the relief of the object.

A drawback to the use of a Shadow Moiré technique for measuring the relief of an object is that the grid must be positioned very close to the object in order to yield accurate results, causing restrictions in the set-up of the measuring assembly.

The Projected Moiré technique is very similar to the Shadow Moiré technique since the grid, positioned between the camera and the object, has a function similar to the shadow of the grid in the Shadow Moiré technique. However, a drawback of the Projected Moiré technique is that it involves many adjustments and therefore creates more risk of inaccuracy in the results since it requires the positioning and tracking of two grids. Furthermore, the second grid tend to obscure the camera, preventing it from being used simultaneously to take other measurements.

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A method and a system to measure the relief of an object free of the above-mentioned drawbacks of the prior-art are thus desirable.

OBJECTS OF THE INVENTION

An object of the present invention is therefore to provide an improved method and system for measuring the relief of an object.

Another object of the invention is to provide such a system suitable for lead coplanarity inspection.

SUMMARY OF THE INVENTION

More specifically, in accordance with the present invention, there is provided a method for measuring the relief of an object using a camera provided with an array of pixels, the method comprising:

a) projecting a grid on a reference object; the grid being located at a first position relative to the camera and to the reference object;

b) taking, with the camera, an image of the reference object illuminated by the projected grid; the image of the reference object having intensity values for each pixel;

c) repeating steps a) and b) at least two times with the grid being located at two different known positions relative to the camera and to the reference object to yield at least three intensity values for each pixel;

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d) computing the reference object phase for each pixel using the at least three reference object intensity values for the corresponding pixel;

e) projecting the grid on the object; the grid being located at the first position;

f) taking with the camera an image of the object illuminated by the projected grid; the image of the object having intensity values for each pixel position;

g) repeating steps e) and f) at least two times with the grid being located at the two different positions to yield at least three intensity values for each pixel;

h) computing the object phase for each pixel position using the at least three object intensity values for the corresponding pixel; and

i) computing the difference of height between the object and the reference object for each pixel using the reference object phase and the object phase for the corresponding pixel.

According to another aspect of the present invention, there is provided a system for measuring the relief of an object, the system comprising:

a grid projecting assembly;

an image acquisition apparatus including a camera provided with an array of pixels;

a computer configured for

a) receiving from the image acquisition apparatus at least three images of the projected grid onto the object and at least three images of the projected grid onto the reference object; each of the images

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of the projected grid onto the object corresponding to a different known position of the grid; each of the images of the projected grid onto the reference object corresponding to one of the known positions of the grid;

b) computing the reference object phase for each pixel using the at least three reference object intensity values for the corresponding pixel;

c) computing the object phase for each pixel using the at least three object intensity values for the corresponding pixel; and

d) computing the difference of height between the object and the reference object for each pixel using the reference object phase and the object phase for the corresponding pixel.

Other objects, advantages and features of the present invention will become more apparent upon reading the following non-restrictive description of preferred embodiments thereof, given by way of example only, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the appended drawings:

Figure 1 is a schematic view of a system for inspecting the surface of an object according to an embodiment of the present invention;

Figure 2 is a schematic view of both the image acquisition apparatus and the grid projection assembly of Figure 1;

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Figure 3 is a schematic view illustrating the projection of a grid on an object;

Figure 4 is a block diagram of a method for measuring the relief of an object according to an embodiment of the present invention;

Figure 5 is an image of a sphere mounted to a board, as taken by the system of Figure 1;

Figure 6 is an image of the board of Figure 5, illuminated by the grid;

Figure 7 is an image computed by the system of Figure 1, representing the phase of the board of Figure 6;

Figure 8 is an image of the sphere of Figure 5 mounted to the board, illuminated by the grid;

Figure 9 is an image computed by the system of Figure 1, representing the phase of the sphere with the board of Figure 8;

Figure 10 is an image illustrating the phase variation between the images of Figures 7 and 9;

Figure 11 is an image representing the phase variation

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between a module comprising lead balls on a substrate and a reference surface;

Figure 12 is an image representing the phase of the module of Figure 11;

Figure 13 is an image representing the phase variation between the phase of the image of Figure 12 and the phase image of a complementary surface;

Figure 14 is an image representing the phase variation between the phases of the images of the complementary surface and the reference plane;

Figure 15 is the image of Figure 14 after unwrapping.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to Figures 1 and 2 of the appended drawings, a system 10 for measuring the relief of an object, according to an embodiment of the present invention, will be described.

The surface inspection system 10 comprises a grid projecting assembly 11, an image acquisition apparatus 12, and a computer 14 advantageously provided with a storing device 16, an output device 18 and an input device 20.

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Turning now more specifically to Figure 2 of the appended drawings, the grid projecting assembly 11 and the image acquisition apparatus 12 will be described in more detail.

The grid projection assembly 11 includes an illuminating assembly 22, a grid 24 mounted to a movable support 26 and a projector 28.

The illuminating assembly 22 advantageously includes a source of white light 34 that is projected through the grid 24. For example, the source 34 is the end of an optical fiber (not shown) providing light from a white light source (not shown). An aspherical lens 36 or any other condenser is also advantageously used between the source 34 and the grid 24. Other light sources may also be used. It is also believed to be within the reach of a person skilled in the art to conceive another illuminating assembly within the spirit of the present invention.

The configuration of the grid 24 may vary depending on the resolution that is required to adequately measure the relief of the object 30. For example, it has been found that a ronchi ruling having 250 lines per inch allows to measure lead coplanarity of a circuit board, where a resolution around 1 mm is required.

The grid 24 is advantageously mounted to a moveable support 26 that allows displacement of the grid 24 in a direction perpendicular (see double arrow 40 on Figure 2) to both the lines on the grid 24 and to the direction of incidence of the light (dashed line 42 on

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Figure 2).

The movable support 26 is actuated by a stepping motor (not shown). The stepping motor is advantageously controlled by a micro-controller (not shown) triggered by the computer 14. Of course, the stepping motor could be directly controlled by the computer 14.

A projector 28, in the form of a 50 mm TV lens, is advantageously used to project the grid 24 onto the object 38.

The angle θ between the direction of incidence of the light (dashed line 42 on Figure 2) and the line of sight of the image acquisition apparatus 12 (dashed line 44 on Figure 2) may vary depending on the nature of the object 30 to be measured.

It is believed to be within the reach of a person skilled in the art to position the illuminating assembly 22, the grid 24 and the grid projector 28 relative to the object 30 to yield a projected grid having the desired pitch *p* onto the object 30.

For example, a ronchi grid, having a density of 250 lines per inch, with a distance 43 of 22 cm between the object 30 and the projector 28, and for an angle θ of 30 degrees, provides a projected grid having a 0.5 mm pitch *p*. Such a pitch is equivalent to a variation of height of about 1 mm on the surface of the object 30.

Obviously, the pitch of the projected grid will vary with the

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pitch of the grid 24.

As will be explained hereinbelow, the displacement of the projected grid 24 on the object 30 may alternatively be achieved by fixing the position of the grid 24 and by moving the object 30 and the camera 46 together.

It is to be noted that the system 10 does not require a grid between the camera 46 and the object 30. This advantage will be discussed hereinbelow.

The image acquisition apparatus 12 includes a camera 46, provided with an array of pixels, and is advantageously in the form of a CCD camera 46. Such a camera provides, for example, a resolution of 1300x1024 pixels.

The image acquisition apparatus 12 also advantageously includes a telecentric lens 48, advantageously mounted to the camera 46 via an optional extension tube 50.

The configuration of the image acquisition apparatus 12 and the distance between the apparatus 12 and the object 30 determines the field of view of the image acquisition apparatus 12. Alternatively, a desired field of view can be achieved without the extension tube 50 by distancing the camera 46 from the object 30.

The CCD camera can be replaced by a conventional

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camera when the computer 14 is configured to digitize the acquired images.

The computer 14 is advantageously configured to control the displacement of the grid 24, to process the images of the object 30 taken by the camera 46 and to analyze these images to measure the relief of the object 30.

The computer 14 is advantageously provided with memory means allowing storing of the images when they are processed by the computer 14 and therefore increasing the processing speed.

The storing device 16 can be, for example, a hard drive, a writable CD-ROM drive or other well-known data storing means. It can be directly connected to the computer 14, or remotely connected via a computer network such as the Internet. According to an embodiment of the invention, the storing device 16 is used to store both the images taken by the image acquisition apparatus 12, the relief of the object 30 and other intermediary results. Those files can be stored in any format and resolution that can be read by the computer 14.

The output device 20 allows visualization of the images and of the data produced by the computer 14, and can take many forms from a display monitor to a printing device.

The input device 18 can be a conventional mouse, a keyboard or any other well-known input device or combination thereof

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which allows inputting of data and commands into the computer 14.

The storing device 16, the display monitor 18 and the input device 20 are all connected to the computer 12 via standard connection means, such as data cables.

The computer 14 can be a conventional personal computer or any other data processing machine that includes a processor, a memory and input/output ports (not shown). The input/output ports may include network connectivity to transfer the images to and from the storing device 16.

Of course, the computer 12 runs software that embodies the method of the present invention thereof, as will be described hereinbelow.

It is to be noted that the system 10 includes adjustable support means (not shown) to position the image acquisition apparatus 12 and the grid projecting assembly 11 relative to each other and to the object 30. Alternatively, other registration means can be used without departing from the nature and spirit of the present invention.

Before giving a detail description of a method for measuring the relief of an object according to an embodiment of the present invention, the general theory underlying such a method will first be described. Since this theory is believed to be well known in the art and for concision purposes, it will only be briefly described herein.

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The intensity $I(x,y)$ for every pixel (x,y) on an interferometric image may be described by the following equation:

$$I(x, y) = A(x, y) + B(x, y) \cdot \cos(\Delta\Phi(x, y)) \quad (1)$$

where $\Delta\Phi$ is the phase variation (or phase modulation), and A and B are coefficient that can be computed for every pixel.

Knowing the phase variation $\Delta\Phi$, the object height distribution (the relief) at every point $h(x,y)$ relative to a reference surface can be computed using the following equation (see Figure 3):

$$h(x, y) = \frac{\Delta\Phi(x, y) \cdot p}{2\pi \cdot \tan(\theta)} \quad (2)$$

where p is the grid pitch and θ is the projection angle, as described hereinabove.

Although the above equation is valid for a parallel projection of the grid on the object, as illustrated in Figure 3 (note that the incidence ray 60 from the grid projection are parallel), it is believed to be within the reach of a person skilled in the art to use another equation if the grid projection is not parallel.

For example, it has been found with a pinhole projection that the pitch p and the angle θ increase with the distance from the grid on

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the plan of the reference surface (see X on Figure 3). It has been found that with a first order approximation, variations in p and θ cancel each other out and the Equation 2 remains valid within a certain limit of the parameters.

It is believed within the reach of someone skilled in the art to re-evaluate the relation between the variation of height $h(x,y)$ and the phase $\Delta\Phi$, and to make corrections to the relation according to the configuration of the system used to measure the relief.

Turning now to Figure 4 of the appended drawings, a method for measuring the relief of an object according to an embodiment of the present invention will be described in more detail.

Generally stated, the method consists in measuring the relief of an object 30 using the system 10 by performing the following steps:

100 - positioning the grid 24 at a first position relative to a reference object;

102 - projecting the grid 24 on the reference object;

104 - taking, with the camera 46, an image of the reference object to gather an intensity value for each pixel of the image;

106 - repeating steps 100 to 104 at least two times with the grid positioned at two new different known positions to yield at least three intensity values for each pixel;

108 - computing the phase for each pixel using the

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three intensity values;

110 - repeating steps 100 to 108 by replacing the reference object with the object 30 to be measured;

112 - computing, for each pixel, the difference of height between the object 30 and the reference object by using the respecting phases thereof for every pixel; and

114 - determining the relief of the object for each pixel using the difference of height at every pixel.

These general steps will now be further described with reference to a first example where the object 62 to measure is a sphere 64 mounted to a board 66. An image of said object 62 can be seen in Figure 5.

By choosing a similar board as the reference object, the difference of height between the object 62 and the reference object will provide the height of the sphere 64. The common element to the object 62 and the reference object is, in this example, the board 66.

In step 100, the grid 24 is moved to a first predetermined position using the support 26 that is actuated by the stepping motor. As it has been discussed hereinabove, the system 10 includes means to register and fix the position of the grid 24 and the camera 46 relative to the reference object (and later the object).

In step 102, the grid 24 is then projected onto the reference object.

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In step 104, the camera 46 takes an image of the reference object.

The image includes an intensity value for each pixel of the image. The computer 14 stores these intensity values for future processing.

Steps 100 to 104 are then repeated at least twice with the grid positioned at two new known different positions (step 106). This will provide three slightly different images and therefore the three intensity values for each pixel. One of the three images of the board illuminated by the grid 24 can be seen in Figure 6.

Since Equation 1 comprises three unknowns, that is A, B and $\Delta\Phi$, three intensity values I_1, I_2 and I_3 for each pixel, and therefore three images, are required to compute the phase variation $\Delta\Phi$.

The two new images are taken following small translations of the grid 24 relative to the surface of the reference object. The displacements are so chosen as to yield phase variations in the images $\Delta\varphi_1$, $\Delta\varphi_2$ and $\Delta\varphi_3$. This results in three equations similar to Equation 1 for each pixel of the pixel array of the camera 46:

$$I_n = A + B \cdot \cos(\Delta\Phi + \Delta\varphi_n) \qquad (3)$$

with n=1,3.

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By solving the system of Equation 3, one obtains the value of $\Delta\Phi$. The displacements of the grid 24 are chosen so as to advantageously provide different values of $\Delta\varphi_1$, $\Delta\varphi_2$ and $\Delta\varphi_3$.

According to a preferred embodiment of the present invention, more than three images are taken. This yield additional intensity values that can be used to increase the precision of the calculated phase.

Methods according to the prior-art often require the use of four images and all four values from these images are taken for phase estimation. Since a method according to the present invention requires only three images, additional images may be used to increase the precision and reliability of the method.

By keeping, for example, four (or more) images, it is possible to discard noisy pixels or images and to keep only the pixels having the most advantageous intensity values. Indeed, if one of the four intensity values is noisy (that can be caused, for example, by an image saturation), the corresponding intensity can be eliminated without compromising the precision of the resulting phase for this particular pixel.

Alternatively, more then three intensity values can be used to traditionally compute the phase using a numerical method such as a least square fit. However, such a method could not prevent erroneous phase values to be computed for certain pixels, potentially

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causing imprecision in the computation of the relief of the object.

According to another preferred embodiment of the present invention, the displacements of the grid between the second and third images (and the fourth image) are chosen so as to provide two images having 180 degrees phase variations $\Delta\varphi_n$ (see Equation 3). This allows obtaining an image of the reference object (or of the object) without the projected grid. This can be achieved by adding the intensity values of the two images phase shifted by 180 degrees.

More generally, if the sum of the phase variations of some of the three or more images taken by the camera 46 is 360 degrees, a corresponding two-dimensional image can be obtained by adding the intensity values of these images for each pixel. This recomposed two-dimensional image does not include the projected grid. This image may be used to perform a preliminary analysis of the reference object (or of the object) that may speed-up any subsequent analysis that will be performed on the image or the values that will result from step 112.

In step 108, the phase is computed using the three intensity values (or the three best intensity values) for each pixel by solving the Equations 3. This can be achieved by using a conventional numerical method, for example. Numerical methods for solving such system of equation are believed to be well known in the art and will not be described herein.

The resulting phase of the reference object for every

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pixel is illustrated in Figure 7.

When the method of Figure 4 is used to inspect a series of objects, steps 100 to 108 may be advantageously performed only once for the reference object before the inspection. This allows the increase of the speed of the inspection.

Steps 100 to 108 are repeated by replacing the reference object by the object to measure, i.e. the object 62.

One of the images of the sphere 64 with the board 66, illuminated by the grid 24, can be seen in Figure 8.

Since there is no difference in performing steps 100 to 108 with the object and with the reference object, and for concision purposes, these steps will not be described again by referring to the object.

The resulting phase of the sphere 64, with the board 66, is illustrated in Figure 9. It is to be noted that the zone 68 in the image of Figure 9 is caused by the shadow of the sphere 64.

In step 112, the difference of height between the object 30 and the reference object is computed for every pixel, as obtained in step 108, by subtracting the phase of the reference object from the phase of the inspected object. The resulting image is shown in Figure 10.

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It is to be noted that the phases computed in step 108 for the object and for the reference object, and illustrated in Figures 7 and 9, correspond to surface phases relative to an imaginary projection plan.

When a non-parallel projection of the grid 24 is done, this imaginary projection plan becomes slightly curved. This is not detrimental with the method for measuring the relief of an object according to the present invention since both the images of the object and of the reference object are taken with the same system 10.

Since the phases of the object and of the reference object at each pixel correspond to the difference of height between the object (or the reference object) and the same imaginary projection plane (since the same system with the same optical set-up is used), their subtraction yields the difference of height between the object and the reference object. This allows the image acquisition of the object and of the reference object to be performed under different illumination.

In the optional step 114, the relief of the object, i.e. its height, is determined for each pixel using the difference of height at every pixel between the object and the reference object and knowing the dimensions of the reference object.

As will now appear obvious to a person of ordinary skills in the art, a method according to an embodiment of the present invention can be used to measure the difference of height between two objects (one being the reference). In this case, step 114 is obviously not performed.

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In some applications, it may be advantageous to use a plane surface on which the object to measure will be laid on during measurement as the reference object.

In some applications, it may be advantageous to provide the system 10 with a registration system to help position the object and the reference object to a known position relative to the camera. Indeed, since a comparison between the object and the reference object is performed for each pixel, a registration system may ensure that corresponding points are compared.

Such registration system may take many forms including indicia on plane surface, a stand or a software program implemented in the computer.

It is to be noted that the images may be first acquired and then processed at a future time without departing from the spirit of the present invention.

As will be apparent upon reading the present description, a method, according to an embodiment of the present invention, allows the measure of the relief of an object using white light.

Although the present invention has been described with an example where spherical objects are measured, it allows the inspection and measurement of objects having other configurations.

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The same object may also act as the reference object when the system 10 is used to study the variation in time of an object's relief.

Alternatively, the reference object may be replaced by a computer model of the object, generated, for example, by a Computer Assisted Design (CAD) that would have been virtually positioned according to the set-up of the system 10.

The reference object may also be a similar object having defects within acceptable parameters. Hence, the subtraction of the phases of the object and of the reference object will set forth the defect of the object under inspection. This aspect of the invention is particularly interesting to inspect the relief of an object having important variations of relief.

Indeed, since the phase values are limited in the range 0 to 2π the maximum height h_o that can be detected by most systems of the prior-art is

$$h_0 = \frac{p}{\tan(\theta)}$$ (see Equation 2).

Usually the unwrapping of phase is done by using a grid having a pitch p sufficiently large to ensure that all height variations will be in a single-phase order (0 to 2π).

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A drawback to this is the loss of precision that it implies. For example, if the object to be measured is tilted according to the image acquisition apparatus, the lost of precision may be important.

The following example will illustrate how a method according to the present invention allows prevention of the above drawback and relates to lead coplanarity inspection on a circuit board.

Figure 11 is an image showing the relief of a module 69 comprising a plurality of lead balls 70 on a substrate 72. The image of Figure 11 is obtained by performing steps 110 to 114 of Figure 4. In this example, the object is the module 69 (including the substrate 72 and the lead balls 70) and the reference object is a reference plane surface (not shown).

It can be seen in Figure 11, by the variation in the grey shade in the image, that the substrate 72 is not parallel to a plane surface. Therefore, such image provides less precision in measuring the height of the object than if the substrate would have been plane. Indeed, it is to be noted that the tilt in the substrate 72 on the image is not caused by the system 12, but reflects the actual configuration of the substrate 72. The small variation in height of each lead ball 70 may be lost in the overall variation in the substrate 72 profile.

Although one can conceive a computer algorithm to virtually rectify the substrate on the image, such algorithm may add to the inspection process time. This can be seen as a drawback when the

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inspection is performed in real-time on a production line.

The proposed solution is to use an approximation of the surface of the substrate as a second reference object.

Indeed, it may be advantageous, at each pixel, to first find the height of the substrate 72 relative to a plane surface, secondly the height of the lead balls 70 relative to the substrate 72 and to finally add these two heights to provide the overall height of the object, i.e. the substrate with the balls.

The phase of the module is illustrated in Figure 12 and is obtained through steps 100 to 108 of the method of Figure 4.

Information about the surface of the substrate 72 is then obtained by analyzing the pixel corresponding to the substrate 72 (between the balls 70) on the image of Figure 12 where a pseudo-phase image of a complementary surface is computed.

The height of the balls 70 is computed for each pixel (step 112) by subtracting the phase of the module (Figure 12), and the phase of the complementary surface. The resulting image can be seen in Figure 13.

Similarly, the height of the substrate 72 is computed for each pixel (step 112) by subtracting the phase of the complementary surface and the phase of the reference plane. The resulting image can be

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seen in Figure 14. This phase image is then unwrapped (see Figure 15).

The height of the module 69 is then obtained by adding the height of the phases of Figures 13 and 15.

Although the present invention has been described hereinabove by way of preferred embodiments thereof, it can be modified without departing from the spirit and nature of the subject invention, as defined in the appended claims.

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WHAT IS CLAIMED IS:

1. A method for measuring the relief of an object using a camera provided with an array of pixels, said method comprising:

j) projecting a grid on a reference object; the grid being located at a first position relative to the camera and to the reference object;

k) taking, with the camera, an image of the reference object illuminated by said projected grid; said image of the reference object having intensity values for each pixel;

l) repeating steps a) and b) at least two times with the grid being located at two different known positions relative to the camera and to the reference object to yield at least three intensity values for each pixel;

m) computing the reference object phase for each pixel using the at least three reference object intensity values for the corresponding pixel;

n) projecting the grid on the object; the grid being located at said first position;

o) taking with the camera an image of the object illuminated by said projected grid; said image of the object having intensity values for each pixel position;

p) repeating steps e) and f) at least two times with the grid being located at said two different positions to yield at least three intensity values for each pixel;

q) computing the object phase for each pixel position using the at least three object intensity values for the corresponding pixel; and

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r) computing the difference of height between the object and the reference object for each pixel using said reference object phase and said object phase for the corresponding pixel.

2. A method as recited in claim 1, further comprising using said difference of heights between the object and the reference object for each said pixel to determine the relief of the object.

3. A method as recited in claim 1, wherein, in at least one of steps d) and h), the phase $\Delta\Phi$ is computed for each pixel by solving the following system of equations:

$$I_n = A + B \cdot \cos(\Delta\Phi + \Delta\varphi_n)$$

where I_n represent the at least three intensity values, A and B are known coefficients and $\Delta\varphi_n$ are phase variations caused by the different locations of the grid.

4. A method as recited in claim 3, wherein said system of equations is solved using a numerical method.

5. A method as recited in claim 1, wherein, in step c), steps a) and b) are repeated more than two times with the grid being located at more than two different known positions relative to the camera and to the reference object to yield said at least three intensity values and at least one additional value for each pixel and, in step d), a selection is performed among the at least three intensity values and the at least one additional

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values to yield the three most advantageous intensity values; said three most advantageous intensity values being used to compute the reference object phase for each pixel.

6. A method as recited in claim 1, wherein, in step c), steps a) and b) are repeated more than two times with the grid being located at more than two different known positions relative to the camera and to the reference object to yield more than three intensity values and, in step d), the three most advantageous values from said more than three most advantageous intensity values are used to compute the reference object phase for each pixel.

7. A method as recited in claim 1, wherein, in step g), steps e) and f) are repeated more than two times with the grid being located at more than two different known positions relative to the camera and to the object to yield said at least three intensity values and at least one additional value for each pixel and, in step h), a selection is performed among the at least three intensity values and the at least one additional values to yield the three most advantageous intensity values and said three most advantageous intensity values are used to compute the object phase for each pixel.

8. A method as recited in claim 1, wherein, in step g), steps a) and b) are repeated more than two times with the grid being located at more than two different known positions relative to the camera and to the object to yield more than three intensity values and, in step d) the three

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most advantageous values form said more than three intensity values are used to compute the object phase for each pixel.

9. A method as recited in claim 1, wherein, in step c), said two known positions of the grid are chosen so as to provide at least two images of the object having a 180 degrees difference in phase therebetween.

10. A method as recited in claim 9, wherein a two-dimensional image of the object is computed by subtracting said at least two images of the object having a 180 degrees difference in phase therebetween; said two dimensional image being used to perform a preliminary analysis of the object.

11. A method as recited in claim 1, wherein, in step g), said two known positions of the grid are chosen so as to provide at least two images of the reference object having a 180 degrees difference in phase therebetween.

12. A method as recited in claim 11, wherein a two-dimensional image of the reference object is computed by subtracting said at least two images of the reference object having a 180 degrees difference in phase therebetween; said two dimensional image being used to perform a preliminary analysis of the reference object.

13. A method as recited in claim 1, wherein said reference object is a plane surface.

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14. A method as recited in claim 1, wherein said reference object is said object at a past predetermined time and said reference object phase is computed around said past time;

whereby step i) provides the variation of height at each pixel between said past time and the approximate time when the object phase is computed.

15. A method as recited of claim 1, wherein said reference object is a CAD of the object; said grid being virtually positioned and projected into said CAD in step a) and said image of said reference object being simulated in step b).

16. A system for measuring the relief of an object, said system comprising:

a grid projecting assembly;

an image acquisition apparatus including a camera provided with an array of pixels;

a computer configured for

a) receiving from the image acquisition apparatus at least three images of the projected grid onto the object and at least three images of the projected grid onto the reference object; each of said images of the projected grid onto the object corresponding to a different known position of the grid; each of said images of the projected grid onto the reference object corresponding to one of said known positions of the grid;

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b) computing the reference object phase for each pixel using the at least three reference object intensity values for the corresponding pixel;

c) computing the object phase for each pixel using the at least three object intensity values for the corresponding pixel; and

d) computing the difference of height between the object and the reference object for each pixel using said reference object phase and said object phase for the corresponding pixel.

17. The use of the method of claim 1 for lead-coplanarity inspection.

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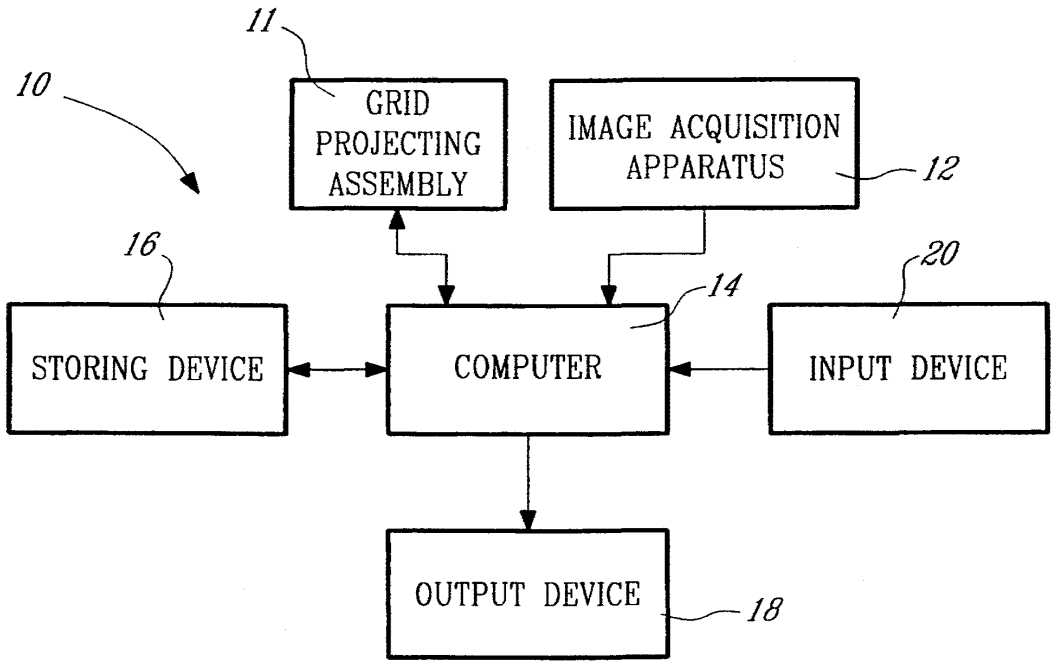


Fig. 1

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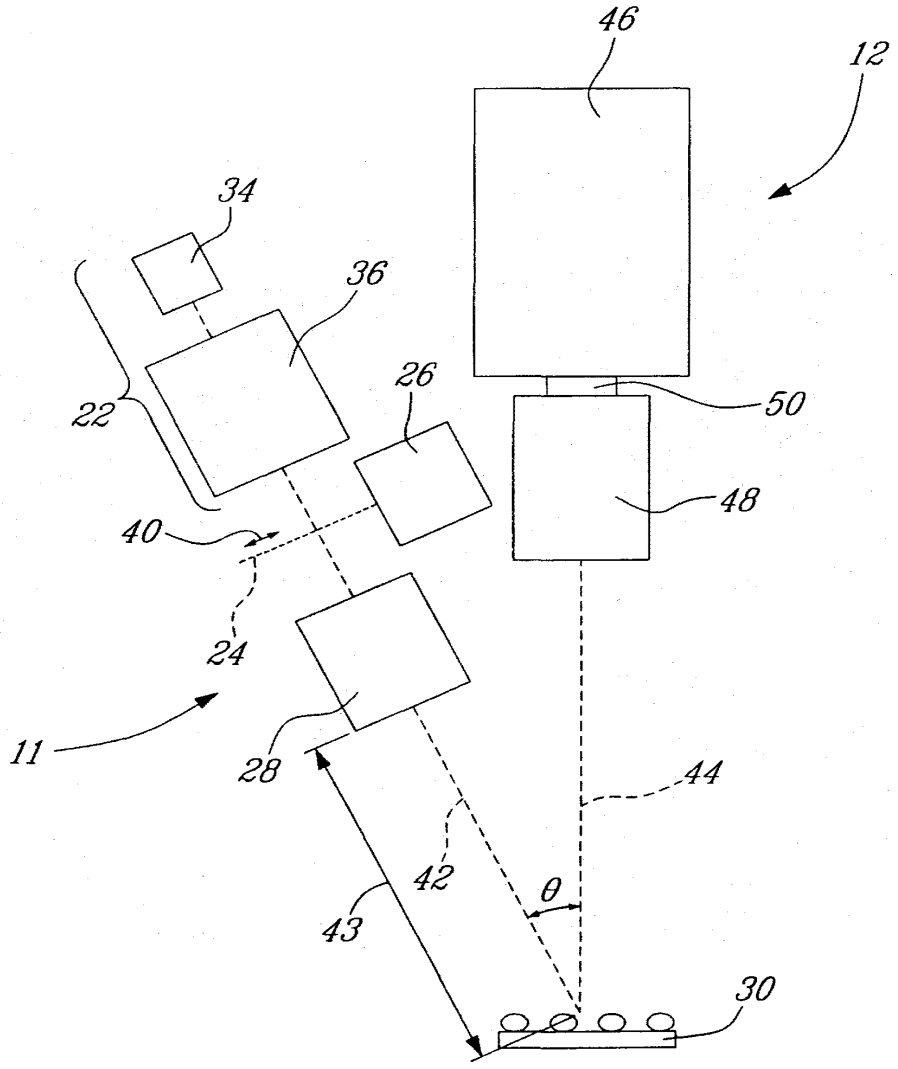


Fig. 2

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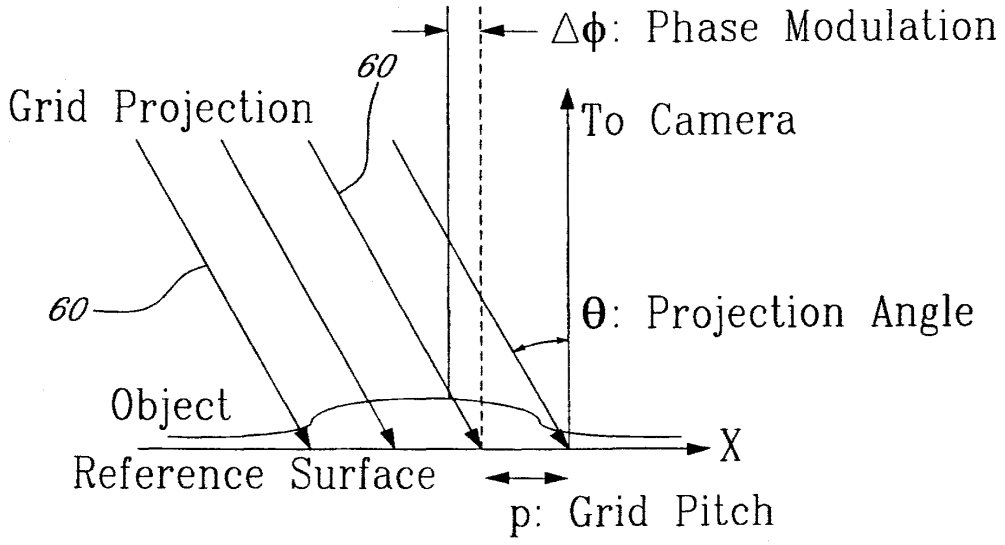


Fig. 3

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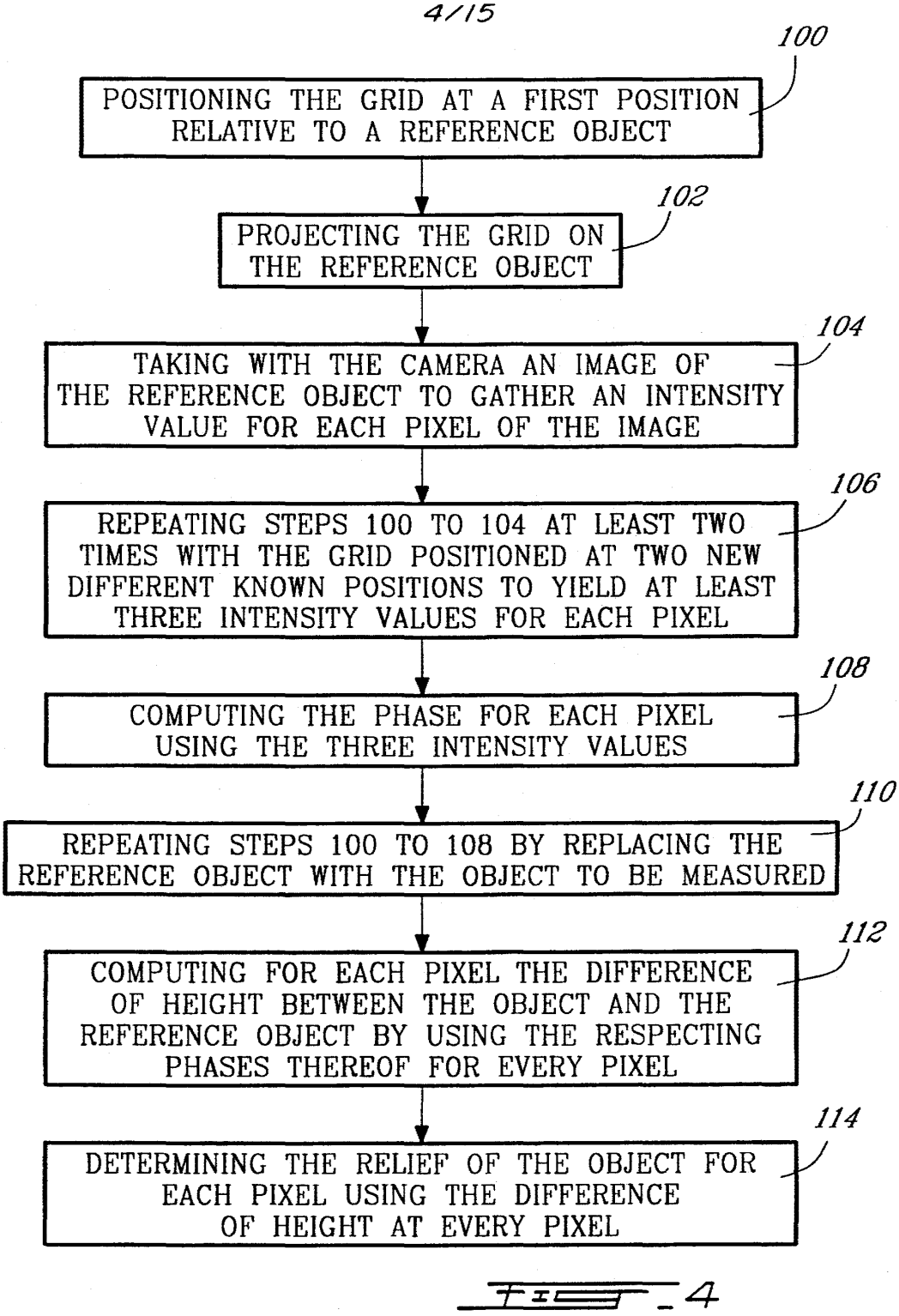


Fig. 4

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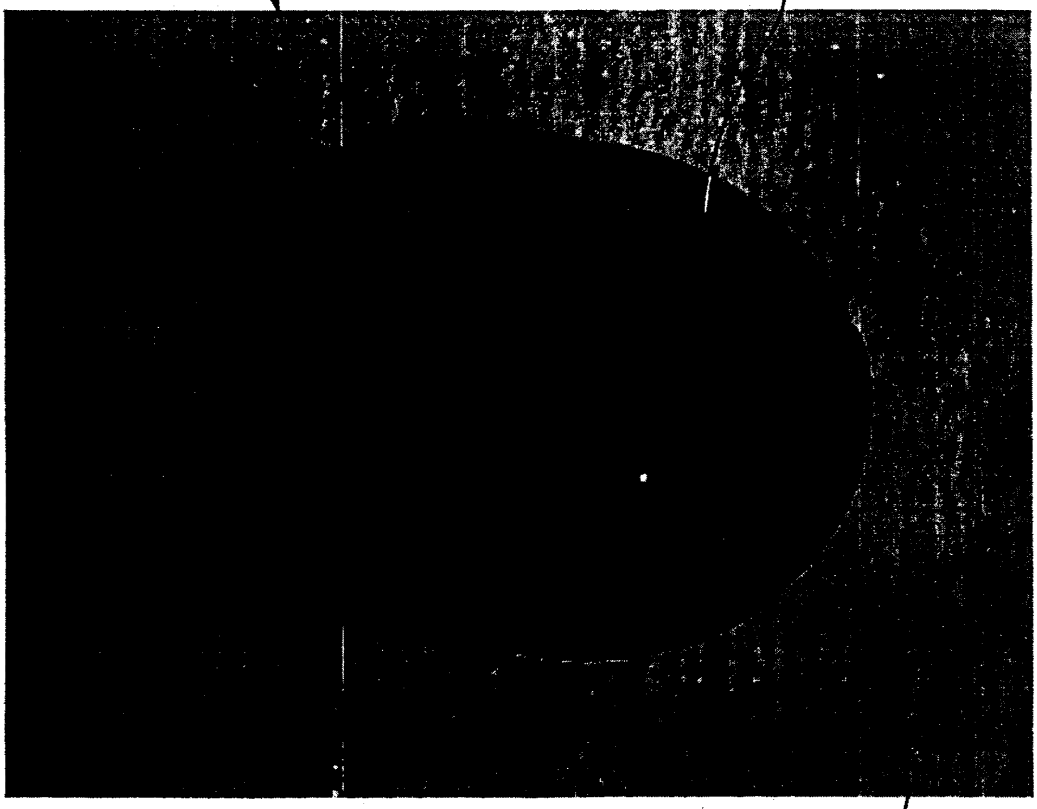


Fig. 5

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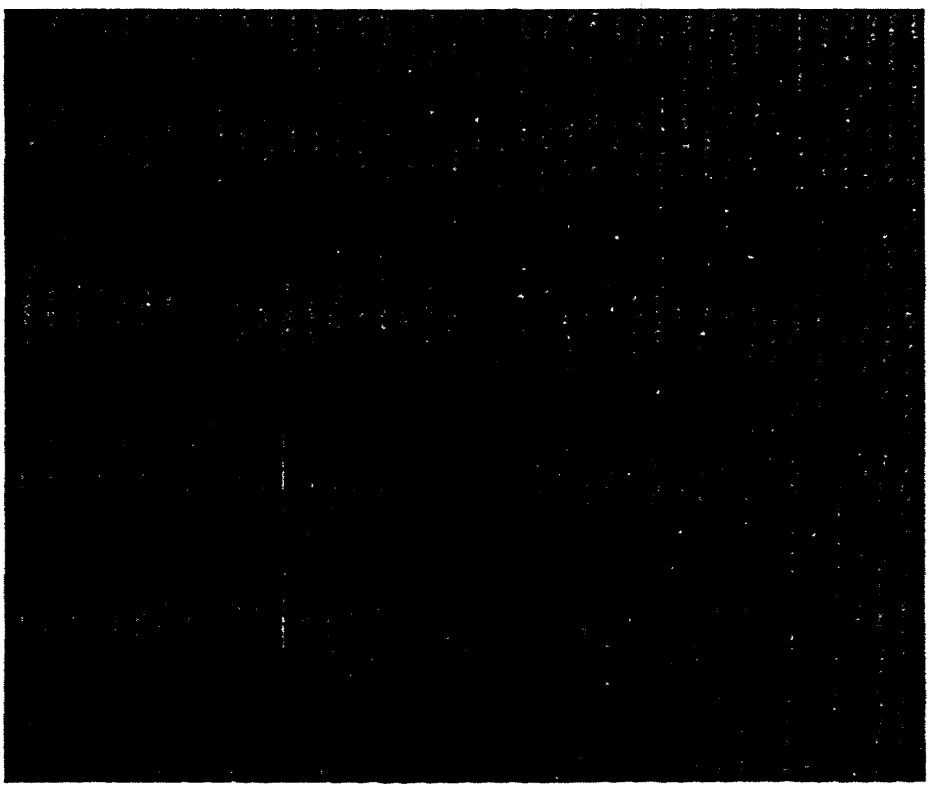


FIG. 6

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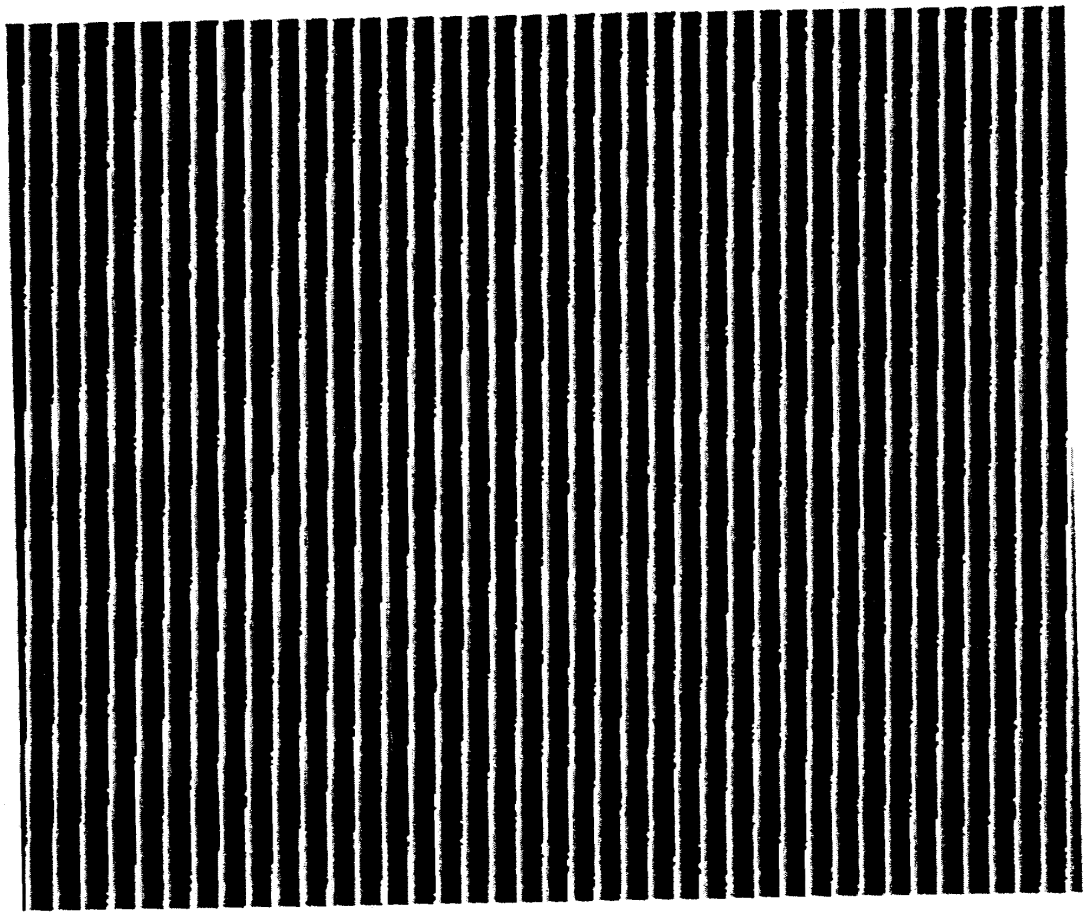


Fig. 7

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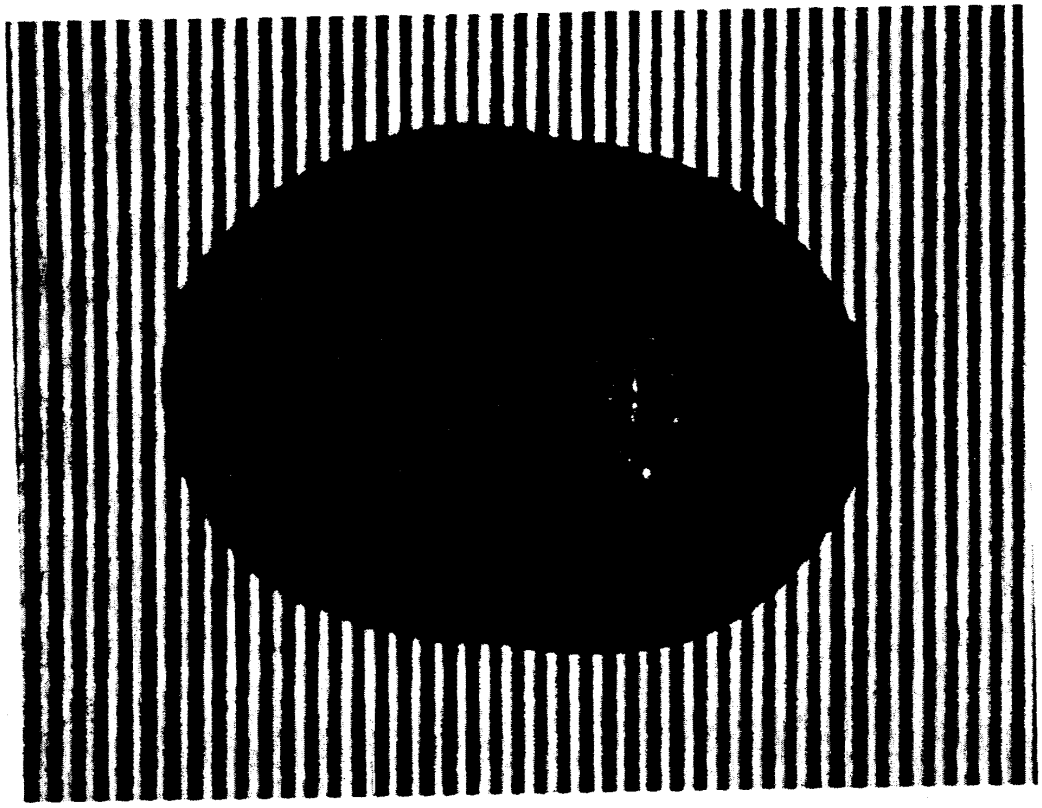


FIG - 8

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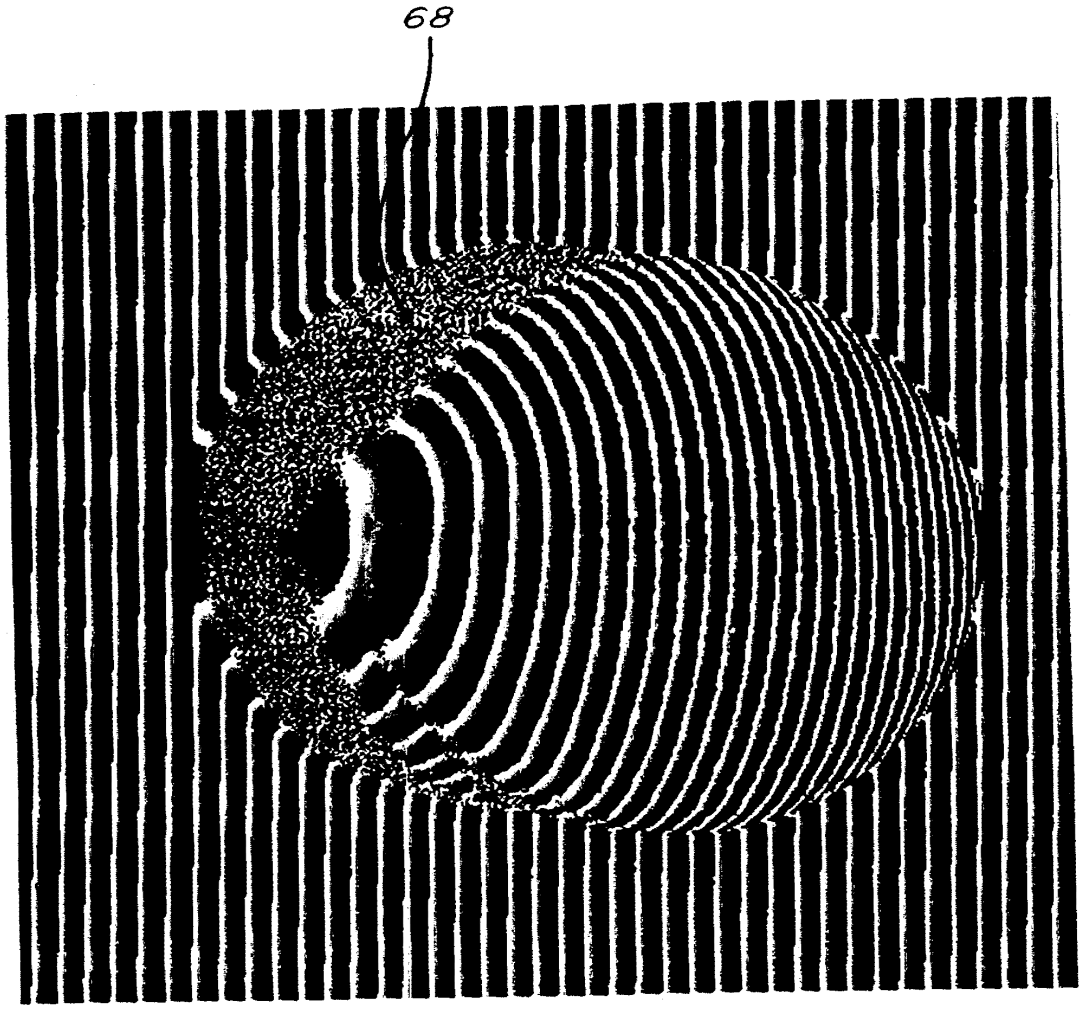


Fig. 9

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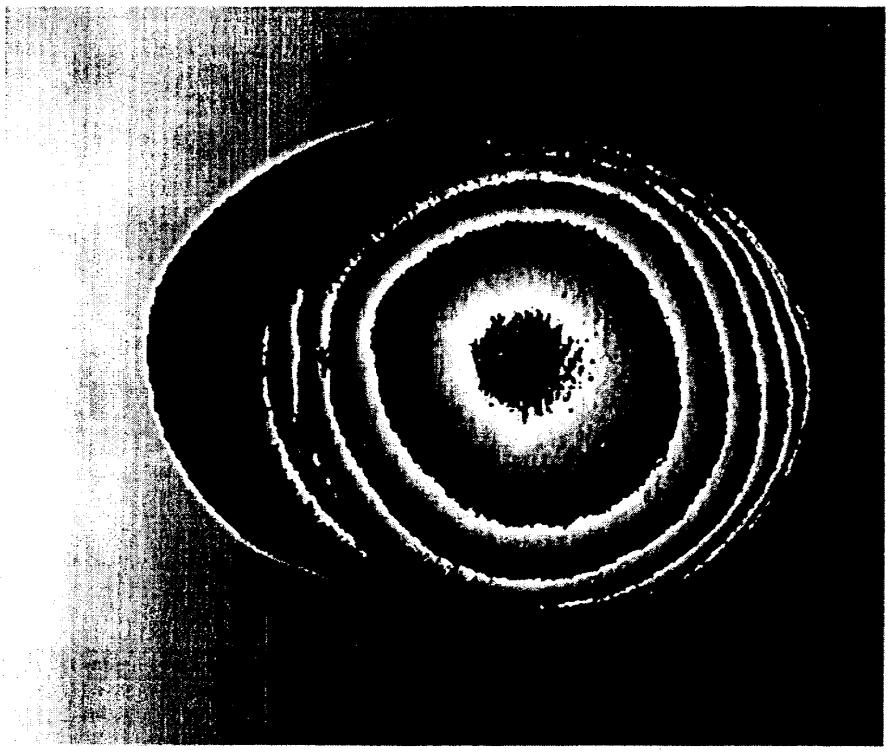


Fig. 10

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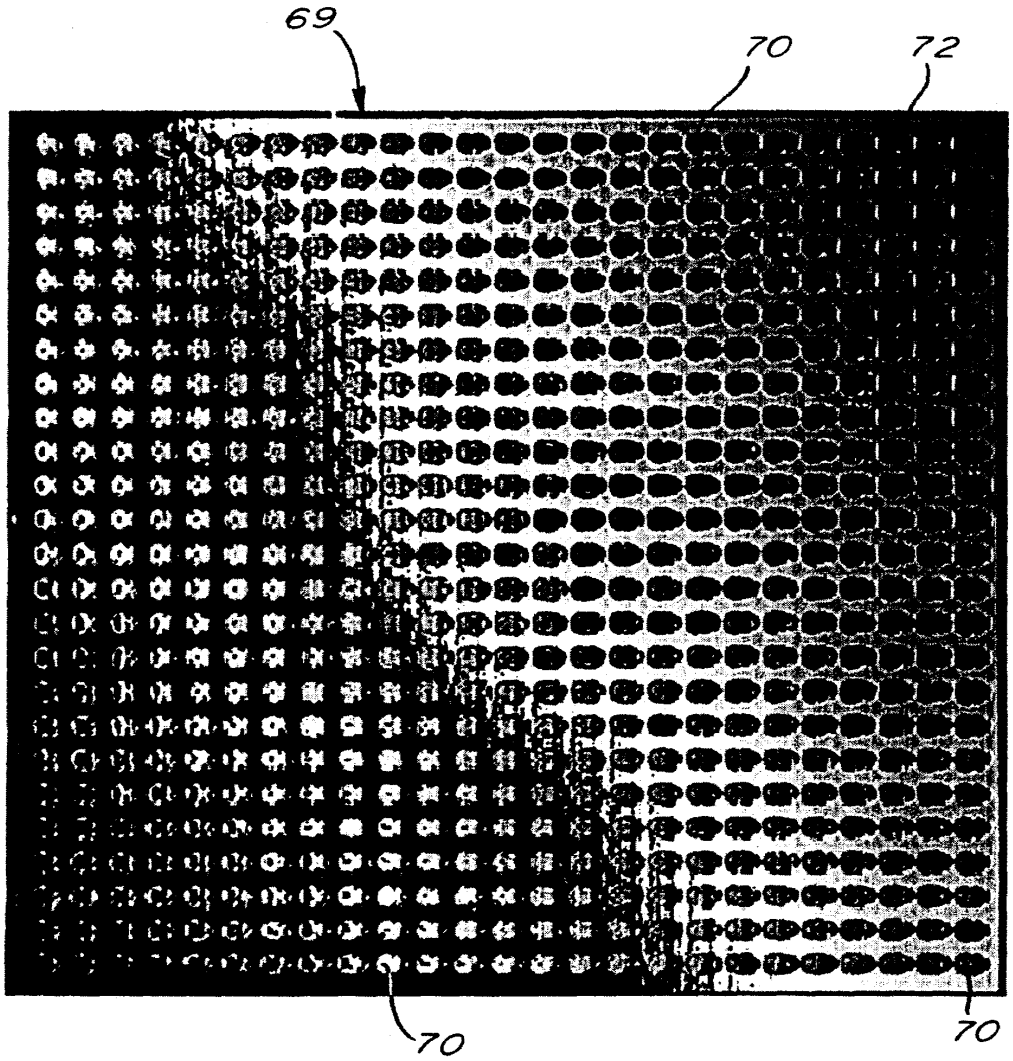


Fig. 11

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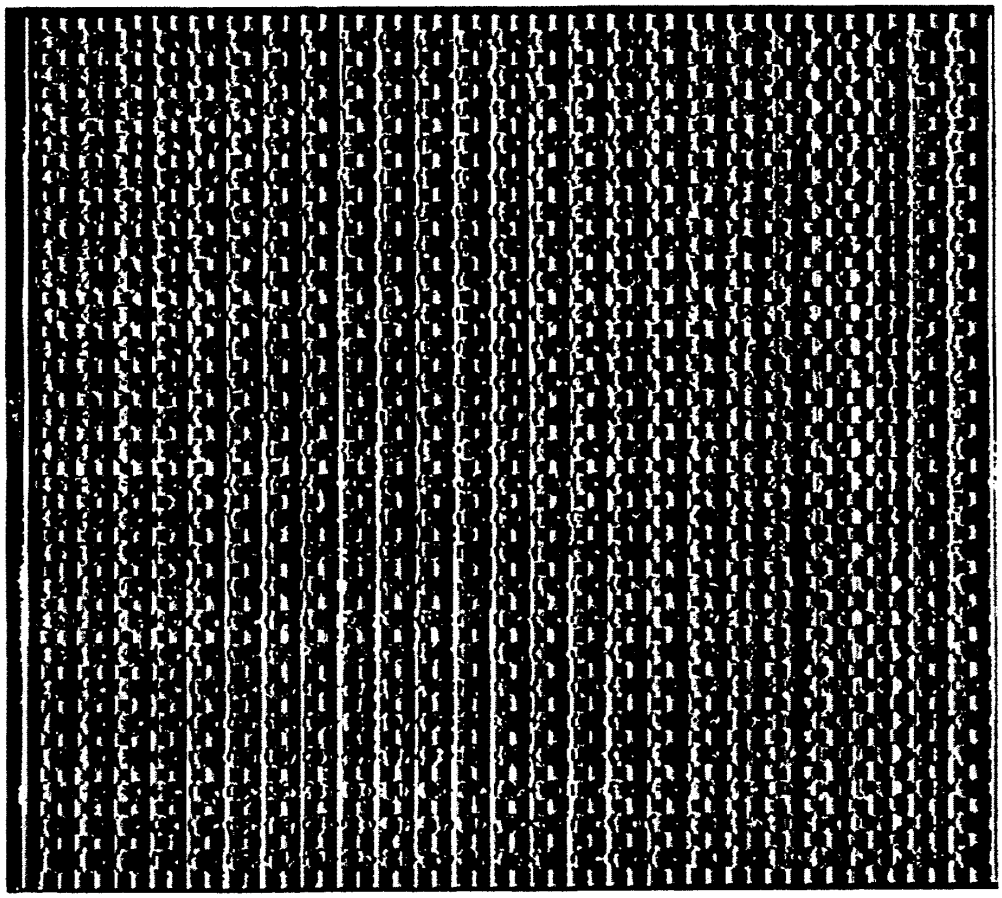


Fig. 12

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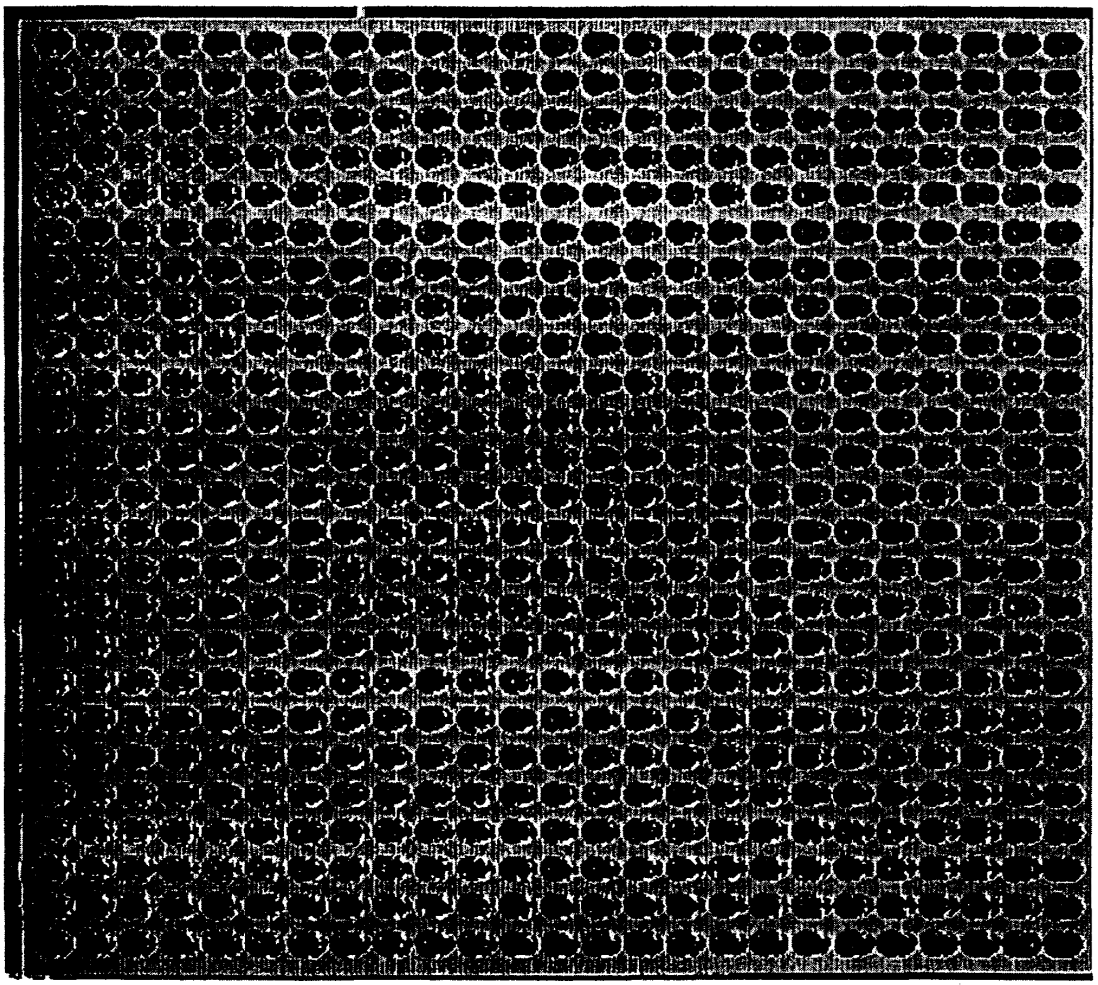


Fig. 13

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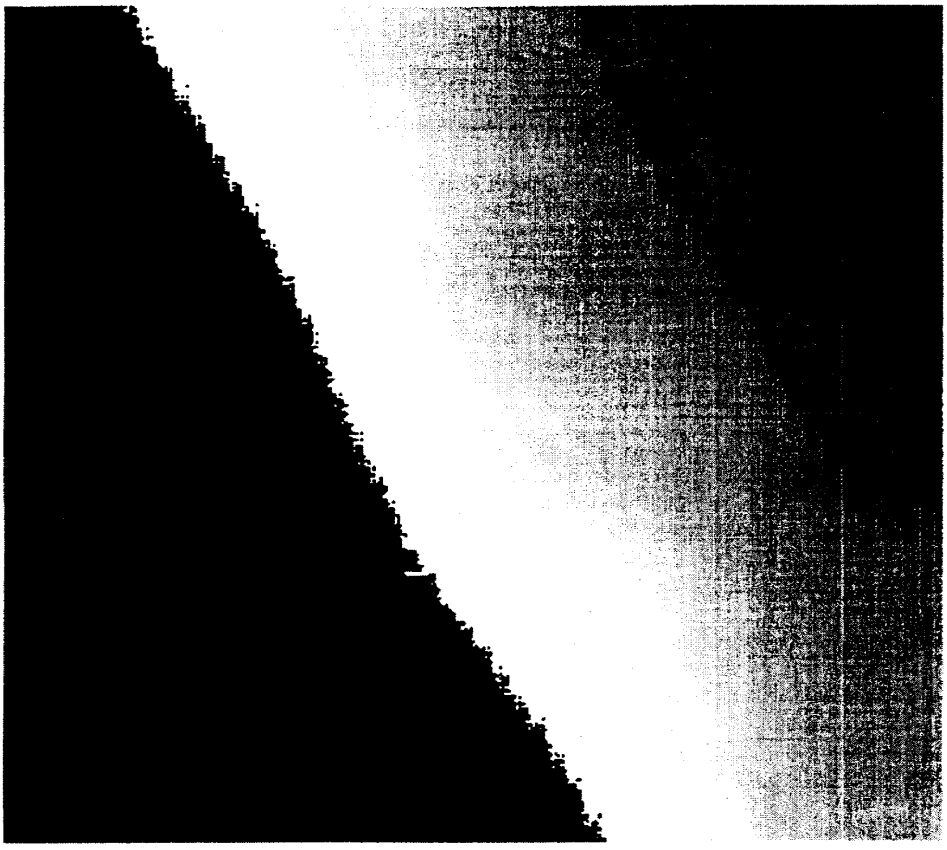


FIG. 14

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Fig. 15

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INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/CA 00/00834

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01B11/24

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)
IPC 7 G01B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 182 469 A (NEW YORK INST TECHN) 28 May 1986 (1986-05-28) page 4, line 1 -page 6, line 4 page 22, line 2 -page 27; figures 7-9	1-4, 9-13,16
X	WO 98 55826 A (ELECTRONIC PACKAGING SERVICES ;WANG YINYAN (US)) 10 December 1998 (1998-12-10) the whole document	1-13,16, 17
X	GB 2 204 397 A (EASTMAN KODAK CO) 9 November 1988 (1988-11-09) page 9 -page 11	1,2,4,16

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2000	19/10/2000

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	Ramboer, P

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INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/CA 00/00834

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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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

BNSDOCID: <WO_____0106210A1_I_>

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IPR2023-01426

INTERNATIONAL SEARCH REPORT

...rmation on patent family members

Interna... ...al Application No
PCT/CA 00/00834

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		EP 0327567 A	16-08-1989
		JP 2500217 T	25-01-1990

BNSDOCID: <WO_____0106210A1_I_>

EP1172183

Publication Title:

Device and arrangement for generating corrected motion data for predefined motion of a mobile installation, mobile installation and system comprising mobile installations

Abstract:

Abstract of EP1172183

A device for ascertaining and calculating the corrected movement data for a specified sequence of movements of a movable device or tooling, has an image detection device, such as a digital camera (11) and a computer unit. The computer unit determines the corrected movement data via a reference device (9) according to controlle 100f d movement of the movable device. The reference device (9) shows unambiguous aspects of the image in a specified solid angle range, while the computer unit calculates a transformation specification for correction of the original movement data, from an actual image of the reference device (9) recorded by the image detection unit (11).

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(19) Europäisches Patentamt
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(11) EP 1 172 183 A2

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(22) Anmeldetag: **13.07.2001**

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AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Benannte Erstreckungsstaaten:
AL LT LV MK RO SI

(30) Priorität: **13.07.2000 DE 10034189**

(71) Anmelder: **Kleck, Rolf**
88213 Ravensburg (DE)

(72) Erfinder: **Kleck, Rolf**
88213 Ravensburg (DE)

(74) Vertreter:
Patentanwälte Eisele, Otten, Roth & Dobler
Karlstrasse 8
88212 Ravensburg (DE)

(54) Vorrichtung und Anordnung zur Ermittlung von korrigierten Bewegungsdaten für einen vorgegebenen Bewegungsablauf einer bewegbaren Einrichtung sowie bewegbare Einrichtung und System aus bewegbaren Einrichtungen

(57) Es wird eine Vorrichtung zur Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung (5) nach einer von der Steuerung der bewegbaren Einrichtung (5) nicht ausreichend erfassten Bewegung der bewegbaren Einrichtung (5) vorgeschlagen. Der Erfindung liegt die Aufgabe zugrunde, die Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung vergleichsweise genauer und kostengünstiger vornehmen zu können. Zur Lösung der Aufgabe umfasst die Vorrichtung eine Bilderfassungseinheit (11) und eine Rechnereinheit, wobei die Rechnereinheit nach einer von der Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung korrigierte Bewegungsdaten mit Hilfe von Bezugsmitteln (9) bestimmt, die wenigstens in einem vorgegebenen Raumwinkelbereich eindeutig zuordenbare Bildansichten aufweisen, indem die Rechnereinheit aus Daten von einem durch die Bilderfassungseinheit (11) aufgenommenen Ist-Bild der Bezugsmittel (9) nach der nicht oder unzureichend erfassten Bewegung und Daten eines Bezugsbildes der Bezugsmittel (9), bei dem die bewegbare Einrichtung eine eingelernte Bewegung entsprechend von in der Rechnereinheit abgelegten Urbewegungsdaten ausführen würde, eine Transformationsvorschrift zur Korrektur der Urbewegungsdaten errechnet. Des Weiteren wird eine Anordnung zur Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung mit Bezugsmittel (9) sowie ein System aus mehreren bewegbaren Einrichtungen vorgeschlagen.

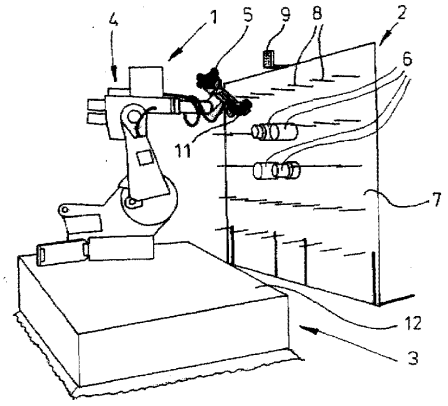


Fig. 1

EP 1 172 183 A2

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Beschreibung

[0001] Die Erfindung betrifft eine Vorrichtung zur Ermittlung von korrigierten Bewegungsdaten für einen vorgegebenen Bewegungsablauf einer bewegbaren Einrichtung, z. B. eines verfahrbaren Roboters, eines Linearachsensystems usw., nach einer von einer Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung der bewegbaren Einrichtung, eine Anordnung, die eine solche Vorrichtung umfasst sowie eine bewegbare Einrichtung nach dem Oberbegriff des Anspruchs 1 und ein System aus mehreren bewegbaren Einrichtungen.

Stand der Technik

[0002] Die deutsche Patentschrift DE 32 46 828 C2 offenbart eine mobile Transport- und Handhabungseinrichtung, die aus einem automatisch steuerbaren, liniengebundenen und im Bereich von Haltestationen grob positionierbaren Flurförderfahrzeug sowie einem mit dem Flurförderfahrzeug fest verbundenen Industrieroboter besteht, der durch einen Rechner gesteuert wird. Im Weiteren ist eine Messanordnung vorgesehen, deren Komponenten zum Teil an der Einrichtung und zum Teil ortsfest im Bereich der Haltestationen angebracht sind und durch welche nach der Positionierung der Einrichtung an der Halteposition die Abweichung der Ist-Position des Flurförderfahrzeugs von der Soll-Position ermittelbar ist. Mittels des Rechners erfolgt eine der Abweichung des Ist-Wertes vom Soll-Wert entsprechende Transformation der Handhabungskoordinaten in der Robotersteuerung.

[0003] Für die Ausgestaltung der Messanordnung sind eine Reihe von Ausführungsvarianten in der DE 32 46 828 C2 beschrieben. Beispielsweise weist die Messanordnung einen Taster mit einem Taststift auf, der am Greifer des Roboters angebracht und von diesem automatisch an ortsfeste Referenzpunkte oder Flächen heranführbar ist. Durch das Antasten dieser Punkte oder der Flächen kann die Ist-Position der Einrichtung ermittelt werden. Des Weiteren wird als Messanordnung ein Lichtsender, der einen gebündelten Lichtstrahl schräg auf eine reflektierende Messfläche sendet sowie ein Lichtempfänger zur Aufnahme des reflektierten Strahls vorgeschlagen, wobei aus dem Auftreffpunkt des Strahls im Empfänger die Ist-Entfernung ermittelbar ist.

[0004] Die vollständig mechanische Bestimmung der Ist-Position mittels des Greifers hat den Nachteil, dass die Position nur so genau bestimmt werden kann, wie es die Wiederholgenauigkeit der Mechanik zulässt.

[0005] Die optische Bestimmung der Ist-Position durch einen Lichtsender ist insofern nachteilig, als dass für eine dreidimensionale Erfassung der Position drei Messungen mit jeweils unterschiedlich positioniertem Sender notwendig sind, worunter wiederum die Genauigkeit der Positionserfassung aufgrund einer begrenzten mechanischen Wiederholgenauigkeit leidet.

Aufgabe und Vorteile der Erfindung

[0006] Der Erfindung liegt die Aufgabe zugrunde, die Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung vergleichsweise genauer und kostengünstiger vornehmen zu können.

[0007] Diese Aufgabe wird durch die Merkmale des Anspruchs 1, 6, 10 und 13 gelöst.

[0008] In den Unteransprüchen sind vorteilhafte und zweckmäßige Weiterbildungen der Erfindung angegeben.

[0009] Die Erfindung geht zunächst von einer Vorrichtung zur Ermittlung von korrigierten Bewegungsdaten für einen vorgegebenen Bewegungsablauf einer bewegbaren Einrichtung, z.B. Elementen eines verfahrbaren Roboters oder eines Systems, bestehend aus mehreren Linearachsen, nach einer von der Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung der bewegbaren Einrichtung aus. Der Kerngedanke der Erfindung liegt nun darin, dass eine Bilderfassungseinheit und eine Rechnereinheit vorgesehen sind und die Rechnereinheit nach einer von der Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung die korrigierten Bewegungsdaten mit Hilfe von Bezugsmitteln bestimmt, die wenigstens in einem vorgegebenen Raumwinkelbereich eindeutig zuordenbare Bildansichten aufweisen, indem die Rechnereinheit aus Daten von einem durch die Bilderfassungseinheit aufgenommenen Ist-Bild der Bezugsmittel im positionierten Zustand der bewegbaren Einrichtung nach der nicht oder unzureichend erfassten Bewegung und Daten eines Bezugsbildes der Bezugsmittel, bei dem die bewegbare Einrichtung eine gewünschte Bewegung entsprechend von in der Rechnereinheit abgelegten Urbewegungsdaten ausführen würde, eine Transformationsvorschrift zur Korrektur der Urbewegungsdaten errechnet. Durch diese Vorgehensweise ist es möglich, durch eine einzige Bildaufnahme, die nicht oder nicht ausreichend erfasste räumliche Positionsänderung einer bewegbaren Einrichtung an einer Messstelle exakt zu bestimmen. Für diese Messstelle, die einer grob angefahrenen Position entspricht, sind die diesbezüglich ermittelten Korrekturdaten für alle Urbewegungsdaten maßgeblich. D.h., die bewegbare Einrichtung kann an der Messstelle mit Urbewegungsdaten gewünschte Bewegungen durchführen, die lediglich einmal mit einer Transformationsvorschrift korrigiert werden müssen. Die in der DE 32 46 828 beschriebene optische Methode bedarf der Vermessung von mindestens drei verschiedenen Messstellen, wodurch das Messergebnis von der Wiederholgenauigkeit des mechanischen Systems zum Anfahren dieser Messstellen nachteilig beeinflusst wird. Die erfindungsgemäßen Maßnahmen haben darüber hinaus den weiteren Vorteil, dass sie sich in einer vergleichsweise deutlich kompakteren Bauform realisieren lassen. Des Weiteren ermöglicht diese Art der Bewegungsdatenkorrektur mit-

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tels einer Bilderfassungseinheit den Einsatz derselben Bilderfassungseinheit und derselben Rechnereinheit zur Objekterkennung, wenn die Vorrichtung beispielsweise an einem Roboter angeordnet ist, der z. B. vorgegebene Objekte greifen oder bearbeiten soll.

[0010] Wird die erfindungsgemäße Vorrichtung zur Bestimmung der räumlichen Position beispielsweise an einem verfahrbaren Roboter mit einem fahrerlosen Transportfahrzeug und einem am Transportfahrzeug angebrachten Manipulator angeordnet, kann dieser Roboter nach einer Grobpositionierung, z. B. über ein induktives Leitsystem, eingelernte Bewegungsabläufe mit korrigierten Bewegungsdaten an der grob positionierten Stelle (Messstelle) dennoch exakt durchführen und zugleich mit Hilfe der Bilderfassungseinheit, z. B. zu bearbeitende Werkstücke, identifizieren und gegebenenfalls in ihrer Lage erkennen. D.h., im Fall eines verfahrbaren Roboters mit Manipulator handelt es sich um eine bewegbare Einrichtung, nämlich den Manipulator, die selbst nochmals bewegbar bzw. verfahrbar ist, denn der Manipulator ist auf einem Transportfahrzeug montiert. Insbesondere in einer solchen Ausgestaltung ist die Erfindung vorteilhaft, da das Transportfahrzeug durch robuste, schnell arbeitende Positioniermittel, die vergleichsweise ungenau sein dürfen, an einen Einsatzort gebracht werden kann, wobei dann eine vergleichsweise hohe Genauigkeit der Bewegung des Manipulators durch die Anpassung der Urbewegungsdaten des Manipulators auf den Einsatzort über die erfindungsgemäße Korrektur erreicht wird. Das Transportfahrzeug bleibt dabei unverändert in der grob angefahrenen Einsatzposition (Messstelle). Um eine bestmögliche Korrektur der Bewegungsbahn eines am Manipulator angeordneten Werkzeugs ohne mechanische Einflüsse zu erhalten, wird vorgeschlagen, die Bilderfassungseinheit oder die Bezugsmittel direkt am Werkzeug zu positionieren.

[0011] Zur Realisierung eines vergleichsweise kostengünstigen Aufbaus kann die Bilderfassungseinheit eine Videokamera, insbesondere eine digitale Videokamera umfassen. Es kann jedoch auch eine analoge oder digitale Kamera eingesetzt werden.

[0012] Als Rechnereinheit kann ein handelsüblicher PC eingesetzt werden.

[0013] Insbesondere beim Einsatz einer digitalen Videokamera ist es bevorzugt, wenn die Rechnereinheit dazu ausgelegt ist, die Transformationsvorschrift zur Korrektur der Bewegungsdaten durch einen Pixelvergleich des Ist-Bildes mit dem Bezugsbild zu bestimmen. Mit Hilfe der Transformationsvorschrift kann dann z. B. ein Roboterarm, ausgehend von Ursprungsbewegungsdaten, auch nach einer von einer Steuerung des Roboters nicht erfassten Bewegung des Roboterarms anhand von korrigierten Bewegungsdaten dennoch in exakter Weise vorgegebene Bewegungsabläufe durchführen.

[0014] Vorzugsweise ist die Rechnereinheit zur Ermittlung einer Transformationsvorschrift in Form eines Verschiebungsvektors in einem dreidimensionalen Koordinatensystem sowie von Winkeldrehungen um die drei Koordinatenachsen ausgelegt, die das Koordinatensystem aufspannen. Durch den Verschiebungsvektor und jeweiligen Drehwinkel lässt sich die Bewegung einer bewegbaren Einrichtung im Raum in Bezug auf Ursprungsbewegungsdaten mit Größen korrigieren, die insbesondere im Zusammenhang mit einem Roboter, z. B. einem 6-Achs-Knickarmroboter, für dessen Ansteuerung leicht weiterverarbeitbar sind.

[0015] Die in einer Anordnung zur Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung nach einer von der Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung notwendigen Bezugsmittel können z. B. ein dreidimensionales Objekt mit Orientierungselementen, z. B. Objektkanten oder zusätzlich angebrachte Markierungselementen, umfassen. Als Bezugsmittel ist außerdem das virtuelle Bild eines solchen dreidimensionalen Objekts möglich, insbesondere in Form eines Hologramms. Bei den Bezugsmitteln kommt es entscheidend darauf an, dass in einem vorgegebenen Raumwinkelbereich eindeutig zuordenbare Bildansichten von einer Bilderfassungseinheit aufgenommen werden können.

[0016] In einer bevorzugten Ausführungsform ist die Bilderfassungseinheit an der bewegbaren Einrichtung angeordnet, wogegen die Bezugsmittel getrennt von der bewegbaren Einrichtung positioniert sind.

[0017] Die Zuordnung von Bilderfassungseinheit und Bezugsmittel kann jedoch auch vertauscht werden. In diesem Fall sind an der bewegbaren Einrichtung die Bezugsmittel angebracht, wogegen die Bilderfassungseinheit getrennt von der bewegbaren Einheit angeordnet ist.

[0018] Für den Fall, dass die Bilderfassungseinheit getrennt von der bewegbaren Einrichtung positioniert ist, muss gewährleistet werden, dass die Bilddaten einen gegebenenfalls an der bewegbaren Einrichtung vorgesehenen Steuerrechner immer sicher erreichen.

[0019] In beiden Fällen können sowohl die Bilderfassungseinheit als auch die Bezugsmittel bewegbar an einer Aufnahme angeordnet werden. Dies setzt jedoch voraus, dass die Position bei einer räumlichen Positionsänderung der Bezugsmittel oder der Bilderfassungseinheit bei der Berechnung einer Transformationsvorschrift für Bewegungsdaten der bewegbaren Einrichtung mit berücksichtigt werden.

[0020] Bei der Anbringung der oben beschriebenen Vorrichtung zur Ermittlung von korrigierten Bewegungsdaten an einer bewegbaren Einrichtung, insbesondere an einem fahrbaren Roboter mit einem fahrerlosen Transportfahrzeug und einem am Transportfahrzeug angebrachten Manipulator kann das Bilderfassungssystem entweder am fahrerlosen Transportfahrzeug, am Manipulator oder an einem am Manipulator angeordneten Werkzeug angebracht werden. Die Anbringung der Bilderfassungseinheit am Manipulator ist dann vorteil-

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haft, wenn nur ein verfahrbarer Roboter eine oder mehrere Haltestationen zu bedienen hat. In diesem Fall kann die Bilderfassungseinheit auch am Transportfahrzeug selber angebracht werden, wobei sich der Manipulator dann nur im Rahmen seiner Wiederholgenauigkeit positionieren lässt.

[0021] Werden jedoch mehrere verfahrbare Roboter eingesetzt, die alle auf eine Reihe von Werkzeuge (z. B. Greifer oder Bearbeitungswerkzeuge) zugreifen sollen, ist es im Weiteren bevorzugt, wenn die Bilderfassungsmittel unmittelbar am Werkzeug, insbesondere als zusätzliche Bilderfassungsmittel angebracht sind. Durch diese Maßnahme wird die Genauigkeit von Arbeitsgängen nicht durch eine begrenzte Wiederholgenauigkeit des mechanischen Systems des Manipulators oder dadurch beeinträchtigt, dass das selbe Werkzeug an verschiedenen Robotern in gegebenenfalls leicht unterschiedlich ausgestalteten Aufnahmen angebracht ist.

[0022] An den Positionen, die soeben für die Bilderfassungseinheit vorgeschlagen wurden, können auch stattdessen die Bezugsmittel positioniert werden. In diesem Fall ist die Bilderfassungseinheit getrennt von der bewegbaren Einrichtung vorzugsweise ortsfest anzubringen.

[0023] Erfindungsgemäß kann auch ein System bewegbarer Einrichtungen, insbesondere verfahrbare Roboter, realisiert werden, bei welchem sich die bewegbaren Einrichtungen respektive die Roboter z. B. an einer Vielzahl von unterschiedlichen Bezugsmitteln orientieren oder über mehrere verteilt angeordnete Bilderfassungseinheiten gesteuert werden.

Der Einsatz der oben beschriebenen Vorrichtung zur Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung ist jedoch nicht notwendigerweise auf beispielhaft genannte verfahrbare Roboter beschränkt. Eine solche Vorrichtung kann auch zur Bewegungsdatenkorrektur von Linearachsen oder automatischen Schwerlastkränen zum Einsatz kommen. Hierdurch lassen sich beispielsweise Positioniertoleranzen, die durch die notwendige mechanische Elastizität solcher Einrichtungen an sich nicht vermeidbar sind, korrigieren.

Zeichnungen

[0024] Ein Ausführungsbeispiel der Erfindung ist in den Zeichnungen dargestellt und unter Angabe weiterer Vorteile und Einzelheiten näher erläutert.

[0025] Es zeigen

Figur 1 einen verfahrbaren Roboter an einer Haltestation mit einem Bezugskörper in einer schematischen räumlichen Darstellung und

Figur 2 eine Teilansicht des Roboters mit Bezugskörper von schräg unten.

Beschreibung des Ausführungsbeispiels

[0026] In Figur 1 ist ein verfahrbarer Roboter 1 vor einer Haltestation 2 dargestellt. Der verfahrbare Roboter umfasst ein fahrerloses Transportfahrzeug 3, auf dem ein 6-Achs-Knickarmmanipulater 4 angeordnet ist. Am vorderen Ende des Knickarmmanipulators 4 ist ein Werkzeug 5 angebracht, mit welchem Werkstücke 6 aufgenommen werden können, die an der Haltestation 2 auf an einer Wand 7 angebrachten Stangen 8 abnehmbar gelagert sind.

[0027] Am oberen Rand der Wand 7 ist ein winkelförmiger Bezugskörper 9 mit Markierungen 10 (vgl. hierzu Figur 2) positioniert. Am Werkzeug 5 ist eine Digitalkamera 11 montiert.

[0028] Das fahrerlose Transportfahrzeug 3 kann z. B. durch induktive Leiteinrichtungen (nicht dargestellt) grob vor der Haltestation 2 positioniert werden. An der Haltestation 2 wird über die digitale Kamera 11 ein Bild vom Bezugskörper 10 aufgenommen. In der nicht dargestellten Rechnereinheit wird aus den Daten des aufgenommenen Bildes des Bezugskörpers 10 und Daten eines Bezugsbildes der Bezugsmittel, bei dem das Werkzeug 5 eine eingelernte Bewegung entsprechend von in der Rechnereinheit abgelegten Urbewegungsdaten ausführen würde, eine Transformationsvorschrift zur Korrektur der Urbewegungsdaten errechnet. Bei der Anwendung dieser Transformationsvorschrift auf die Urbewegungsdaten erhält man korrigierte Bewegungsdaten, durch die dann ein eingelernter Bewegungsablauf ideal ausgeführt wird.

[0029] Durch die Markierungen 12 auf dem Bezugskörper 9 besitzt der Bezugskörper in einem bestimmten Raumwinkelbereich eindeutig zuordenbare Bildansichten. Dies erlaubt dem nicht dargestellten Rechner, aus dem aktuellen Bild des Bezugskörpers 9 nach einer groben Positionierung des verfahrbaren Roboters Daten zu gewinnen, die eindeutig zu Daten eines Bezugsbildes in Bezug gesetzt werden können, um hieraus die Transformationsvorschrift für die Urbewegungsdaten zu erhalten. Vorzugsweise wird zur Transformation ein Verschiebungsvektor in einem dreidimensionalen rechtwinkligen Koordinatensystem ermittelt sowie drei Winkeldrehungen um die Koordinatenachsen, welche das Koordinatensystem aufspannen.

[0030] Mit dieser Kenntnis kann das Werkzeug 5 in unterschiedlichen Positionen des fahrerlosen Transportfahrzeugs über den Manipulator 4 durch eine jeweils für eine Position des fahrerlosen Transportfahrzeugs neu zu errechnende Transformationsvorschrift die Werkstücke 6 an der Wand 7 anfahren, gegebenenfalls aufnehmen und falls gewünscht, auf einem vorbereiteten Transportbereich 12 neben dem Manipulator 4 am fahrerlosen Transportfahrzeug 3, z. B. auf einer nicht dargestellten Palette, ablegen. Dabei werden die Bewegungen, die das Werkzeug 5 am Manipulator 4 ausübt, immer durch den Verschiebungsvektor und die drei Winkeldrehungen korrigiert, womit sie letztendlich mit Be-

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wegungen übereinstimmen, die in der Stellung, in welcher das Bezugsbild aufgenommen wurde, dem Roboter eingelernt worden sind.

[0031] Durch die Ermittlung einer Transformationsvorschrift im dreidimensionalen Raum durch lediglich die Aufnahme eines einzigen Bildes mittels eines optischen Erfassungssystems, das z. B. starr an einem Werkzeug oder Manipulator angebracht sein kann, ist der korrigierte Bewegungsablauf nicht durch mechanische Wiederholungenauigkeiten belastet, die dann auftreten, wenn beispielsweise entsprechend der DE 32 46 828 C2 der Manipulator zur Positionserfassung einen Taststift gegebenenfalls dreimal an Referenzpunkte bewegen muss oder ein optisches System drei Referenzpunkte anzufahren hat.

[0032] Die Genauigkeit des korrigierten Bewegungsablaufs durch die erfindungsgemäße Vorgehensweise kann noch weiter verbessert werden, indem während eines Bewegungsablaufs des Manipulators (z. B. während ein Bearbeitungswerkzeug über das Werkzeug 5 des Manipulators 4 an einer Bearbeitungsmaschine angebracht werden soll) die Bilderfassungseinheit 11 Aufnahmen vom Anbringungsort des Bearbeitungswerkzeugs macht, dessen Daten mit den Daten eines bekannten Bildes vergleicht, bei welchem die Bewegungsbahn zum Anbringungsort exakt bekannt ist und gegebenenfalls daraufhin vom Rechner nochmals eine Positionskorrektur vorgenommen wird, falls aus den Daten des aktuellen Bildes und den Daten des Bezugsbildes Abweichungen errechnet werden.

[0033] Durch den Einsatz einer Bilderfassungseinheit z. B. in Form einer digitalen Kamera ist das System auch in der Lage, eine Objekterkennung auszuführen, wodurch die erfindungsgemäße Korrigiervorrichtung einem zusätzlichen Verwendungszweck zugeführt wird. Normalerweise muss zur Bereitstellung einer Objekterkennung ein zusätzliches optisches System am Roboter vorgesehen werden, was die Anfälligkeit des Systems erhöht und letztendlich die Kosten in die Höhe treibt.

Bezugszeichenliste:

[0034]

1	verfahrbarer Roboter
2	Haltestation
3	fahrerloses Transportfahrzeug
4	Manipulator
5	Werkzeug
6	Werkstück
7	Wand
8	Stange
9	Bezugskörper
10	Markierung
11	Digitalkamera
12	Transportbereich

Patentansprüche

1. Vorrichtung zur Ermittlung von korrigierten Bewegungsdaten für einen vorgegebenen Bewegungsablauf einer bewegbaren Einrichtung (5) nach einer von einer Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung der bewegbaren Einrichtung (5), **dadurch gekennzeichnet, dass** eine Bilderfassungseinheit (11) und eine Rechnereinheit vorgesehen sind, und die Rechnereinheit nach der von der Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung korrigierte Bewegungsdaten mit Hilfe von Bezugsmitteln (9) bestimmt, die wenigstens in einem vorgegebenen Raumwinkelbereich eindeutig zuordenbare Bildansichten aufweisen, indem die Rechnereinheit aus Daten von einem durch die Bilderfassungseinheit (11) aufgenommenen Ist-Bild der Bezugsmittel (9) im positionierten Zustand der bewegbaren Einrichtung (5) nach der nicht oder unzureichend erfassten Bewegung und Daten eines Bezugsbildes der Bezugsmittel (9), bei dem die bewegbare Einrichtung eine gewünschte Bewegung entsprechend von in der Rechnereinheit abgelegten Urbewegungsdaten ausführen würde, eine Transformationsvorschrift zur Korrektur der Urbewegungsdaten errechnet.

2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** die Bilderfassungseinheit eine Kamera oder eine Videokamera (11) umfasst.

3. Vorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Rechnereinheit ein handelsüblicher PC ist.

4. Vorrichtung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Rechnereinheit dazu ausgelegt ist, die Transformationsvorschrift durch einen Pixel-Vergleich des Ist-Bildes mit dem Bezugsbild zu bestimmen.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Rechnereinheit zur Ermittlung einer Transformationsvorschrift in Form eines Verschiebungsvektors in einem dreidimensionalen Koordinatensystem sowie von Winkeldrehungen um die drei Koordinatenachsen ausgelegt ist, die das Koordinatensystem aufspannen.

6. Anordnung zur Ermittlung von korrigierten Bewegungsdaten für einen Bewegungsablauf einer bewegbaren Einrichtung (5) mit einer Vorrichtung nach einem der vorhergehenden Ansprüche sowie mit Bezugsmittel (9), die wenigstens in einem vorgegebenen Raumwinkelbereich eindeutig zuordenbare Bildansichten aufweisen.

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7. Anordnung nach Anspruch 6, **dadurch gekennzeichnet, dass** die Bezugsmittel ein dreidimensionales Objekt mit Orientierungselementen oder dessen virtuelles Bild umfassen.

8. Anordnung nach Anspruch 6 oder 7, **dadurch gekennzeichnet, dass** die Bezugsmittel (9) an der bewegbaren Einrichtung (5) und die Bilderfassungseinheit (11) getrennt von der bewegbaren Einrichtung (5) angeordnet ist.

9. Anordnung nach einem der vorhergehenden Ansprüche 6 bis 8, **dadurch gekennzeichnet, dass** die
Bilderfassungseinheit (11) an der bewegbaren Einrichtung (5) und die Bezugsmittel (9) getrennt von der bewegbaren Einrichtung (5) angeordnet sind.

10. Bewegbare Einrichtung, insbesondere verfahrbare Roboter mit einem fahrerlosen Transportfahrzeug (3) und einem am Transportfahrzeug angebrachten Manipulator (4), **dadurch gekennzeichnet, dass** zur Ermittlung von korrigierten Bewegungsdaten für die bewegbare Einrichtung (5) nach einer von der Steuerung der bewegbaren Einrichtung nicht oder nicht ausreichend erfassten Bewegung eine Vorrichtung nach einem der Ansprüche 1 bis 5 vorgesehen ist.

11. Bewegbare Einrichtung nach Anspruch 10, **dadurch gekennzeichnet, dass** die Bezugsmittel (9) an der bewegbaren Einrichtung (5) angeordnet sind.

12. Bewegbare Einrichtung nach Anspruch 10 oder 11, **dadurch gekennzeichnet, dass** die Bilderfassungseinheit (11) an der bewegbaren Einrichtung (5) angeordnet ist.

13. System aus mehreren bewegbaren Einrichtungen, insbesondere verfahrbaren Robotern, gemäß einem der Ansprüche 10 bis 11 sowie mehreren Bezugsmittel (9) oder Bilderfassungseinheiten (11).

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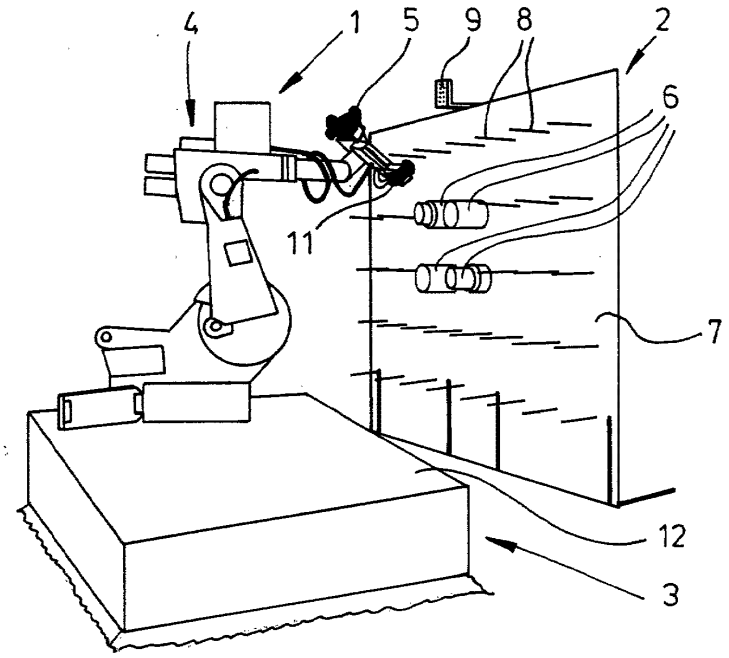


Fig. 1

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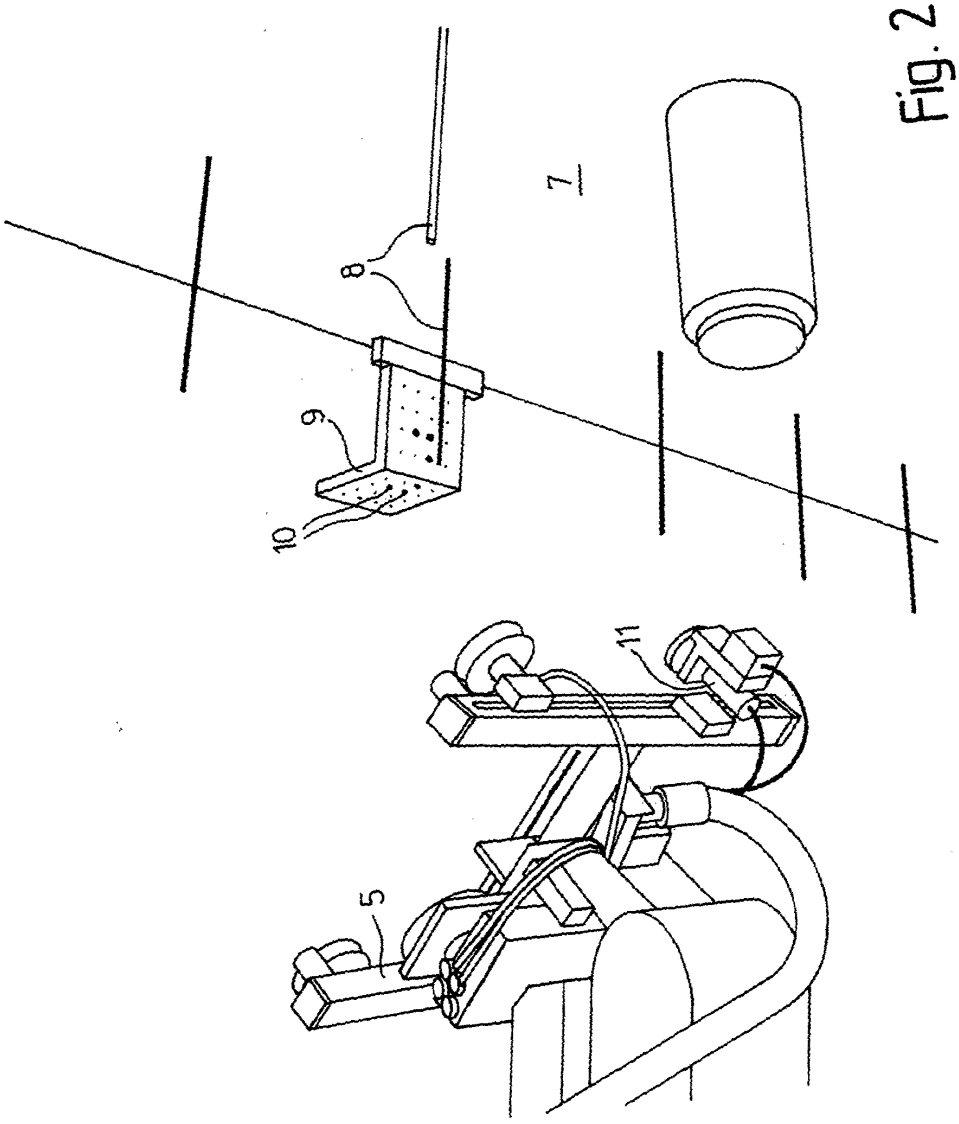


Fig. 2

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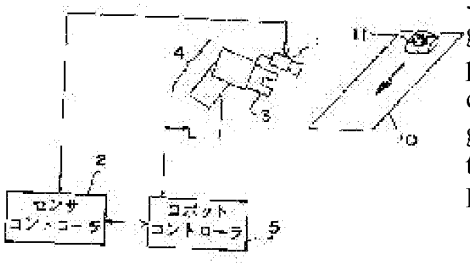
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(54) **ROBOT DEVICE AND ITS CONTROL METHOD**



(57)Abstract:
PROBLEM TO BE SOLVED: To save labor for troublesome teaching work and calibration and allow easy work for objects, as predetermined.
SOLUTION: In teaching work, a robot controller 5 stores a position Pd of a gripper 3 in the state of gripping the object 11 and further stores any position (Ps) after the object 11 is released. In clamping work, the robot controller 5 makes the gripper 3 follow the object 11 being carried, go to the object 11 in accordance with the positions Ps, Pd and grip the object 11.

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CLAIMS

[Claim(s)]
[Claim 1]A robot device which grasps a subject which exercises relatively, comprising:
A holding means which has a gripping mechanism which grasps said subject and said gripping mechanism comprised movable.
An imaging means which is fixed movable with a gripping mechanism of said holding means, and picturizes a subject.
A feature amount extracting means which extracts coordinates of one or more characteristic quantity from a picture of a subject which said imaging means picturized.
A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when moving said gripping mechanism within limits which can make said subject able to open wide and in which said imaging means can picturize a subject is memorized as the 2nd end point position, A memory measure which memorizes coordinates of each characteristic quantity of said subject which said imaging means picturized in said 2nd end point position, and said feature amount extracting means extracted.
A calculating means which computes a move procession for moving from said 2nd end point position to said end point position of 1.
A follow-up control means by which coordinates of each characteristic quantity of a subject under movement extracted by said feature amount extracting means carry out control which said gripping mechanism is made to follow to a subject under said movement by moving said holding means so that it may be in agreement with coordinates of each characteristic quantity memorized by said memory measure.
A grasping control means which controls said holding means to bring said gripping mechanism close to a subject under said movement based on a move procession which said calculating means computed, and to make said subject grasp when a subject while said gripping mechanism is exercising is followed.

[Claim 2]While said gripping mechanism separates said memory measure prescribed distance to a subject under said movement by said follow-up control means, when it follows, Coordinates of each characteristic quantity of said subject which said feature amount extracting means extracted are newly memorized, The robot device according to claim 1 which memorizes a position of said gripping mechanism when said follow-up control means makes said gripping mechanism follow a subject thoroughly from said 2nd end point position using coordinates of each newly memorized characteristic quantity as the 2nd new end point position.
[Claim 3]In a control method of a robot device which grasps a subject which exercises relatively by a gripping mechanism constituted movable, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when making said subject open wide and moving said gripping mechanism within limits which can picturize a subject is memorized as the 2nd end point position, In said 2nd end point position,

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picturize said subject, and coordinates of one or more characteristic quantity are extracted from a picture of said picturized subject, In the state where memorized coordinates of each of said extracted characteristic quantity, computed a move procession for moving from said 2nd end point position to said end point position of 1, and it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Coordinates of each characteristic quantity of a subject under said extracted movement by moving said gripping mechanism so that it may be in agreement with coordinates of each of said characteristic quantity memorized. When said gripping mechanism is made to follow a subject under said movement and a subject while said gripping mechanism is exercising is followed, based on said computed move procession, said gripping mechanism is brought close to a subject under said movement, A control method of a robot device of making said gripping mechanism grasping said subject.
[Claim 4]While said gripping mechanism is made to follow a subject under said movement, and said gripping mechanism separates prescribed distance to a subject under said movement, when it follows, in the state where it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Newly memorize coordinates of each characteristic quantity of said said extracted subject, and coordinates of each of said newly memorized characteristic quantity are used, A control method of the robot device according to claim 3 of memorizing a position of said gripping mechanism as the 2nd new end point position when said gripping mechanism is moved so that said gripping mechanism may follow a subject thoroughly from said 2nd end point position, and followed thoroughly.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to a robot device and a method for controlling the same, and relates to a robot device which grasps the object under movement especially, and a method for controlling the same.
[0002]
[Description of the Prior Art]When working to a subject using a robot (for example, objective grasping), information, including the position of a subject, a posture, etc., is acquired by a sensor, and many examples which work based on the sensor information are put in practical use. As such an equipment configuration, it divides roughly and, generally there are the following two methods.
[0003]For example, there are some which detect the position of a subject and a posture from the picture acquired by picturizing with the camera which had the subject which has a conveyor top conveyed fixed, and transmit the information to a robot as indicated to JP,8-63214,A. This robot is working grasping etc. from the position information on a subject.
[0004]Sensors, such as a camera, are attached to the hand of a robot, the target positional attitude is detected from the picture from a camera as mentioned above, and there are

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some which follow the subject which moves based on the information, and work grasping etc.

[0005]

[Problem(s) to be Solved by the Invention]However, when realizing the work of grasping of a subject, etc. using the camera installed apart from the robot like the former, the work which asks for the installed position of a robot and a camera correctly beforehand is needed. It is necessary to perform the camera calibration which computes a focal distance, a lens strain coefficient, etc. of the camera beforehand.

[0006]In addition, in the example in JP,8-63214,A etc., it is necessary to install so that the optic axis of a camera may generally become vertical still more nearly parallel to the transportation direction of a conveyor at a conveyor flat surface in the x axis or the y-axis in a screen. Since the subject is running by the band conveyor etc., in addition to the position attitude information of the subject detected by the picture from a camera, another means (for example, encoder of a conveyor) needs to detect the speed information of a conveyor, etc., and it is necessary to generate the command value to a robot based on both information. The orbit at the time of a robot grasping a subject from the installation position information of a camera and a robot, the position information on a subject, and the speed information of a conveyor must be generated. Therefore, there are problems, like the procedure for teaching work and trajectory generation becomes very complicated.

[0007]It can say such a problem that the same may be said of the example of the latter which installed the camera to the hand of the robot in conventional technology. That is, when a subject is grasped by the gripper etc. which were attached to the hand of a robot based on the position attitude information of the subject detected from the picture from a camera, What is called a hand eye calibration that needs to change the position attitude information of the subject acquired from the camera into the position attitude information seen from the standard coordinates of the robot, and searches for the physical relationship of a robot hand and a camera precisely beforehand is needed. When sensors, such as a camera, are especially installed in a robot hand, a camera position relation with a robot hand frequently changes with the malfunctions under work, etc., and it is necessary to do calibration work again in that case. When the subject is moving like the former example, since the position attitude information of the subject seen from the robot normal coordinate changes every moment, it becomes very complicated [the trajectory generation for grasping].

[0008]In the former, even if the method of the former and the latter changes neither a component (the installation condition of a conveyor, a bearer rate, or the installed position relation between a camera and a robot), nor the shape of a subject which should be grasped, Whenever the robot and sensor to be used changed, the above-mentioned highly precise calibration and complicated teaching work needed to be performed.

[0009]This invention is proposed in order to cancel the problem mentioned above, and it is a thing.

The purpose is to provide a robot device which can save the time and effort which performs work and a calibration, and can make predetermined work do on a subject easily, and a method for controlling the same.

[0010]

[Means for Solving the Problem]A holding means from which the invention according to

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claim 1 has a gripping mechanism which grasps a subject and which said gripping mechanism comprised movable, An imaging means which is fixed movable with a gripping mechanism of said holding means, and picturizes a subject, A feature amount extracting means which extracts coordinates of one or more characteristic quantity from a picture of a subject which said imaging means picturized, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when moving said gripping mechanism within limits which can make said subject able to open wide and in which said imaging means can picturize a subject is memorized as the 2nd end point position, A memory measure which memorizes coordinates of each characteristic quantity of said subject which said imaging means picturized in said 2nd end point position, and said feature amount extracting means extracted, A calculating means which computes a move procession for moving from said 2nd end point position to said end point position of 1, Coordinates of each characteristic quantity of a subject under movement extracted by said feature amount extracting means by moving said holding means so that it may be in agreement with coordinates of each characteristic quantity memorized by said memory measure. When a follow-up control means which carries out control which said gripping mechanism is made to follow to a subject under said movement, and a subject while said gripping mechanism is exercising are followed, Based on a move procession which said calculating means computed, said gripping mechanism is brought close to a subject under said movement, and it has a grasping control means which controls said holding means to make said subject grasp.

[0011]The robot device according to claim 1 grasps a subject which exercises relatively to the robot device concerned. Therefore, a case where said robot device exercises and said subject is being fixed, when said robot device and said subject are exercising at a speed different, respectively, and not only when said robot device is fixed and said subject exercises, but when, it can apply. Although said subject may be carrying out the acceleration straight-line motion of linear uniform motion, the uniform circular motion, etc. relatively to said robot device, it may be standing it still relatively.

[0012]First, the operator needs to perform the following two things as teaching work. A gripping mechanism is moved to the 1st end point position, and a subject is made 1st to grasp here. A subject is made to release from a gripping mechanism and an imaging means moves [2nd] a gripping mechanism within limits which can picturize a subject to the 2nd end point position. Such teaching work is performed and a memory measure is made to memorize the 1st and 2nd end point positions. A memory measure is made to also memorize coordinates of one or more characteristic quantity extracted from a picture which an imaging means picturized in the 2nd end point position. An imaging means serves as a sensor of a gripping mechanism, and it is being fixed so that it may move with a holding means. A move procession for moving from the 2nd end point position to the 1st end point position is computed.

[0013]If such teaching work is completed, grip operations which grasp a subject under movement can be performed. A gripping mechanism is moved so that coordinates of each characteristic quantity of a subject under movement may be in agreement with coordinates of each characteristic quantity memorized by said memory measure. That is, what is called a visual servo is performed so that a subject while a gripping mechanism is exercising may be followed. Relative physical relationship of a subject at this time and a

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gripping mechanism is the same as a subject at the time of teaching work, and that relative of a gripping mechanism. When a subject while said gripping mechanism is exercising is followed, based on the 1st move procession that said calculating means computed, said gripping mechanism is brought close to a subject under said movement, and said subject is made to grasp.

[0014]It is desirable for a gripping mechanism to follow a subject under movement thoroughly in a case where a visual servo is being performed. However, a gripping mechanism may follow, separating prescribed distance to a subject under movement. In such a case, it is preferred that re-teaching work which is indicated to claim 2 is performed. While said gripping mechanism separates said memory measure prescribed distance to a subject under said movement by said follow-up control means, when it follows, specifically, Coordinates of each characteristic quantity of said subject which said feature amount extracting means extracted are newly memorized, What is necessary is just to memorize a position of said gripping mechanism when said follow-up control means makes said gripping mechanism follow a subject thoroughly from said 2nd end point position using coordinates of each newly memorized characteristic quantity as the 2nd new end point position.

[0015]The invention according to claim 3 is the control method of a robot device which grasps a subject by a gripping mechanism constituted movable, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when making said subject open wide and moving said gripping mechanism within limits which can picturize a subject is memorized as the 2nd end point position, In said 2nd end point position, picturize said subject, and coordinates of one or more characteristic quantity are extracted from a picture of said picturized subject, In the state where memorized coordinates of each of said extracted characteristic quantity, computed a move procession for moving from said 2nd end point position to said end point position of 1, and it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Coordinates of each characteristic quantity of a subject under said extracted movement by moving said gripping mechanism so that it may be in agreement with coordinates of each of said characteristic quantity memorized. When said gripping mechanism is made to follow a subject under said movement and a subject while said gripping mechanism is exercising is followed, based on said computed move procession, said gripping mechanism is brought close to a subject under said movement, Said gripping mechanism is made to grasp said subject.

[0016]This invention is a method for controlling a robot device indicated to claim 1, and the operator should just perform two things mentioned above as teaching work. That is, only by an operator performing two easy teaching work, a gripping mechanism can be made to be able to follow a subject which is exercising and the subject can be grasped.

[0017]It is desirable for a gripping mechanism to follow a subject under movement thoroughly in a case where a visual servo is being performed. However, a gripping mechanism may follow, separating prescribed distance to a subject under movement. In such a case, it is preferred that re-teaching work which is indicated to claim 4 is performed. While said gripping mechanism specifically separates prescribed distance to a subject under said movement, when it makes said gripping mechanism follow a subject

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under said movement, and it follows, it is in a state fixed movable with said gripping mechanism, Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Newly memorize coordinates of each characteristic quantity of said said extracted subject, and coordinates of each of said newly memorized characteristic quantity are used, What is necessary is just to memorize a position of said gripping mechanism as the 2nd new end point position, when said gripping mechanism is moved so that said gripping mechanism may follow a subject thoroughly from said 2nd end point position, and followed thoroughly.

[0018]

[Embodiment of the Invention]Hereafter, it explains in detail, referring to drawings for an embodiment of the invention.

[0019](A 1st embodiment) As shown in drawing 1, the robot device concerning this embodiment grasps the subject 11 currently conveyed by conveyor 10 in the state where it was fixed. This invention is not limited to such an embodiment, and if the subject 11 is exercising relatively to a robot device, it is applicable. That is, they may be a case where a robot device exercises and the subject 11 is standing it still, and a case where it is exercising at the speed from which a robot device and the subject 11 differ. 2nd and 3rd embodiments are also the same.

[0020]A robot device is provided with the following.

CCD camera 1 which picturizes the subject 11.

The sensor controller 2 which extracts characteristic quantity from the picture which CCD camera 1 picturized.

The gripper 3 which grasps the subject 11.

The robot controller 5 which performs the robot arm 4 which moves the gripper 3 in the direction of a three dimension, coordinate conversion, trajectory generation, etc., has a servo circuit, amplifier, etc. which are not illustrated, and controls operation of the gripper 3 or the robot arm 4.

[0021]CCD camera 1 has adhered near the gripper 3 which is a tip of the robot arm 4. The robot controller 5 computes error vector E (t) and the speed commanding value vector V (t) based on the image characteristic quantity Fi obtained with the sensor controller 2, and controls movement of the robot arm 4, and grasping of the subject 11 by the gripper 3 according to these values. The conveyor 10 conveys the subject 11 at a fixed speed.

[0022]Before the robot device of such composition actually grasps the subject 11 currently conveyed, teaching work for grasping the subject 11 is performed.

[0023](Teaching work) First, an operator makes a robot device grasp the subject 11, and teaches the robot end point position P. The position which should be grasped may be restricted by the shape of gripping mechanisms, such as the gripper 3, and the subject 11. The position which should be grasped for next processing (for example, attach other parts to the subject 11, or supply to a parts box) may be specified beforehand.

[0024]Here, as shown, for example in drawing 2, the subject 11 was formed in 7 prismatic forms, and is provided with the seven sides 111-117. Six attachment holes (for example, tapped hole) for attaching the parts which are not illustrated are formed in the upper surface 118 of the subject 11. Such an attachment hole is not formed in the

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undersurface 119 of the subject 11. As for the portion by which the subject 11 is grasped, it is preferred that they are the side 111,115 in which it faces among seven sides in consideration of stability when grasped, or the side 113,116. Although the subject 11 of the above-mentioned shape was used in this embodiment, this invention may not be limited to this shape and the subjects 11 may be other shape. And teaching work is specifically performed according to processing of step ST1 to step ST6 shown in drawing 3.

[0025]In step ST1, an operator shifts to step ST2, as the gripper 3 grasps the side 111,115 or the side 113,116 of the subject 11 using the teaching pendant etc. which are not illustrated.

[0026]In step ST2, as shown in drawing 4, the gripper 3 is in the state which grasped the subject 11, and the robot controller 5 memorizes, the position, i.e., robot end point position Pd, of the gripper 3 in robot standard coordinates, and shifts to step ST3. The "position" said here is expressed with the parameter of 6 flexibility including a posture. The parameter of 6 flexibility including a posture is called "position" like the following.

[0027]In step ST3, the robot controller 5 makes the subject 11 which the gripper 3 grasped release, and moves the gripper 3 to arbitrary positions, and shifts to step ST4.

[0028]It requires that the position which the gripper 3 moves is in the visual field range of CCD camera 1. That is, it is a position where the characteristic quantity of the subject 11 is extracted from the picture picturized with CCD camera 1. It is a position where characteristic quantity which should be extracted, such as a position to which the subject 11 is not settled in the view of CCD camera 1, and a position in which CCD camera 1 picturizes the subject 11 from just beside, is specifically suitably obtained from a picture.

[0029]In step ST4, the robot controller 5 memorizes, as shown in drawing 5, the position Ps, i.e., the robot end point position, of the gripper 3 in the present robot standard coordinates, and it shifts to step ST5.

[0030]Here, the following formulas will be realized if the positional attitude transformation matrix for changing into Pd from the robot end point position Ps is made into P_O.

[0031]$Ps\text{-}P_O=Pd$ therefore $P_O=Ps^{-1}$ and the Pd robot controller 5 compute positional attitude transformation-matrix P_O at this time, and memorizes this. The robot controller 5 may compute positional attitude transformation-matrix P_O in the case of the grip operations mentioned later.

[0032]In step ST5, CCD camera 1 picturizes the subject 11 in the robot end point position Ps, and supplies this picture to the sensor controller 2. The sensor controller 2 extracts image characteristic quantity based on the picture from CCD camera 1, and shifts to step ST6. Here, CCD camera 1 acquires the picture of the subject 11 as shown, for example in drawing 6.

[0033]In step ST6, six attachment holes processed into the upper surface 118 of the subject 11 are extracted as the image characteristic quantity Fi (i= 1-6), the center position of each image characteristic quantity Fi carries out coordinate value (Xi, Yi) memory, and the sensor controller 2 ends processing of teaching work.

[0034]What is necessary is just to use publicly known techniques, such as binarization image processing and edge processing, as an instrumentation method of the center position of the attachment hole in a picture. Although it attached here and the center position of the hole was made into the image characteristic quantity Fi, the area center of

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gravity of the isolated field of a line segment corner point, a corner, and a binarization picture, etc. may use other image characteristic quantity. An operator may give a definition artificially by the input means in which neither a mouse nor a keyboard illustrates the image characteristic quantity Fi at the time of instruction.

[0035](Grip operations) A robot device grasps the subject 11 under conveyance using the coordinates of the image characteristic quantity Fi memorized on the occasion of the work, and the robot end point positions Pd and Ps, after teaching work is completed. In these grip operations, processings from step ST11 to step ST18 shown in drawing 7 are performed.

[0036]In step ST11, as shown in drawing 8, CCD camera 1 picturizes a transportation area [of the subject 11] 10, i.e., conveyor, top, and shifts to step ST12.

[0037]In step ST12, the sensor controller 2 judges whether the subject 11 was detected. In order to detect the subject 11 and to extract characteristic quantity from the picture, it is required for the subject 11 whole to enter within the limits of the view of CCD camera 1. Here, the luminosity of a picture is used for detection of the subject 11. For example, when the subject 11 is upstream of the conveyor 10 and there is into the visual field range of CCD camera 1, the luminosity of the picture acquired with CCD camera 1 hardly changes. [no] On the other hand, if the subject 11 is conveyed by conveyor and it enters in the visual field range of CCD camera 1, the luminosity will change. Then, it judges with the sensor controller 2 providing the window which is not illustrated in the suitable position in a picture, and the subject 11 being in a visual field range, when the luminosity in the window is beyond a predetermined threshold, and when luminosity is less than a predetermined threshold, it judges with there being nothing within the limits of the view. And when the sensor controller 2 detects the subject 11, it shifts to step ST13, and when it does not detect, it returns to step ST11.

[0038]image-characteristic-quantity fi(t) (i=1 in the time T from a picture when CCD camera 1 picturized the sensor controller 2 in step ST13, and 2 ...) -- it extracts and shifts to step ST14. Here, drawing 9 is a figure showing the picture picturized at the time of execution of grip operations. It is necessary to extract the image characteristic quantity fi (t) from the picture picturized at the time t at the time of grip operations. However, there is a thing which should extract essentially by a certain cause and for which the image characteristic quantity f3 (t) is extracted for example, it does not come out. Then, the characteristic quantity f1 (t) - f7 (t) need to perform corresponding point searching which asks for any of F1 - F6 which show drawing 6 are supported.

[0039]This corresponding point searching can be performed with what is called checking methods, such as dynamic programming, a largest faction method, etc. which various methods are proposed, for example, are indicated to "robot vision" (Masahiko Yanaida work, Shokodo, 1990). If F1 - the thing corresponding to F6 are obtained out of f1-f7, the following image characteristic quantity can once be calculated easily.

[0040]What is necessary is just to specifically extract the image characteristic quantity fi (t+deltat) in the next time (t+deltat) of the time t near the image characteristic quantity fi in the inside of a previous picture (t), if cycle time of the repetition processings from step ST13 to step ST16 is set to deltat. Thereby, the stability of characteristic quantity extraction can ease increase and the burden of computation.

[0041]In step ST14, the sensor controller 2, It judges whether the error vector E (t) in the time t is small enough, or the judging standard of ||E(t) ||<epsilon is specifically met,

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when small enough, it shifts to step ST17, and when not small enough, it shifts to step ST15.

[0042]Here, the error vector E (t) is searched for based on the image characteristic quantity fi (t) extracted from the picture of present CCD camera 1, and the image characteristic quantity Fi memorized by step ST6 mentioned above.

[0043]In this invention, literature B.Espiau et al., A New Approach to Visual Servoing in Robotics, IEEE Trans.Robotics and Automation, 8 (3), and 313-326-1992, Literature F.Bensalha et al. and Real Time Visual Tracking using the Generalized Likelihood Ratio Test,Int.Conf.Automation,Robotics and. Based on Computer Vision and the technique indicated to 1379-1383-1994, the error vector E (t) and the speed commanding value vector V (t) mentioned later are computed.

[0044]It asks for characteristic quantity deviation vector e (t) by the following formulas (1) using image-characteristic-quantity fi (t) = (Xi (t), Yi (t)) obtained from the picture picturized at image-characteristic-quantity Fi= at the time of instruction (Xi, Yi), and the time t.

[0045]

[Equation 1]

$$e(t)=\begin{pmatrix} x_1(t)-x_1 \\ y_1(t)-y_1 \\ x_2(t)-x_2 \\ y_2(t)-y_2 \\ \vdots \\ x_N(t)-x_N \\ y_N(t)-y_N \end{pmatrix} \quad \cdots (1)$$

[0046](xi, yi) and (xi(t), and yi (t)) are expressed with a pixel value (Xi, Yi), and change (Xi(t) and Yi (t)) into the value in a camera coordinate system, respectively. N expresses the number of image characteristic quantity.

[0047]The error vector E (t) is expressed with a formula (2) using above-mentioned characteristic quantity deviation vector e (t).

[0048]

[Equation 2]

$$E(t)=L^{T+}e(t) \quad \cdots (2)$$

[0049]Here, L^{T+} is a false inverse matrix of picture Jacobian L^{T} calculated from the image characteristic quantity F and F (t).

[0050]It judges with the sensor controller 2 having followed the subject 11 which exercises, when the judging standard of ||E(t) ||<epsilon was met. epsilon is scalar quantity beforehand given by an operator. Or as long as it expresses E=(E1 E2 E3 E4 E5 E6) ^{T}, the judging standard shown in a formula (3) may be used.

[0051]

[Equation 3]

$$\max_i E_i < \varepsilon \quad \cdots (3)$$

[0052]In step ST15, the robot controller 5 computes the speed commanding value vector

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