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Application Number: 16557261 Document Date: 08/30/2019

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Doc Code: TRACK1.REQ
Document Description: TrackOne Request

PTO/AIA/424 (04-14)

CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION UNDER 37 CFR 1.102(e) (Page 1 of 1)

First Named Inventor:	Purang Abolmaesumi	Nonprovisional Application Number (if known):	Unknown
Title of Invention:	ULTRASONIC IMAGE ANALYSIS		

APPLICANT HEREBY CERTIFIES THE FOLLOWING AND REQUESTS PRIORITIZED EXAMINATION FOR THE ABOVE-IDENTIFIED APPLICATION.

1. The processing fee set forth in 37 CFR 1.17(i)(1) and the prioritized examination fee set forth in 37 CFR 1.17(c) have been filed with the request. The publication fee requirement is met because that fee, set forth in 37 CFR 1.18(d), is currently $0. The basic filing fee, search fee, and examination fee are filed with the request or have been already been paid. I understand that any required excess claims fees or application size fee must be paid for the application.

2. I understand that the application may not contain, or be amended to contain, more than four independent claims, more than thirty total claims, or any multiple dependent claims, and that any request for an extension of time will cause an outstanding Track I request to be dismissed.

3. The applicable box is checked below:

I. ☑ Original Application (Track One) - Prioritized Examination under § 1.102(e)(1)

i. (a) The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a). This certification and request is being filed with the utility application via EFS-Web.

---OR---

(b) The application is an original nonprovisional plant application filed under 35 U.S.C. 111(a). This certification and request is being filed with the plant application in paper.

ii. An executed inventor's oath or declaration under 37 CFR 1.63 or 37 CFR 1.64 for each inventor, **or** the application data sheet meeting the conditions specified in 37 CFR 1.53(f)(3)(i) is filed with the application.

II. ☐ Request for Continued Examination - Prioritized Examination under § 1.102(e)(2)

i. A request for continued examination has been filed with, or prior to, this form.
ii. If the application is a utility application, this certification and request is being filed via EFS-Web.
iii. The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a), or is a national stage entry under 35 U.S.C. 371.
iv. This certification and request is being filed prior to the mailing of a first Office action responsive to the request for continued examination.
v. No prior request for continued examination has been granted prioritized examination status under 37 CFR 1.102(e)(2).

Signature /Keith M. Lim/	Date 2019-08-29
Name (Print/Typed) Keith M. Lim	Practitioner Registration Number 68,912

Note: *This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. Submit multiple forms if more than one signature is required.**

☑ *Total of 1 forms are submitted.

Privacy Act Statement

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

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

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

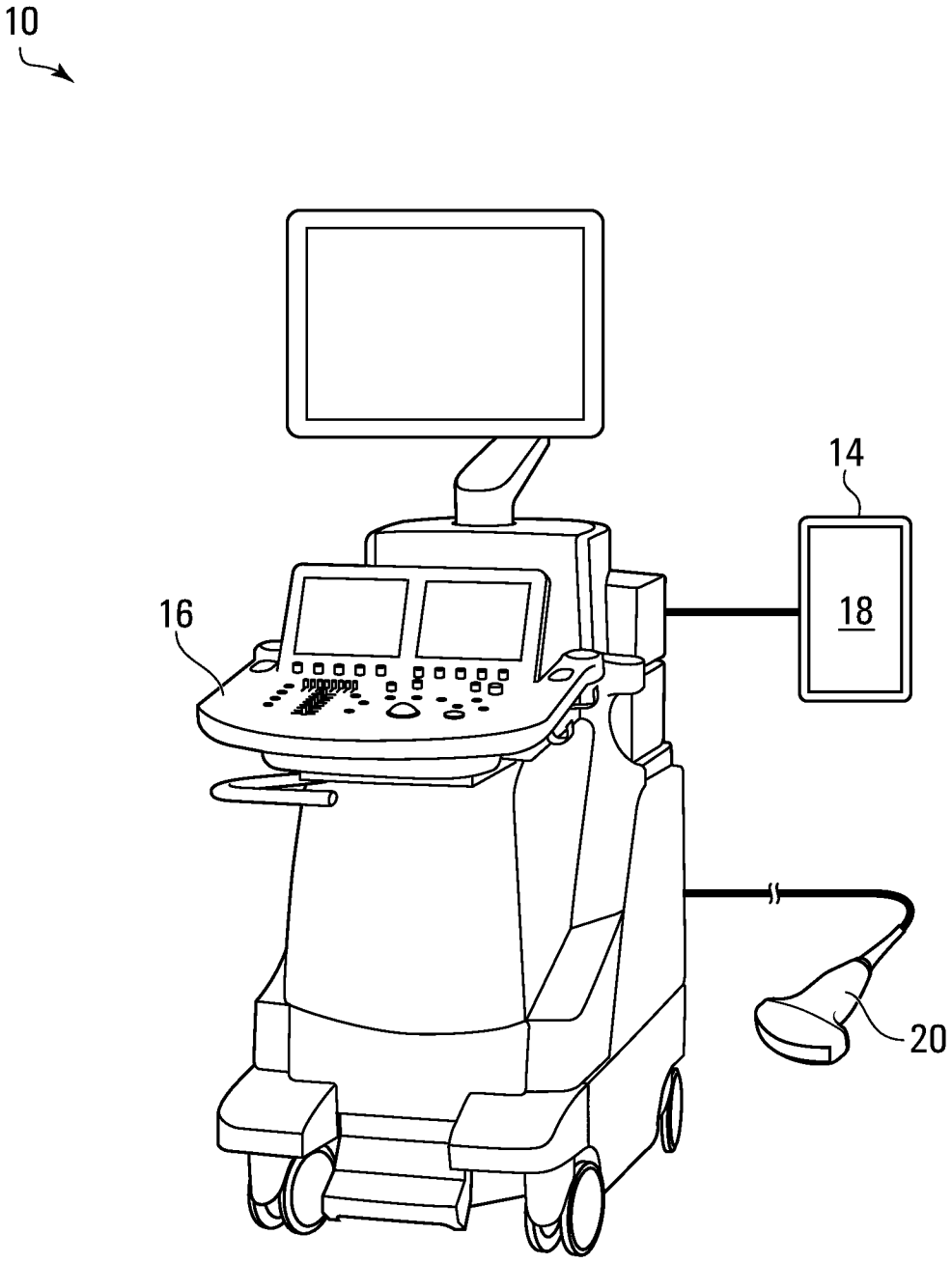


FIG. 1

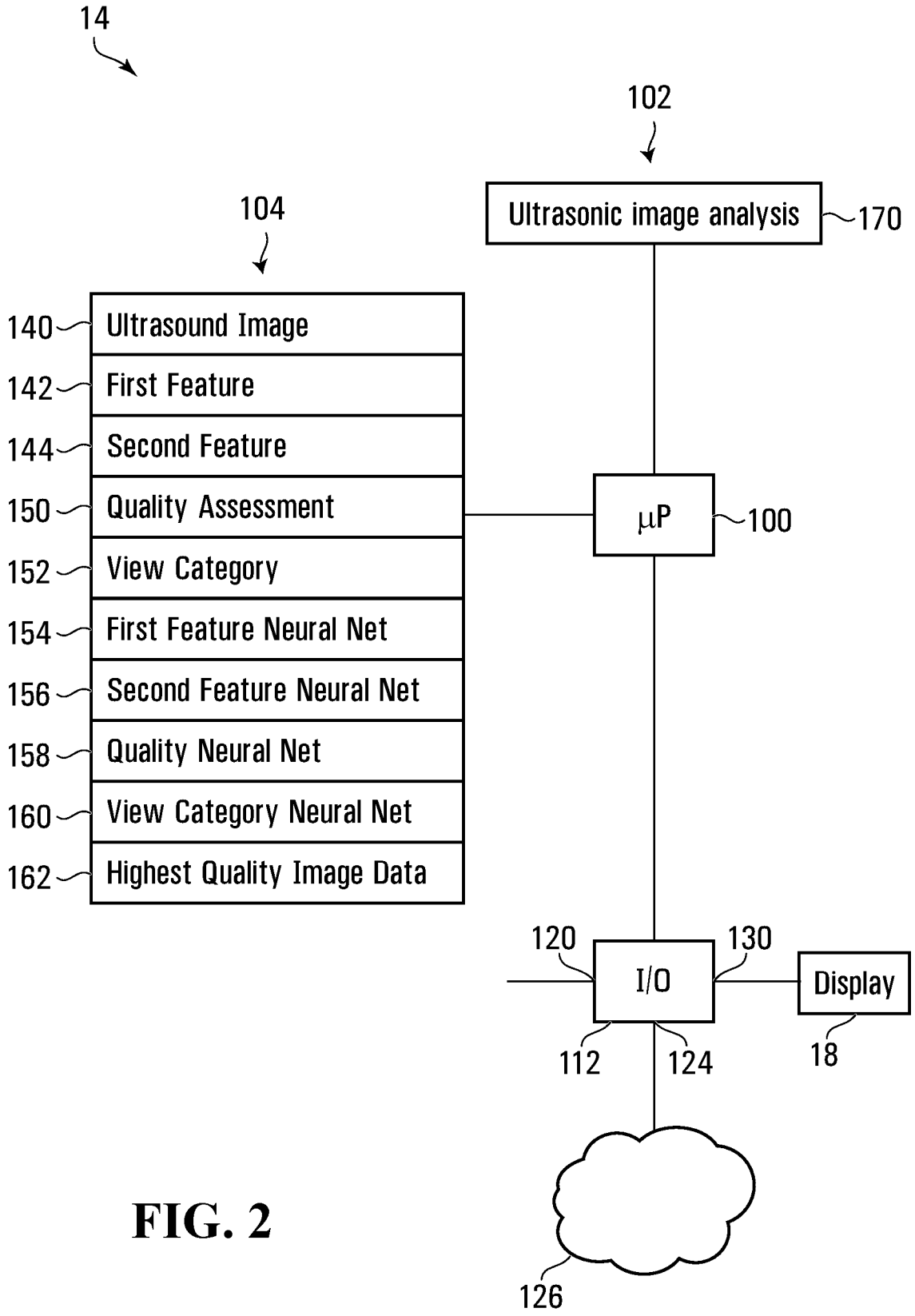

14
102
Ultrasonic image analysis
170
104
140
Ultrasound Image
142
First Feature
144
Second Feature
150
Quality Assessment
152
View Category
154
First Feature Neural Net
156
Second Feature Neural Net
158
Quality Neural Net
160
View Category Neural Net
162
Highest Quality Image Data
μP
100
120
130
I/O
Display
112
124
18
126

FIG. 2

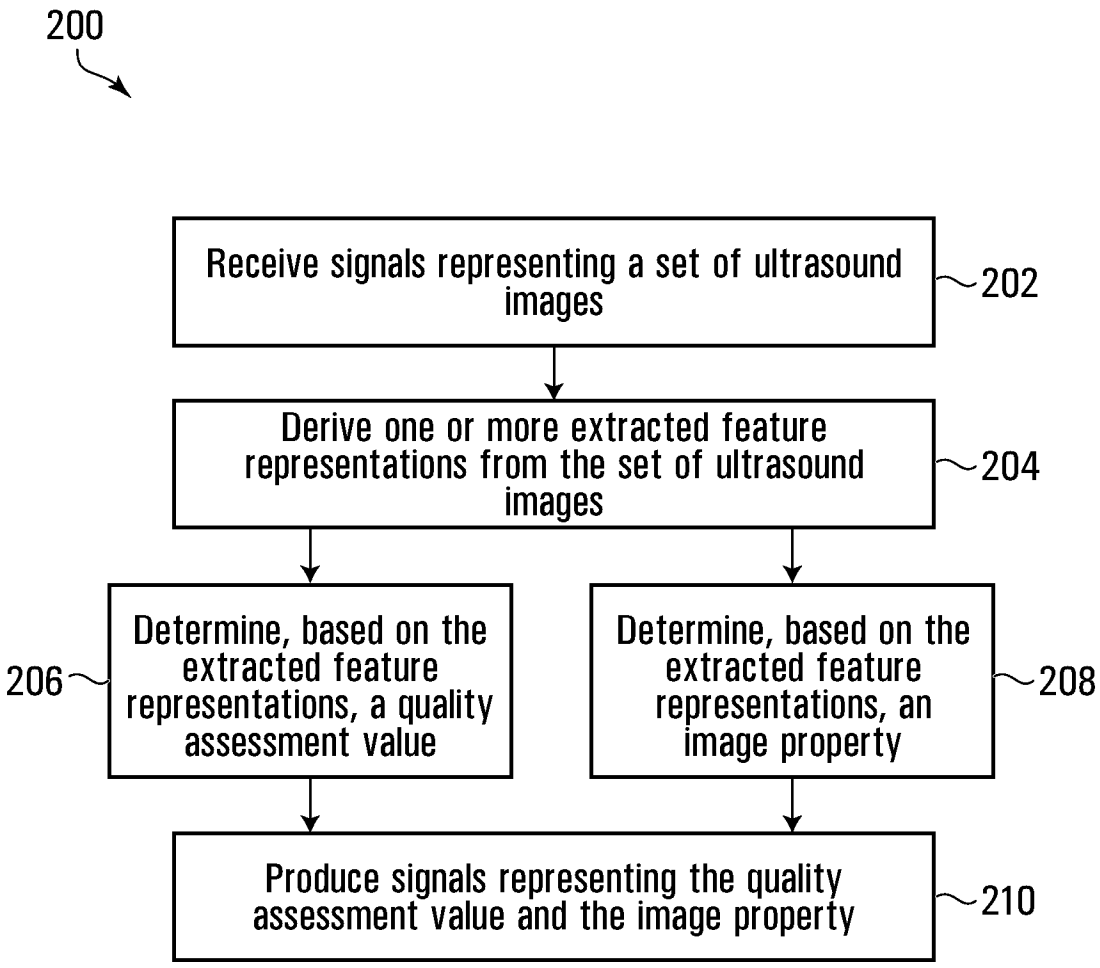

200
Receive signals representing a set of ultrasound images
202
Derive one or more extracted feature representations from the set of ultrasound images
204
206
Determine, based on the extracted feature representations, a quality assessment value
Determine, based on the extracted feature representations, an image property
208
Produce signals representing the quality assessment value and the image property
210

FIG. 3

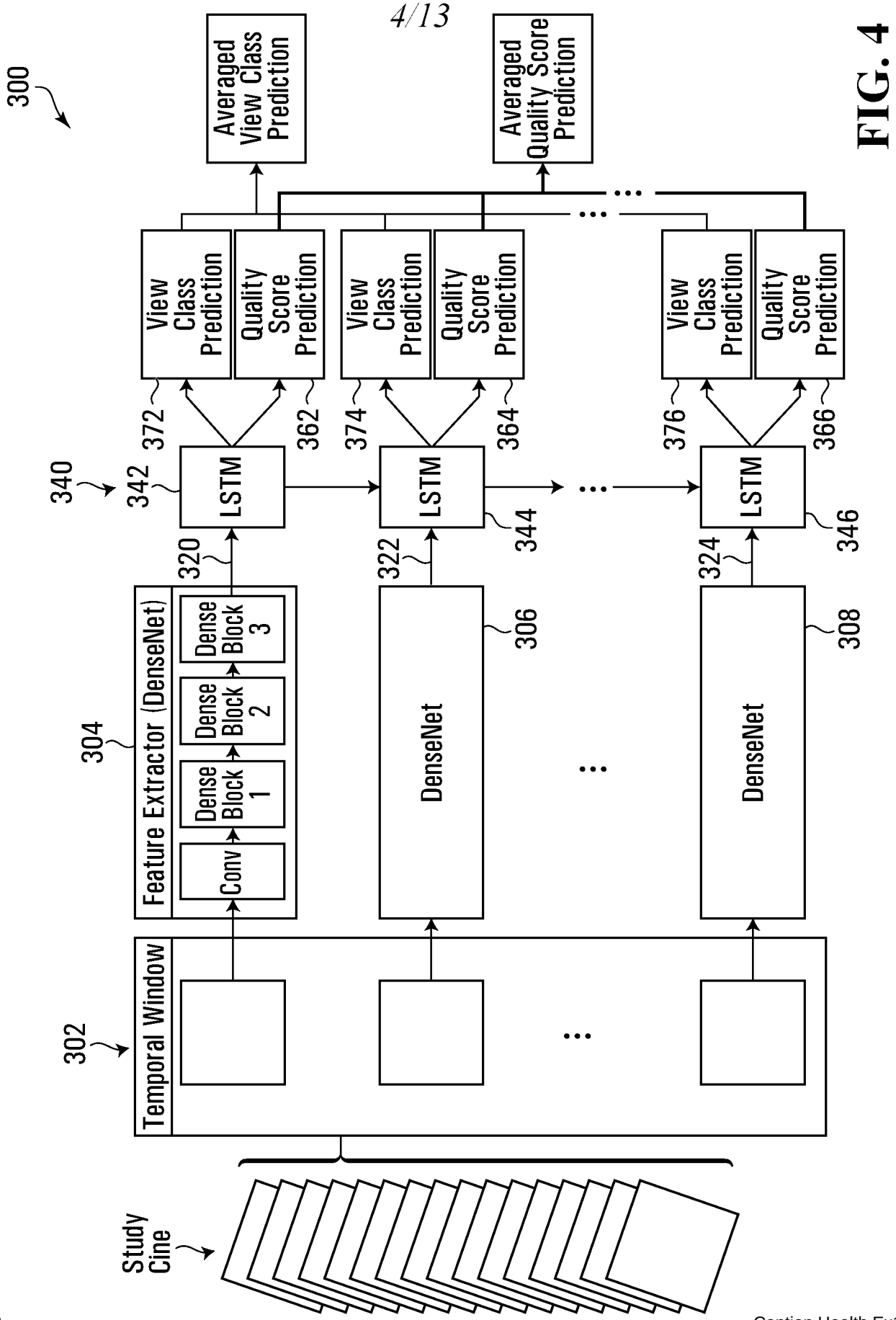

300
Averaged View Class Prediction
Averaged Quality Score Prediction
View Class Prediction
Quality Score Prediction
372
362
374
364
376
366
340
342
LSTM
344
346
320
322
324
304
Feature Extractor (DenseNet)
Conv
Dense Block 1
Dense Block 2
Dense Block 3
306
308
DenseNet
302
Temporal Window
Study Cine

FIG. 4

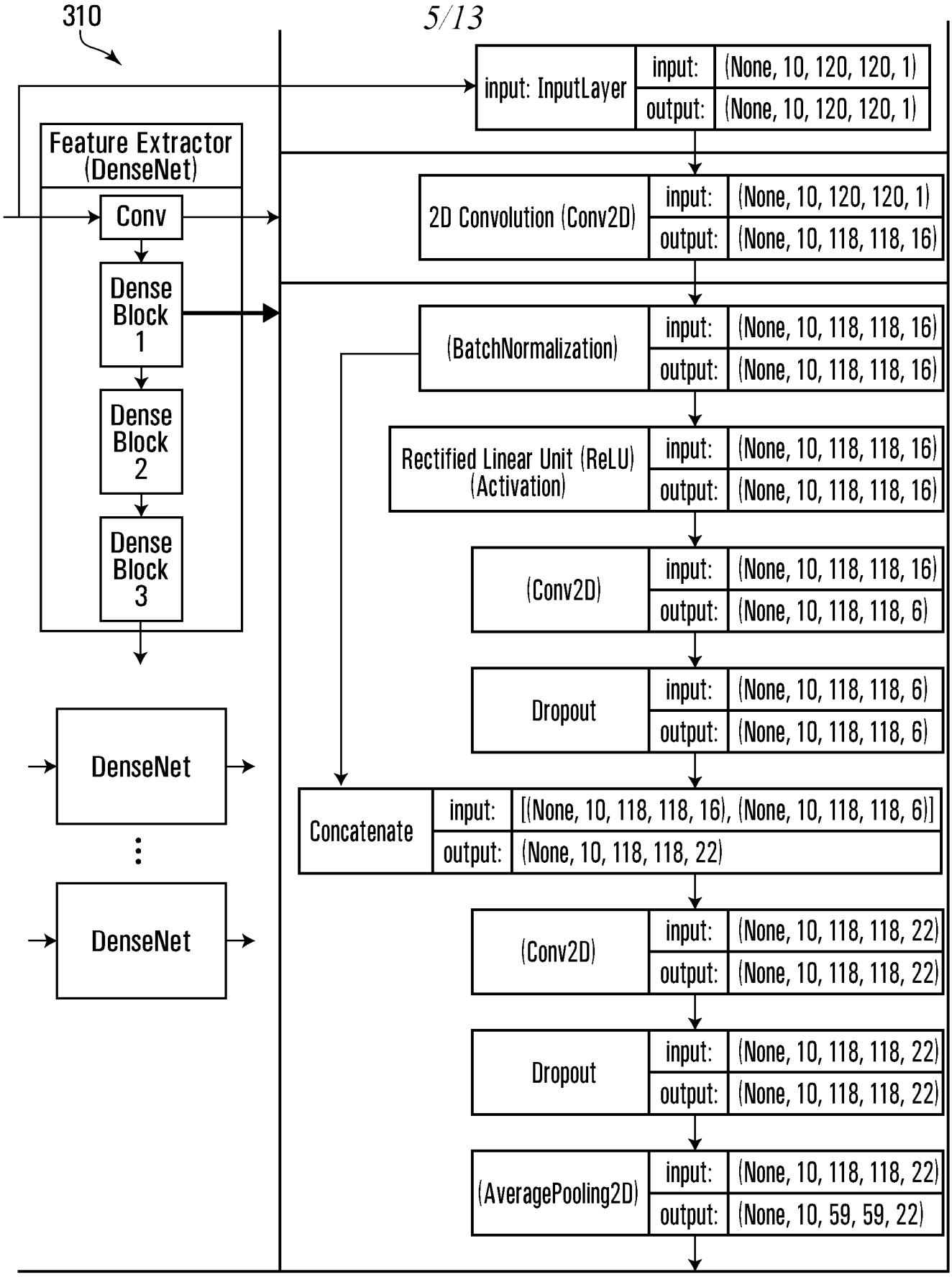

310
Feature Extractor (DenseNet)
Conv
Dense Block 1
Dense Block 2
Dense Block 3
DenseNet
DenseNet
input: InputLayer
input: (None, 10, 120, 120, 1)
output: (None, 10, 120, 120, 1)
2D Convolution (Conv2D)
input: (None, 10, 120, 120, 1)
output: (None, 10, 118, 118, 16)
(BatchNormalization)
input: (None, 10, 118, 118, 16)
output: (None, 10, 118, 118, 16)
Rectified Linear Unit (ReLU) (Activation)
input: (None, 10, 118, 118, 16)
output: (None, 10, 118, 118, 16)
(Conv2D)
input: (None, 10, 118, 118, 16)
output: (None, 10, 118, 118, 6)
Dropout
input: (None, 10, 118, 118, 6)
output: (None, 10, 118, 118, 6)
Concatenate
input: [(None, 10, 118, 118, 16), (None, 10, 118, 118, 6)]
output: (None, 10, 118, 118, 22)
(Conv2D)
input: (None, 10, 118, 118, 22)
output: (None, 10, 118, 118, 22)
Dropout
input: (None, 10, 118, 118, 22)
output: (None, 10, 118, 118, 22)
(AveragePooling2D)
input: (None, 10, 118, 118, 22)
output: (None, 10, 59, 59, 22)

FIG. 5

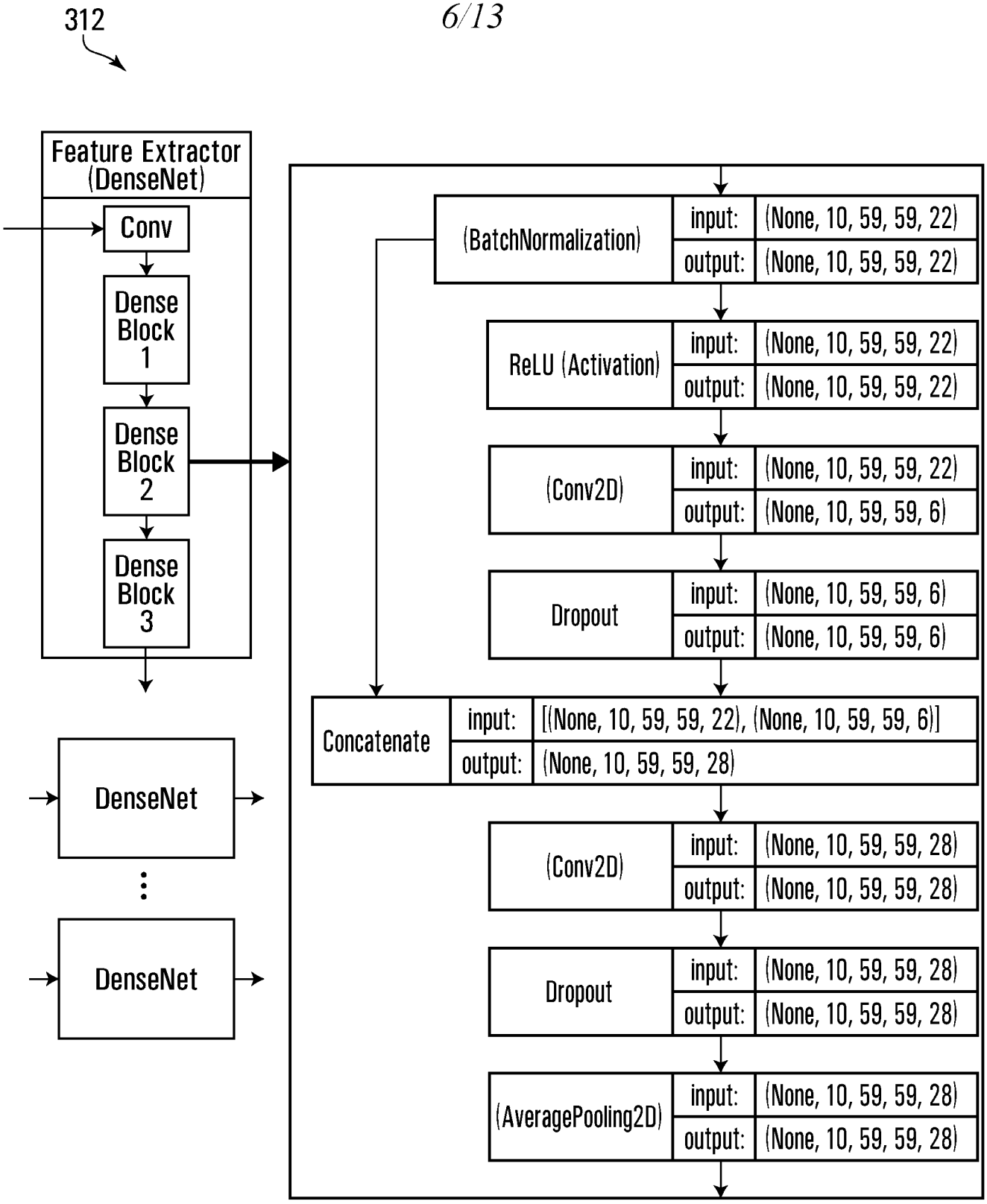

312
Feature Extractor (DenseNet)
Conv
Dense Block 1
Dense Block 2
Dense Block 3
DenseNet
DenseNet
(BatchNormalization)
input: (None, 10, 59, 59, 22)
output: (None, 10, 59, 59, 22)
ReLU (Activation)
input: (None, 10, 59, 59, 22)
output: (None, 10, 59, 59, 22)
(Conv2D)
input: (None, 10, 59, 59, 22)
output: (None, 10, 59, 59, 6)
Dropout
input: (None, 10, 59, 59, 6)
output: (None, 10, 59, 59, 6)
Concatenate
input: [(None, 10, 59, 59, 22), (None, 10, 59, 59, 6)]
output: (None, 10, 59, 59, 28)
(Conv2D)
input: (None, 10, 59, 59, 28)
output: (None, 10, 59, 59, 28)
Dropout
input: (None, 10, 59, 59, 28)
output: (None, 10, 59, 59, 28)
(AveragePooling2D)
input: (None, 10, 59, 59, 28)
output: (None, 10, 59, 59, 28)

FIG. 6

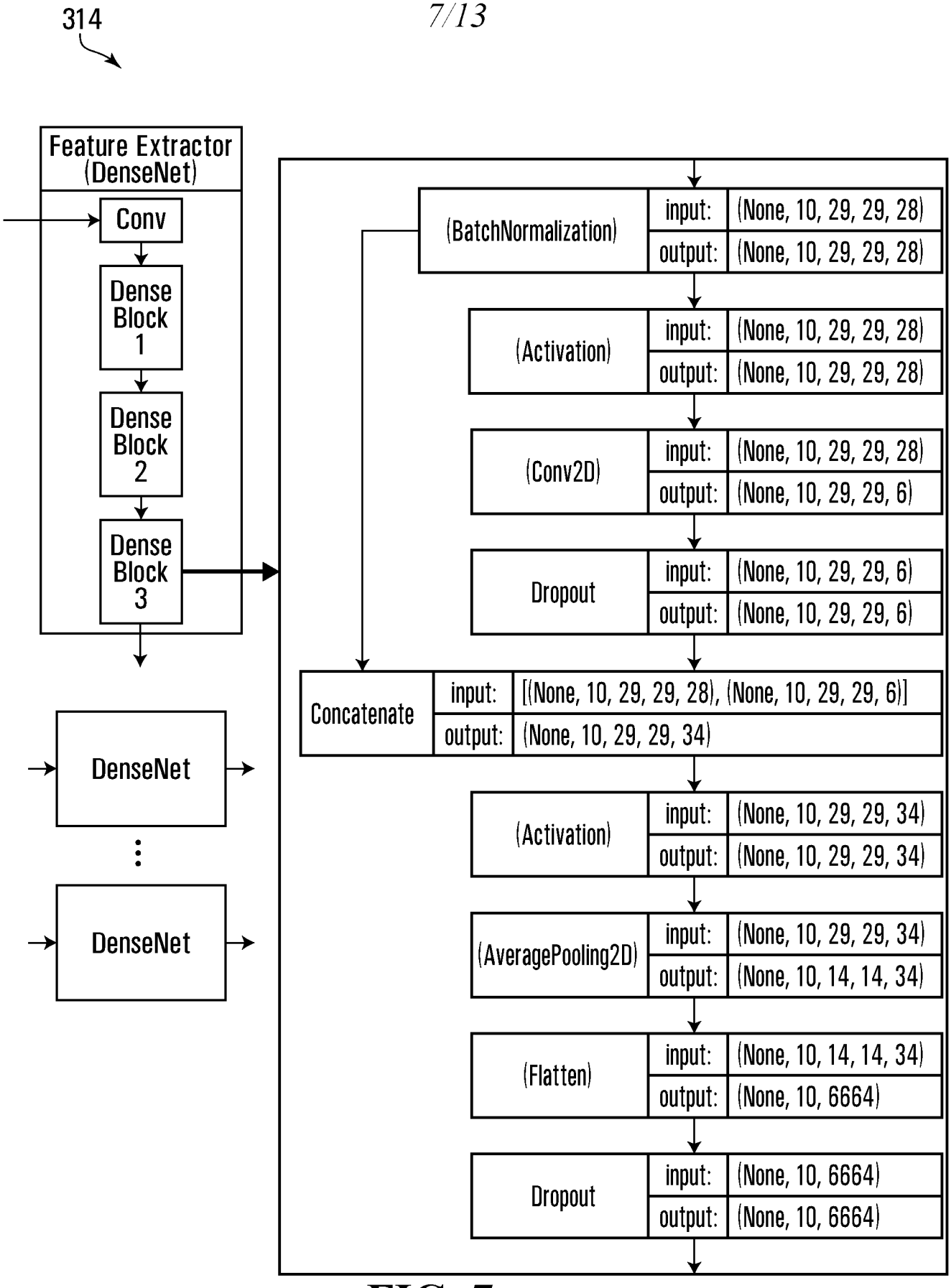

314
Feature Extractor (DenseNet)
Conv
Dense Block 1
Dense Block 2
Dense Block 3
DenseNet
DenseNet
(BatchNormalization)
input: (None, 10, 29, 29, 28)
output: (None, 10, 29, 29, 28)
(Activation)
input: (None, 10, 29, 29, 28)
output: (None, 10, 29, 29, 28)
(Conv2D)
input: (None, 10, 29, 29, 28)
output: (None, 10, 29, 29, 6)
Dropout
input: (None, 10, 29, 29, 6)
output: (None, 10, 29, 29, 6)
Concatenate
input: [(None, 10, 29, 29, 28), (None, 10, 29, 29, 6)]
output: (None, 10, 29, 29, 34)
(Activation)
input: (None, 10, 29, 29, 34)
output: (None, 10, 29, 29, 34)
(AveragePooling2D)
input: (None, 10, 29, 29, 34)
output: (None, 10, 14, 14, 34)
(Flatten)
input: (None, 10, 14, 14, 34)
output: (None, 10, 6664)
Dropout
input: (None, 10, 6664)
output: (None, 10, 6664)

FIG. 7

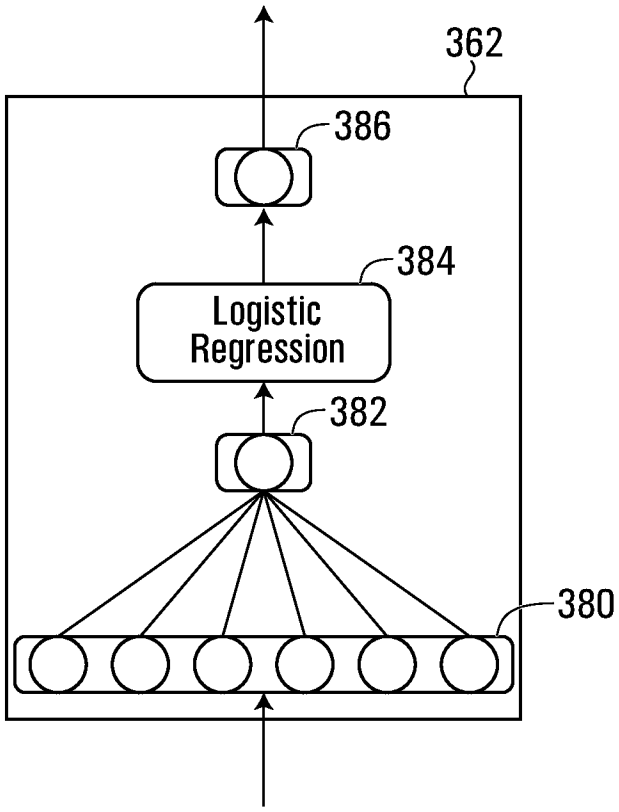


FIG. 8

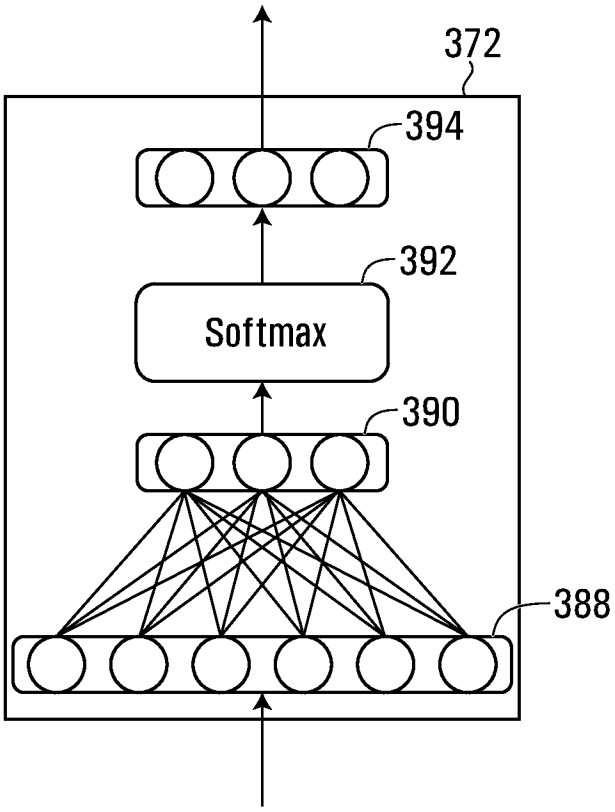


FIG. 9

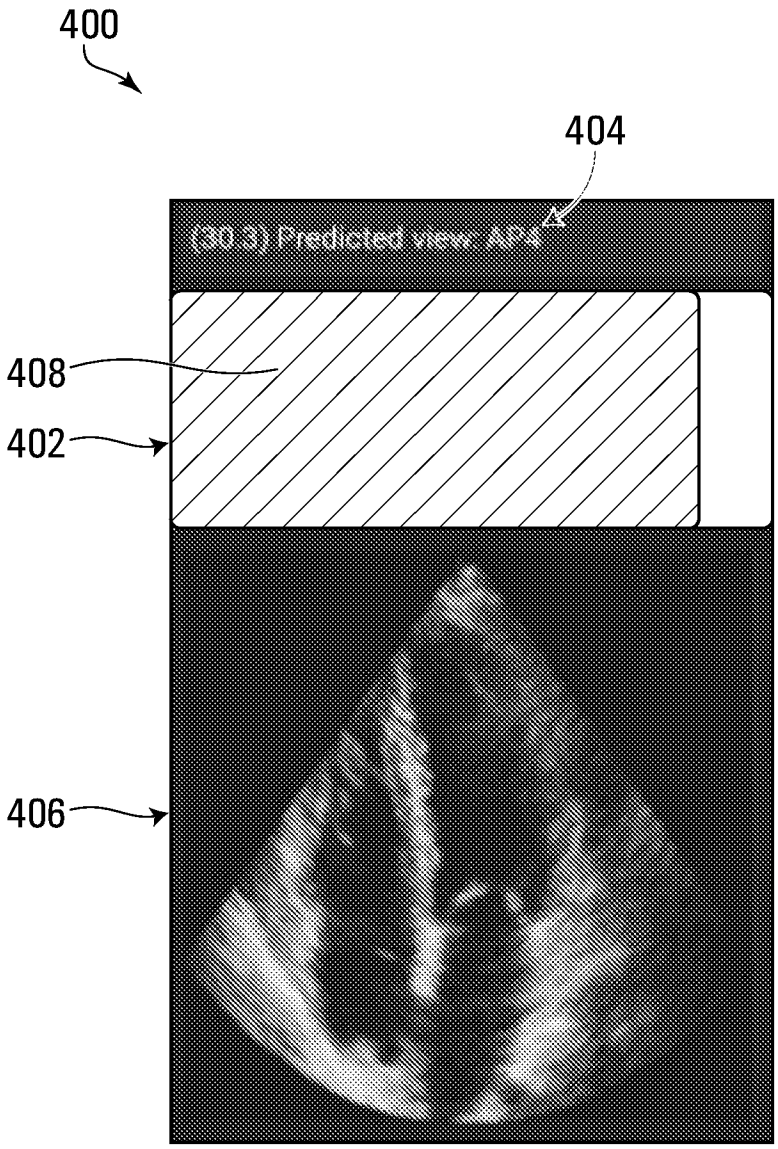


FIG. 10

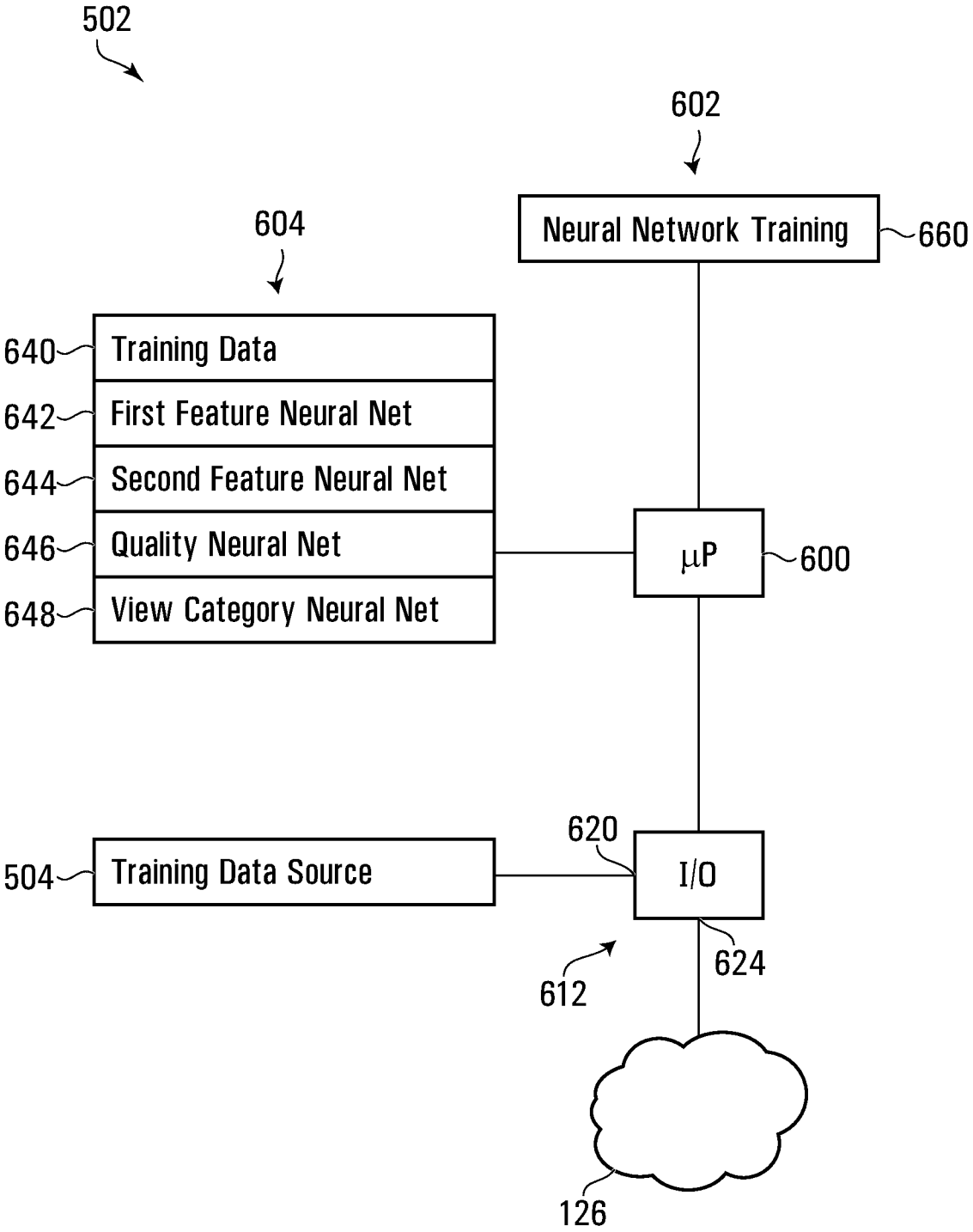

502
602
Neural Network Training
660
604
640
Training Data
642
First Feature Neural Net
644
Second Feature Neural Net
646
Quality Neural Net
648
View Category Neural Net
μP
600
620
504
Training Data Source
I/O
624
612
126

FIG. 11

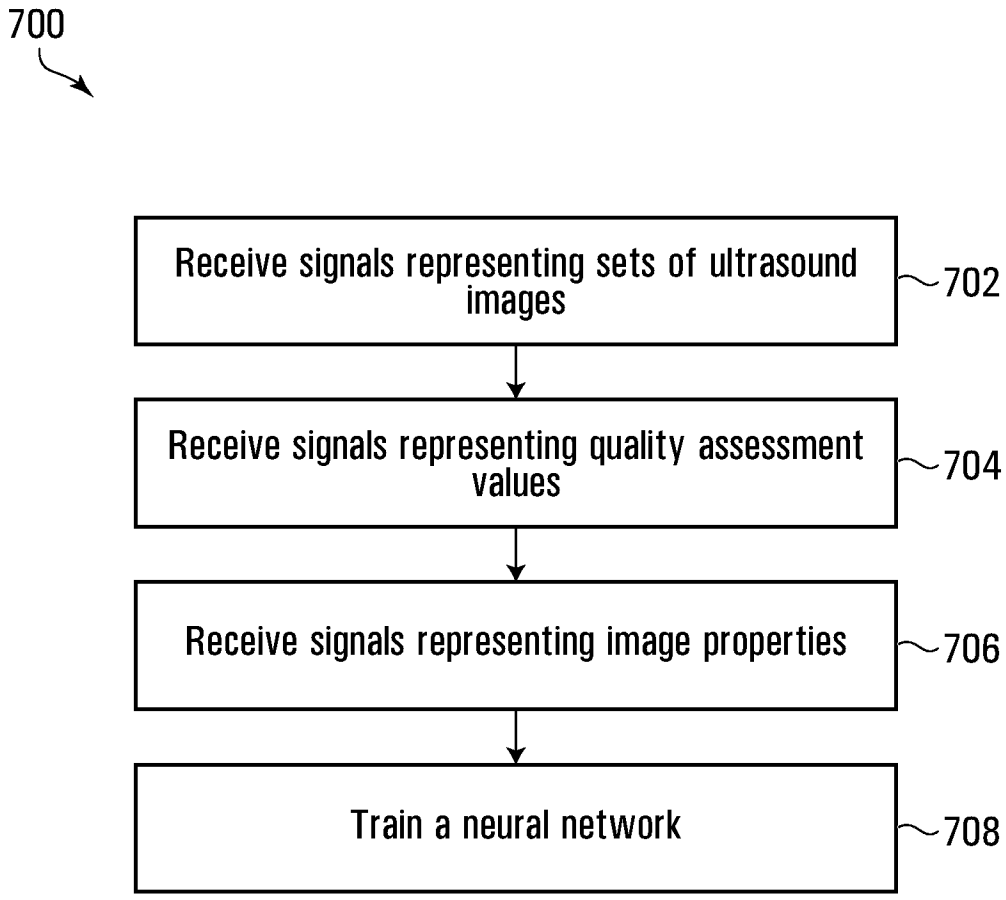

700
Receive signals representing sets of ultrasound images
702
Receive signals representing quality assessment values
704
Receive signals representing image properties
706
Train a neural network
708

FIG. 12

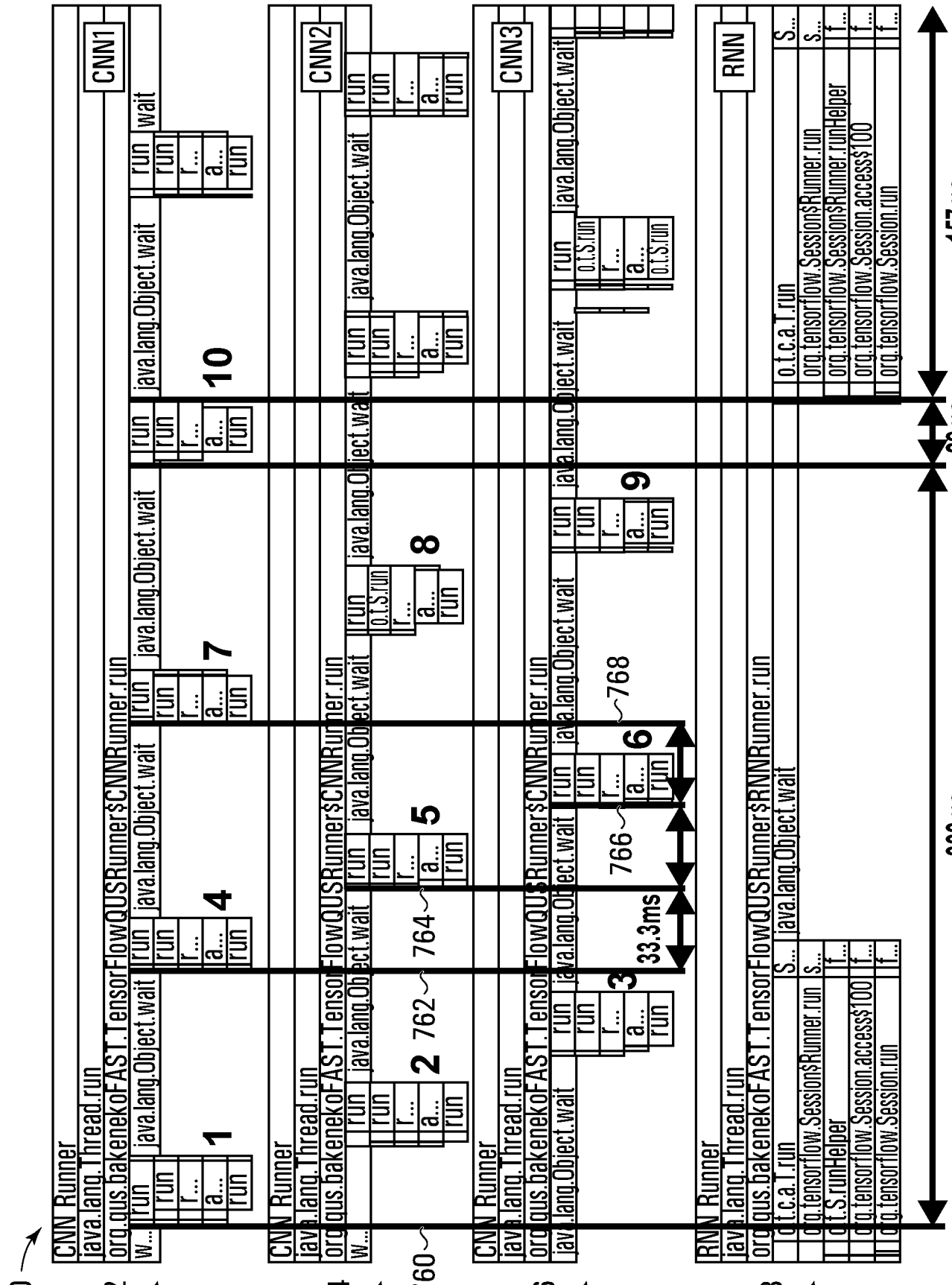

750
752
754
760
756
758
CNN Runner
java.lang.Thread.run
org.gus.bakenekoFAST.TensorFlowQUSRunner$CNNRunner.run
CNN1
CNN2
CNN3
RNN
RNN Runner
org.gus.bakenekoFAST.TensorFlowQUSRunner$RNNRunner.run
java.lang.Object.wait
o.t.c.a.T.run
org.tensorflow.Session$Runner.run
org.tensorflow.Session$Runner.runHelper
org.tensorflow.Session.access$100
org.tensorflow.Session.run
1
2
3
4
5
6
7
8
9
10
762
764
766
768
33.3ms
333ms
~29ms
~157ms

FIG. 13

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.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Purang		Abolmaesumi	

Residence Information (Select One) US Residency ● Non US Residency Active US Military Service

City	Country of Residence [i]
Vancouver	CA

Mailing Address of Inventor:

Address 1	c/o University Industry Liaison Office
Address 2	103-6190 Argonomy Road
City	Vancouver
State/Province	BC
Postal Code	V6T 1Z3
Country [i]	CA

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Robert		Rohling	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	Country of Residence [i]
Vancouver	CA

Mailing Address of Inventor:

Address 1	c/o University Industry Liaison Office
Address 2	103-6190 Argonomy Road
City	Vancouver
State/Province	BC
Postal Code	V6T 1Z3
Country [i]	CA

Inventor 3 Remove

Legal Name

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

Prefix	Given Name	Middle Name	Family Name	Suffix
	Teresa		Tsang	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	North Vancouver	Country of Residence [i]	CA

Mailing Address of Inventor:

Address 1	c/o University Industry Liaison Office
Address 2	103-6190 Argonomy Road

City	Vancouver	State/Province	BC
Postal Code	V6T 1Z3	Country [i]	CA

Inventor 4 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Zhibin		Liao	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	Adelaide	Country of Residence [i]	AU

Mailing Address of Inventor:

Address 1	c/o University Industry Liaison Office
Address 2	103-6190 Argonomy Road

City	Vancouver	State/Province	BC
Postal Code	V6T 1Z3	Country [i]	CA

Inventor 5 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Amir		Abdi	

Residence Information (Select One) US Residency ◉ Non US Residency Active US Military Service

City	Vancouver	Country of Residence [i]	CA

Mailing Address of Inventor:

Address 1	c/o University Industry Liaison Office
Address 2	103-6190 Argonomy Road

City	Vancouver	State/Province	BC
Postal Code	V6T 1Z3	Country [i]	CA

PTO/AIA/14 (02-18)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	20995		
Email Address	efiling@knobbe.com	Add Email	Remove Email

Application Information:

Title of the Invention	ULTRASONIC IMAGE ANALYSIS		
Attorney Docket Number	CRBN001.002AUS	**Small Entity Status Claimed**	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	13	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	20995		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	PCT/CA2019/051192	2019-08-28
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Claims benefit of provisional	62/725913	2018-08-31

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

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If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

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● Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.	Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

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Organization Name	The University of British Columbia		
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
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Signature	/Keith M. Lim/			Date (YYYY-MM-DD)	2019-08-30
First Name	Keith	Last Name	Lim	Registration Number	68,912

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	CRBN001.002AUS
	Application Number	
Title of Invention	ULTRASONIC IMAGE ANALYSIS	

This collection of information is required by 37 CFR 1.76. 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 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet 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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ULTRASONIC IMAGE ANALYSIS

RELATED APPLICATION

This application is a continuation of International Application No. PCT/CA2019/051192, filed on August 28, 2019, and claims the benefit of U.S. Provisional Application No. 62/725,913 entitled "ULTRASONIC IMAGE ANALYSIS", filed on August 31, 2018, both of which are hereby incorporated by reference herein in their entirety.

BACKGROUND

1. Field

Embodiments of this disclosure relate to ultrasonic image analysis and more particularly to ultrasonic image analysis for determining image quality and image properties.

2. Description of Related Art

Accurate diagnosis in ultrasound requires high quality ultrasound images, which may need to show or contain different specific features and structures depending on various properties of the images. Some ultrasound systems may not provide feedback to operators regarding quality of the image and/or other image properties. Inexperienced ultrasound operators may have a great deal of difficulty using such known systems to recognize features in the ultrasound images and thus can fail to capture diagnostically relevant ultrasound images.

SUMMARY

In accordance with various embodiments, there is provided a computer-implemented method of facilitating ultrasonic image analysis of a subject. The method involves receiving signals representing a set of ultrasound images of the subject, deriving one or more extracted feature representations from the set of ultrasound images, determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality

assessment of the set of ultrasound images, determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

The image property may be a view category.

Deriving the one or more extracted feature representations from the ultrasound images may involve, for each of the ultrasound images, deriving a first feature representation associated with the ultrasound image.

Deriving the one or more extracted feature representations may involve, for each of the ultrasound images, inputting the ultrasound image into a commonly defined first feature extracting neural network to generate the first feature representation associated with the ultrasound image.

Deriving the one or more extracted feature representations may involve concurrently inputting each of a plurality of the ultrasound images into a respective implementation of the commonly defined first feature extracting neural network.

The commonly defined first feature extracting neural network may include a convolutional neural network.

Deriving the one or more extracted feature representations may involve inputting the first feature representations into a second feature extracting neural network to generate respective second feature representations, each associated with one of the ultrasound images. The one or more extracted feature representations may include the second feature representations.

The second feature extracting neural network may be a recurrent neural network.

Determining the quality assessment value may involve inputting the one or more extracted feature representations into a quality assessment value specific neural network and determining the image property may involve inputting the one or more extracted feature representations into an image property specific neural network.

Inputting the one or more extracted feature representations into the quality assessment value specific neural network may involve inputting each of the one or more extracted feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork and inputting the one or more extracted feature representations into the image property determining neural network may involve inputting each of the one or more extracted feature representations into an implementation of a commonly defined image property specific neural network.

Producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images may involve producing signals for causing a representation of the quality assessment value and a representation of the image property to be displayed by at least one display in association with the set of ultrasound images.

In accordance with various embodiments, there is provided a computer-implemented method of training one or more neural networks to facilitate ultrasonic image analysis. The method involves receiving signals representing a plurality of sets of ultrasound training images, receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images, receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images, and training a neural network, the training comprising,

for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network.

Each of the image properties may be a view category.

The neural network may include a feature extracting neural network, an image property specific neural network, and a quality assessment value specific neural network. The feature extracting neural network may be configured to take an input set of the plurality of sets of ultrasound training images as an input and to output one or more extracted feature representations. The image property specific neural network may be configured to take the one or more extracted feature representations as an input and to output a representation of an image property associated with the input set of ultrasound training images. The quality assessment specific neural network may be configured to take the one or more extracted feature representations as an input and to output a quality assessment value associated with the input set of ultrasound training images.

The feature extracting neural network may be configured to, for each of the ultrasound training images included in the input set of ultrasound training images, derive a first feature representation associated with the ultrasound image.

The feature extracting neural network may include, for each of the ultrasound images included in the input set of ultrasound training images, a commonly defined first feature extracting neural network configured to take as an input the ultrasound training image and to output a respective one of the first feature representations.

More than one implementation of the commonly defined first feature extracting neural networks may be configured to concurrently generate the first feature representations.

The commonly defined first feature extracting neural network may be a convolutional neural network.

The feature extracting neural network may include a second feature extracting neural network configured to take as an input the first feature representations and to output respective second feature representations, each associated with one of the ultrasound images included in the input set of ultrasound training images and the one or more extracted feature representations may include the second feature representations.

The second feature extracting neural network may be a recurrent neural network.

In accordance with various embodiments, there is provided a system for facilitating ultrasonic image analysis including at least one processor configured to perform any of the above methods.

In accordance with various embodiments, there is provided a non-transitory computer readable medium having stored thereon codes which when executed by at least one processor cause the at least one processor to perform any of the above methods.

In accordance with various embodiments, there is provided a system for facilitating ultrasonic image analysis, the system including means for receiving signals representing a set of ultrasound images of the subject, means for deriving one or more extracted feature representations from the set of ultrasound images, means for determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images, means for determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and means for producing signals representing the quality

assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

In accordance with various embodiments, there is provided a system for training one or more neural networks to facilitate ultrasonic image analysis, the system including means for receiving signals representing a plurality of sets of ultrasound training images, means for receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images, means for receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images, and means for training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network.

Other aspects and features of embodiments of the disclosure will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the disclosure in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the disclosure,

Figure **1** is a schematic view of a system for facilitating ultrasonic image analysis of a subject according to various embodiments of the disclosure;

Figure **2** is a schematic view of an image analyzer of the system shown in Figure **1** including a processor circuit in accordance with various embodiments of the disclosure;

Figure **3** is a flowchart depicting blocks of code for directing the analyzer of the system shown in Figure **1** to perform image analysis functions in accordance with various embodiments of the disclosure;

Figure **4** is a representation of an exemplary neural network that may be used in the system shown in Figure **1** in accordance with various embodiments of the disclosure;

Figure **5** is a representation of part of the neural network shown in Figure **4** in accordance with various embodiments of the disclosure;

Figure **6** is a representation of part of the neural network shown in Figure **4** in accordance with various embodiments of the disclosure;

Figure **7** is a representation of part of the neural network shown in Figure **4** in accordance with various embodiments of the disclosure;

Figure **8** is a representation of part of the neural network shown in Figure **4** in accordance with various embodiments of the disclosure;

Figure **9** is a representation of part of the neural network shown in Figure **4** in accordance with various embodiments of the disclosure;

Figure **10** is a representation of a display that may be provided by the system shown in Figure **1** in accordance with various embodiments of the disclosure;

Figure **11** is a schematic view of a neural network trainer that may be included in the system shown in Figure **1** in accordance with various embodiments of the disclosure;

Figure **12** is a flowchart depicting blocks of code for directing the trainer shown in Figure **11** to perform neural network training functions in accordance with various embodiments of the disclosure; and

Figure **13** is a timing diagram representing thread timing that may be used in the system shown in Figure **1** in accordance with various embodiments of the disclosure.

DETAILED DESCRIPTION

Referring to Figure **1**, there is provided a system **10** for facilitating ultrasonic image analysis of a subject according to various embodiments. The system **10** includes a computer-implemented image analyzer **14** in communication with an ultrasound machine **16** having a transducer **20**. In various embodiments, the analyzer **14** may include a display **18**. In some embodiments, the analyzer **14** may be implemented as a mobile device, for example.

In various embodiments, the system **10** may provide feedback to an operator of the ultrasound machine **16** regarding quality of the ultrasound images being captured and other image properties. For example, in some embodiments, the system **10** may provide real-time or near real-time feedback to the operator in the form of a view category or classification and image quality estimation. In various embodiments, this may allow the operator to capture ultrasound images that facilitate more accurate analysis, which may in some embodiments allow more accurate diagnosis of a patient acting as the subject of the analysis.

In some embodiments, for example, by providing real-time or near real-time feedback to the operator, the system **10** may be used to facilitate capturing high quality images for cardiac ultrasound imaging wherein specific features and structures may need to be imaged. The required features and structures in cardiac

ultrasound imaging may depend on which of the **14** standard cardiac views the operator is attempting to acquire and so real-time or near real-time feedback that provides both a quality assessment value and a view category for the images the operator is capturing may be particularly helpful. In some embodiments, by providing real-time or near real-time feedback to the operator, the system **10** may allow inexperienced operators to more easily recognize the specific features and structures required of various views and thus the system **10** may be able to capture diagnostically relevant sets of ultrasound images or heart cines.

In various embodiments, the system **10** may be particularly useful because some of the view categories for ultrasound imaging may be quite similar to an inexperienced eye and switching between them may require precise adjustments of the probe's position and orientation. In various embodiments, the system **10** may reduce the adverse effect of inter-operator variability on the quality of the acquired ultrasound images. In some embodiments, the system **10** may do this by providing the operator with real-time or near real-time feedback of both view classification and image quality.

In various embodiments, this may be done through the use of a deep learning neural network, which may, for example, be capable of simultaneously determining which view category of fourteen (**14)** possible view categories the captured images fall into and determining a quality assessment value acting as a quality estimation score. In various embodiments, the architecture of the neural network implemented by the analyzer **14** may allow the analyzer to be implemented by a device that does not require an extremely high computing power, such as, for example an application on a mobile device or running on an off-the-shelf mobile device with the result being that the analyzer **14** may be portable and/or cost effective. In some embodiments, by combining quality assessment and another image property assessment, such as view categorization, a highly shared neural network may yield faster processing time compared to using a separate quality assessment and image property assessment, such as view categorization. In

some embodiments, by combining quality assessment and another image property assessment, such as view categorization, the joint training of the two modalities may prevent the neural network from overfitting the label from either modality. In some embodiments, by combining quality assessment and another image property assessment, such as view categorization, there may be cost savings since a single model needs to be maintained rather than multiple separate models.

Referring now to Figure **1**, use of the system **10** will be discussed in accordance with various embodiments. In use, the ultrasound machine **16** and transducer **20** may be controlled by an operator to send and receive ultrasound signals to and from the subject via the transducer **20**, to produce ultrasound image representations of the subject. For example, in some embodiments, the subject may be a person or patient. In some embodiments, the transducer **20** may be manipulated such that the ultrasound machine **16** produces ultrasound images of a heart of the person, for example.

In some embodiments, a representation of the ultrasound images may be transmitted to the analyzer **14**. In some embodiments, the system **10** may include a frame grabber configured to capture raw video output from the ultrasound machine **16** and to transmit a serial data stream representing a set of ultrasound images to the analyzer **14**. For example, in some embodiments, the frame grabber may be configured to receive its input directly from a DVI port of the ultrasound machine **16**, using an Epiphan AV.IO frame grabber, for example, to capture and convert the raw video output to a serial data stream. In some embodiments, the frame grabber output may be adapted from USB-A to USB-C with an On-The-Go (OTG) adapter, allowing the frame grabber to pipe video output from the ultrasound machine **16** directly into the analyzer **14**. As described below, the analyzer **14** may run or implement a neural network which is configured to process the video output received from the frame grabber. In some embodiments, the analyzer **14** may use TensorFlow Java inference interface, for example.

In some embodiments, referring to Figure **1**, the analyzer **14** may receive signals representing a set of ultrasound images of the subject. For example, in various embodiments, the analyzer **14** may receive ultrasound images from a frame grabber in communication with the ultrasound machine **16** and the analyzer **14**. In various embodiments, the set of ultrasound images received may represent a video or cine and may be a temporally ordered set of ultrasound images. In some embodiments, the set of ultrasound images received may represent an echocardiographic cine, for example, showing a patient's heart over time.

The analyzer **14** may then derive one or more extracted feature representations from the received set of ultrasound images. In some embodiments, the analyzer **14** may implement a neural network including a feature extracting neural network and the analyzer **14** may input the set of ultrasound images into the feature extracting neural network in order to derive the one or more extracted feature representations.

The analyzer **14** may then determine, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images. In some embodiments, the analyzer **14** may input the one or more extracted feature representations into a quality assessment value specific neural network in order to determine the quality assessment value. In some embodiments, a neural network including the feature extracting neural network and the quality assessment specific neural network may have been previously trained such that the quality assessment value determined by the analyzer **14** may represent an assessment of suitability of the received set of ultrasound images for quantified clinical measurement of anatomical features.

The analyzer **14** may also determine, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images. In some embodiments, the image property may be a view category, for example. Accordingly, in some embodiments, the analyzer **14** may input the one

or more extracted feature representations into a view category specific neural network in order to determine a view category within which the set of ultrasound images are determined to fall. In some embodiments, the neural network including the feature extracting neural network and the view category specific neural network may have been previously trained such that the view category determined by the analyzer **14** may represent the category of view represented by the set of ultrasound images.

The analyzer **14** may then produce signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images. In some embodiments, the analyzer **14** may produce signals for causing a representation of the quality assessment value and a representation of the view category to be displayed by the display **18** in association with the set of ultrasound images. For example, the classified view and its associated quality score may be displayed in a graphical user interface (GUI) on the display **18** as feedback to the operator.

In various embodiments, this near real-time or real-time feedback to the operator may help the operator improve their skills and/or improve image quality for subsequently captured images. For example, in some embodiments, the operator may, in response to viewing a low-quality assessment value or undesired view category on the display **18**, adjust positioning of the transducer and/or adjust image capture parameters, such as, for example, depth, focus, gain, frequency, and/or another parameter which may affect image quality, and/or the view category of the images being captured. In some embodiments, the operator may make such adjustments until a high-quality assessment value and/or a desired view category is displayed by the display **18**, for example, at which point the operator may be confident that the images captured are suitable for subsequent quantified clinical measurement of anatomical features and/or to assist in diagnosing a medical condition of the subject, for example.

In some embodiments, the analyzer **14** may produce signals representing the quality assessment value and the image property in association with the set of ultrasound images for facilitating automatic adjustment, using another neural network or machine learning, of image capture parameters to maximize quality assessment values. For example, in some embodiments, another neural network may use the quality assessment value and image property as inputs for generating control signals for adjusting image capture parameters to maximize quality assessment values.

Analyzer - Processor Circuit

Referring now to Figure **2**, a schematic view of the analyzer **14** of the system **10** shown in Figure **1** according to various embodiments is shown. In various embodiments, the analyzer **14** may be implemented as a mobile device, such as a Samsung™ Galaxy S**8**+™ running an operating system, such as Android™, for example.

Referring to Figure **2**, the analyzer **14** includes a processor circuit including an analyzer processor **100** and a program memory **102**, a storage memory **104**, and an input/output (I/O) interface **112**, all of which are in communication with the analyzer processor **100**. In various embodiments, the analyzer processor **100** may include one or more processing units, such as for example, a central processing unit (CPU), a graphical processing unit (GPU), and/or a field programmable gate array (FPGA). In some embodiments, any or all of the functionality of the analyzer **14** described herein may be implemented using one or more FPGAs.

The I/O interface **112** includes an interface **120** for communicating with the ultrasound machine **16** or a frame grabber in communication with the ultrasound machine **16** and an interface **130** for communicating with the display **18**. In some embodiments, the I/O interface **112** may also include an interface **124** for facilitating networked communication through a network **126**. In some embodiments, any or all of the interfaces **120**, **130**, or **124** may facilitate a wireless or wired communication.

In some embodiments, the I/O interface **112** may include a network interface device or card with an input/output for connecting to the network **126**, through which communications may be conducted with devices connected to the network **126**, such as the neural network trainer (as shown at **502** in Figure **11**), for example. In some embodiments, the network **126** may be a private network to which both the analyzer **14** and the trainer **502** are connected. In some embodiments the network **126** may be a public network, such as the Internet, for example.

In some embodiments, each of the interfaces shown in Figure **2** may include one or more interfaces and/or some or all of the interfaces included in the I/O interface **112** may be implemented as combined interfaces or a single interface.

In some embodiments, where a device is described herein as receiving or sending information, it may be understood that the device receives signals representing the information via an interface of the device or produces signals representing the information and transmits the signals to the other device via an interface of the device.

Processor-executable program codes for directing the analyzer processor **100** to carry out various functions are stored in the program memory **102**. Referring to Figure **2**, the program memory **102** includes a block of codes **170** for directing the analyzer **14** to perform ultrasound image analysis functions. In this specification, it may be stated that certain encoded entities such as applications or modules perform certain functions. Herein, when an application, module or encoded entity is described as taking an action, as part of, for example, a function or a method, it will be understood that at least one processor (e.g., the analyzer processor **100**) is directed to take the action by way of programmable codes or processor-executable codes or instructions defining or forming part of the application.

The storage memory **104** includes a plurality of storage locations including location **140** for storing ultrasound image data, location **142** for storing first extracted feature data, location **144** for storing second extracted feature data, location **150** for storing determined quality assessment value data, location **152** for storing determined view category data, location **154** for storing first feature extracting neural network parameter data, location **156** for storing second feature extracting neural network parameter data, location **158** for storing quality assessment value specific neural network parameter data, location **160** for storing view category specific neural network parameter data, and location **162** for storing highest quality image data. In various embodiments, the plurality of storage locations may be stored in a database in the storage memory **104**.

In various embodiments, the block of codes **170** may be integrated into a single block of codes or portions of the block of codes **170** may include one or more blocks of code stored in one or more separate locations in the program memory **102**. In various embodiments, any or all of the locations **140**, **142**, **144**, **150**, **152**, **154**, **156**, **158**, **160**, and **162** may be integrated and/or each may include one or more separate locations in the storage memory **104**.

Each of the program memory **102** and storage memory **104** may be implemented as one or more storage devices including random access memory (RAM), a hard disk drive (HDD), a solid-state drive (SSD), a network drive, flash memory, a memory stick or card, any other form of non-transitory computer-readable memory or storage medium, and/or a combination thereof. In some embodiments, the program memory **102**, the storage memory **104**, and/or any portion thereof may be included in a device separate from the analyzer **14** and in communication with the analyzer **14** via the I/O interface **112**, for example.

In various embodiments, other device components described herein, such as memory, program memory, blocks of code, storage memory, locations in memory,

and/or I/O interfaces, may be implemented generally similarly to as described above for the analyzer **14**.

Image analysis

Referring now to Figure **3**, a flowchart depicting blocks of code for directing the analyzer processor **100** shown in Figure **2** to perform ultrasonic image analysis functions in accordance with various embodiments is shown generally at **200**. The blocks of code included in the flowchart **200** may be encoded in the block of codes **170** of the program memory **102** shown in Figure **2** for example.

Referring to Figure **3**, the flowchart **200** begins with block **202** which directs the analyzer processor **100** shown in Figure **2** to receive signals representing a set of ultrasound images of a subject. In various embodiments, block **202** may direct the analyzer processor **100** to receive the set of ultrasound images from the ultrasound machine **16** and to store the received set of ultrasound images in the location **140** of the storage memory **104**. In some embodiments, block **202** may direct the analyzer processor **100** to receive the set of ultrasound images from a frame grabber in communication with the ultrasound machine **16** and the analyzer **14**. In some embodiments, the set of ultrasound images may be a temporally ordered set of ultrasound images representing a video or cine of the subject. In some embodiments, the subject may be a heart of a patient and the set of ultrasound images may be referred as an echocine. Each image of the set of ultrasound images may be referred to herein as a frame.

In some embodiments, block **202** may direct the analyzer processor **100** to pre-process raw ultrasound images received from the ultrasound machine **16** and/or to select a subset of the ultrasound images received from the ultrasound machine **16** as the set of ultrasound images to be analyzed. For example, in some embodiments, block **202** may direct the analyzer processor **100** to receive raw ultrasound images at a resolution of **640**x**480** at **30** Hz. Block **202** may direct the analyzer processor **100** to crop the raw frames down to include only the ultrasound

beam, the boundaries of which may be adjustable by the user. The cropped data may be resized down to **120**x**120** to match input dimensions of the neural network implemented by the analyzer **14**. In some embodiments, block **202** may direct the analyzer processor **100** to perform a simple contrast enhancement step to mitigate quality degradation introduced by the frame grabber.

In some embodiments, block **202** may direct the analyzer processor **100** to store a subset of the received ultrasound images in the location **140** of the storage memory **104**. For example, in some embodiments, block **202** may direct the analyzer processor **100** to store ten **120**x**120** ultrasound images in the location **140** of the storage memory **104** and those ten ultrasound images may act as the received set of ultrasound images. In some embodiments, block **202** may direct the analyzer processor **100** to store the most recent ultrasound images in the location **140** of the storage memory **104**. In some embodiments, a copy of the full-resolution data may also be stored in the storage memory **104** for later expert evaluation.

Referring to Figure **3**, after block **202** has been executed, the flowchart continues to block **204**. In various embodiments, execution of blocks **204**, **206** and **208** of the flowchart **200** may result in the analyzer processor **100** being directed to input the received set of ultrasound images into a neural network **300** shown in Figure **4**, to generate an output of a quality assessment value and an image property, which in some embodiments may be a view category. The parameters defining the neural network **300** may be stored in the storage memory **104** and may have been previously determined during neural network training, which is described in further detail in accordance with various embodiments below.

Referring to Figure **3**, block **204** directs the analyzer processor **100** to derive one or more extracted feature representations from the set of ultrasound images received at block **202**. In some embodiments, deriving the one or more extracted feature representations may involve deriving a first feature representation and then

deriving a second feature representation based on the first feature representation for each ultrasound image.

In various embodiments, block **204** may direct the analyzer processor to, for each of the set of ultrasound images stored in the location **140** of the storage memory **104**, derive a first feature representation associated with the ultrasound image. In some embodiments, block **204** may direct the analyzer processor **100** to derive the first feature representations by inputting each image of the set of ultrasound images (shown at **302** in Figure **4**) into a commonly defined first feature extracting neural network, instances of which are shown at **304**, **306**, and **308** of the neural network **300** shown in Figure **4**, for example. In some embodiments, block **204** may direct the analyzer processor **100** to input each of the ten ultrasound images stored in the location **140** of the storage memory **104** into one of the commonly defined first feature extracting neural networks **304**, **306**, and **308**.

In some embodiments parameters defining the commonly defined first feature extracting neural network may be stored in the location **154** of the storage memory **104** and block **204** may direct the analyzer processor **100** to retrieve the parameters from the location **154** of the storage memory **104**. In various embodiments, because the first feature extracting neural networks (e.g., **304**, **306**, and **308**) are commonly defined, this may save memory in the storage memory **104**.

In some embodiments, the commonly defined first feature extracting neural networks (e.g., **304**, **306**, and **308**) may include convolutional neural networks. For example, in some embodiments, each of the neural networks **304**, **306**, and **308** may be implemented as a seven-layer DenseNet model as described in Huang, G., Liu, Z., Weinberger, K.Q., van der Maaten, L.: Densely connected convolutional networks. In: IEEE CVPR. vol. **1-2**, p. **3** (**2017**). In some embodiments, the DenseNet model implementing the commonly defined first feature extracting neural networks **304**, **306**, and **308** may use the following hyper-parameters. First,

the DenseNet may have one convolution layer with sixteen **3**x**3** filters, which turns gray-scale (**1**-channel) input images to sixteen channels. Then, the DenseNet may stack three dense blocks, each followed by a dropout layer and an average-pooling layer with filter size of **2**x**2**. In various embodiments, after the third dense block, the average-pooling layer may be applied before the dropout layer. Each dense block may have exactly one dense-layer, which may include a sequence of batch-normalization layer (as per Ioffe, S., Szegedy, C.: Batch normalization: Accelerating deep network training by reducing internal covariate shift. In: Proceedings of the **32**nd International Conference on Machine Learning. pp. **448**-**456**. ICML'**15**, JMLR (**2015**), for example), a Rectified Linear layer (ReLU) (as per Nair, V., Hinton, G.E.: Rectified linear units improve restricted boltzmann machines. In: Proceedings of the **27**th international conference on machine learning (ICML-**10**). pp. **807**-**814** (**2010**), for example), a 2D convolution layer with **3**x**3** filters, a dropout layer, a concatenation layer, another 2D convolution layer, another dropout layer, and an average pooling layer.

A batch normalization layer may first normalize the input features by the mean and standard deviation of the features themselves. For each channel (the second dimension) of input, the features from all training samples within a mini-batch may be jointly used to compute the mean and standard deviation values, hence the name *batch* normalization. After the normalization, the features may be rescaled and shifted by a linear transformation operation. A ReLU activation layer may be used to provide a non-linear transformation to the features. The ReLU activation function is noted as:

$$\mathrm{ReLU(x)} = \max(0, x),$$

Where x denotes any single element of the input feature vector. A concatenation layer may concatenate features at a given dimension, where in this case, the features may be concatenated at the channel (the second) dimension. A dropout layer may omit a percentage of feature values according to a given value between 0 and 1, which is a regularization technique to reduce overfitting towards the training data.

An exemplary implementation of portions of the commonly defined first feature extracting neural networks including dense blocks **1**, **2**, and **3** in accordance with various embodiments is shown at **310**, **312**, and **314** in Figures **5**, **6**, and **7,** respectively.

In some embodiments, the commonly defined first feature extracting neural networks (e.g., **304**, **306**, and **308** shown in Figure **4**) may be each configured to extract features that are encodings of image patterns of a single echo frame which are correlated with the image quality and view category of the single input echo frame. In some embodiments, these features (encodings or mappings) may be in the form of a vector of real-valued numbers (after the *flatten* operation), and each number may be considered as the level of presence of a specific spatial pattern in the input echo frame. In various embodiments, alternative or additional feature extracting functions and/or neural networks may be used to extract features of the input set of ultrasound images.

In some embodiments, more than one of the commonly defined first feature extracting neural networks may be run concurrently. For example, in some embodiments, block **204** may direct the analyzer processor **100** to run three of the commonly defined first feature extracting neural networks as three identical Convolutional Neural Networks (CNN-**1**, CNN-**2**, or CNN-**3**) in separate threads at the same time in order to prevent lag during particularly long inference times.

In various embodiments, the first feature representations (e.g., as shown at **320**, **322**, and **324** shown in Figure **4**) output by the commonly defined first feature extracting neural networks **304**, **306**, and **308** may act as first feature representations of the ultrasound images included in the set of ultrasound images received at block **202**. In some embodiments, for example, the first feature representations may each represent a tensor having dimensions **14**x**14**x**34** which

is flattened to a tensor having length **6664** such that it can be input into a second feature extracting neural network **340**.

Block **204** may direct the analyzer processor to store the extracted first feature representations in the location **142** of the storage memory **104**, for example, in a feature buffer which may be shared between all three threads. Once all of the ultrasound images included in the set of ultrasound images have been input to an instance of the commonly defined first feature extracting neural network, block **204** may direct the analyzer processor **100** to input the stored first feature representations into a second feature extracting neural network **340** shown in Figure **4** to generate respective second feature representations, each associated with one of the ultrasound images. In some embodiments, the second feature representations generated by the second feature extracting neural network **340** may act as the one or more extracted feature representations derived by block **204** of the flowchart **200** shown in Figure **3**.

Referring to Figure **4**, in some embodiments, the second feature extracting neural network **340** may include a plurality of recurrent neural networks (RNNs) (e.g., **342**, **344**, and **346** shown in Figure **4**). In some embodiments, the RNNs may each be implemented using a long short term memory module (LSTM). In some embodiments parameters defining the second feature extracting neural network **340** may be stored in the location **156** of the storage memory **104** and block **204** may direct the analyzer processor **100** to retrieve the parameters from the location **156** of the storage memory **104**. Referring to Figure **4**, each RNN (e.g., **342**, **344**, and **346** shown in Figure **4**) may output a respective second feature representation, which may be used as an input for further processing. In various embodiments, each of the second feature representations may be a tensor having a length of **128**.

In some embodiments, the LSTM layer (which is a type of RNN layer) may operate on the outputs of the Densenet networks of multiple frames. As a result, in some

embodiments, the features extracted by the LSTM networks may be encodings of both spatial and temporal patterns of a multitude of echo frames. The sequence of frames whose spatial and temporal patterns contribute to the extracted features may depend on the type of RNN layer included in the second feature extracting neural network **340**. In some embodiments, conventional RNN architectures may look backward in time and extract features from the previous N (e.g. N=**10**) frames. However, in various embodiments, other types of RNNs may be considered/used (i.e. bidirectional RNN) where features may be extracted from the collective of previous and future frames. In various embodiments, the number of frames included in the feature extraction of the RNNs (such as LSTM) could be N=**10** or more. In some embodiments, the features may be in the form of real-valued numbers (for example, the features may usually be between -**1** and **1** as the activation function of RNN is usually hyperbolic tangent). In some embodiments, each number may be considered as representing a level of presence of a specific spatial and temporal pattern.

In various embodiments, block **204** may direct the analyzer processor **100** to store the second feature representations in the location **144** of the storage memory **104**.

Referring to Figure **3**, in various embodiments, blocks **206** and **208** may be executed sequentially or in parallel. Block **206** directs the analyzer processor **100** to determine based on the derived one or more extracted feature representations from block **202**, a quality assessment value representing a quality assessment of the set of ultrasound images.

Block **206** may direct the analyzer processor **100** to retrieve the second feature representations from the location **144** of the storage memory **104**, the second feature representations acting as the one or more extracted feature representations. Block **206** may direct the analyzer processor **100** to use the second feature representations as inputs to a quality assessment value specific neural network configured to produce as an output a representation of a quality

assessment value. In some embodiments, block **206** may direct the analyzer processor **100** to input each of the second feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork (e.g., **362**, **364**, and **366**) to generate a quality assessment value for each of the input second feature representations. Referring to Figure **4**, in various embodiments the commonly defined quality assessment value specific neural subnetworks may each be defined by the same neural network parameters. In some embodiments, parameters defining the quality assessment value specific neural subnetworks may be stored in the location **158** of the storage memory **104** and block **206** may direct the analyzer processor **100** to retrieve the parameters from the location **158** of the storage memory **104**.

In various embodiments, each of the commonly defined quality assessment value specific neural subnetworks may apply logistic regression to the input second feature representations to generate a scalar value representing quality of an ultrasound image. Referring to Figure **8**, there is shown a detailed representation of the quality assessment value specific neural subnetwork **362** in accordance with various embodiments. The quality assessment value specific neural subnetwork **362** shown in Figure **8** is represented in a simplified manner as it may apply to a single cine (i.e., for providing an output having dimension **1**). In various embodiments, each of the commonly defined quality assessment value specific neural subnetworks may be defined by the same neural network parameters.

Referring to Figure **8**, in some embodiments, the quality assessment value specific neural subnetwork **362** may include input nodes **380** for holding the output of the second feature extracting neural network **342**. In some embodiments, the input nodes **380** may hold a **1**x**128** feature tensor, for example. In some embodiments, input nodes **364** may be connected to a feature node **382**, which may, for example, hold a **1**x**1** feature tensor acting as an input for a logistic regression function **384**. The logistic regression function **384** may be connected to an output node **386**, which may include a **1**x**1** probability tensor holding an output of the quality

assessment value specific neural subnetwork **362**. In some embodiments, output node **386** may hold a value in the range of [**0**,**1**], where a value of **0** corresponds to a bad quality and a value of **1** corresponds to perfect quality.

Block **206** may direct the analyzer processor **100** to determine an average or mean of the quality assessment values output by the quality assessment value specific determining neural subnetworks and to store the average quality assessment value in the location **150** of the storage memory **104**.

Referring back to Figure **3**, block **208** directs the analyzer processor **100** to determine, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images. In some embodiments, the image property may be a view category. In some embodiments, block **208** may direct the analyzer processor **100** to retrieve the second feature representations from the location **144** of the storage memory **104**, the second feature representations acting as the one or more extracted feature representations. Block **208** may direct the analyzer processor **100** to use the second feature representations as inputs to a view category specific neural network configured to produce as an output a representation of a view category. In some embodiments, block **208** may direct the analyzer processor **100** to input each of the second feature representations into an implementation of a commonly defined view category specific neural subnetwork (e.g., **372**, **374**, and **376**) to determine a view category for each of the input second feature representations.

Referring to Figure **4**, in various embodiments the commonly defined view category specific neural subnetworks may each be defined by the same neural network parameters. In some embodiments parameters defining the view category specific neural network may be stored in the location **160** of the storage memory **104** and block **208** may direct the analyzer processor **100** to retrieve the parameters from the location **160** of the storage memory **104**.

In various embodiments, each of the commonly defined view category specific neural subnetworks may apply a softmax to the input second feature representations to generate a probability vector wherein each position in the vector corresponds to a view category and the value stored therein represents a probability that the ultrasound image is in the view category corresponding to the vector position. For example, where there are fourteen (**14**) possible view categories, the output of the view category specific neural subnetwork **372** may be a **14**-element length probability vector. In various embodiments, each position in the output probability vector may represent a determined probability that the input set of ultrasound images depicts a particular view category, such as, for example, one chosen from AP**2**, AP**3**, AP**4**, AP**5**, PLAX, RVIF, PSAXA, PSAXM, PSAXPM, PSAXAP, SC**4**, SC**5**, IVC, and SUPRA Referring to Figure **9**, there is shown a detailed representation of the view category specific neural subnetwork **372** in accordance with various embodiments. The view category specific neural subnetwork **372** shown in Figure **9** is represented in a simplified manner as it may apply to a single cine case (i.e., for providing an output having dimension **1**x**14**). In various embodiments, each of the commonly defined view category specific neural subnetworks may be defined by the same neural network parameters.

Referring to Figure **9**, in some embodiments, view category specific neural subnetwork **372** may include input nodes **388** for holding the output of the second feature extracting neural network **342**. In some embodiments, the input nodes **388** may hold a **1**x**128** feature tensor, for example. In some embodiments, input nodes **388** may be connected to feature nodes **390**, which may, for example, hold a **1**x**14** feature tensor acting as an input for a softmax function **392**. The softmax function **392** may be connected to an output node **394**, which may include a **1**x**14** probability tensor holding an output of the view category specific neural subnetwork **372**. In some embodiments, output node **394** may hold values that are each in the range of [**0**,**1**] and the sum of the values may be equal to **1**.

Block **208** may direct the analyzer processor **100** to determine an average of the probability vectors output by the view category specific determining neural subnetworks and to store a representation of the view category associated with the vector position having the highest average probability in the location **152** of the storage memory **104**.

Referring back to Figure **3**, block **210** directs the analyzer processor **100** to produce signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images. In some embodiments, block **210** may direct the analyzer processor **100** to produce signals for causing a representation of the quality assessment value and a representation of the image property to be displayed by the display **18** in association with the set of ultrasound images. For example, in some embodiments, block **210** may direct the analyzer processor **100** to retrieve the quality assessment value from the location **150** of the storage memory **104** and to retrieve the view category from the location **152** of the storage memory **104** and to transmit signals to the display **18** via the interface **130** of the I/O interface **112** shown in Figure **2**, representing the quality assessment value and the view category for causing the graphical user interface **400** shown in Figure **10** to be displayed by the display **18**.

Referring to Figure **10**, the graphical user interface **400** includes a bar indicator **402** showing a graphical representation of the quality assessment value and an indicator **404** representing the view category in association with a representation of an ultrasound image **406** included in the set of ultrasound images. In various embodiments, the bar indicator **402** may include a fill portion **408** which grows in length as the quality assessment value increases. In some embodiments, the fill portion **408** may change color depending on the quality assessment value. In various embodiments, an operator viewing the displayed representations of both the quality assessment value and the view category, may be able to use this

information to recognize the specific features and structures required of various views and/or to capture diagnostically relevant heart cines.

In various embodiments, the flowchart **200** shown in Figure **3** may be executed repeatedly and/or continuously to update the quality assessment value bar indicator **402** and view category indicator **404** of the graphical user interface **400** shown in Figure **10**.

Neural network training

As discussed above, in various embodiments, the analyzer **14** may use a neural network **300** shown in Figure **4** which includes various subnetworks. In various embodiments, the parameters defining the neural network **300** may be stored in the storage memory **104** and may have been previously determined during neural network training. For example, in some embodiments, the system **10** shown in Figure **1** may include a neural network trainer configured to train the neural network **300**.

Referring to Figure **11**, a schematic view of a neural network trainer **502** which may be included in the system **10** shown in Figure **1** in various embodiments is shown. In various embodiments, the neural network trainer **502** may be incorporated in one or more computers, for example.

Referring to Figure **11**, in various embodiments, the neural network trainer **502** includes a processor circuit including a trainer processor **600** and a program memory **602**, a storage memory **604**, and an I/O interface **612**, all of which are in communication with the trainer processor **600**.

The I/O interface **612** includes an interface **620** for communicating with a training data source **504**. In some embodiments, the interface **620** may provide a connection to a network to which the training data source **504** is connected such that communication between the training data source **504** and the trainer **502** is

facilitated. For example, in some embodiments, the training data source **504** may include a server computer for storing and archiving medical electronic images and associated image properties, such as, for example, an archive device. In some embodiments, the I/O interface **612** also includes an interface **624** for facilitating networked communication with the analyzer **14** through the network **126**. In some embodiments, the interface **620** may provide a connection to the network **126** and the training data source **504** may also be connected to the network **126**.

Processor-executable program codes for directing the trainer processor **600** to carry out various functions are stored in the program memory **602**. The program memory **602** includes a block of codes **660** for directing the neural network trainer **502** to perform neural network training functions.

The storage memory **604** includes a plurality of storage locations including location **640** for storing training data, location **642** for storing first feature extracting neural network data, location **644** for storing second feature extracting neural network parameter data, location **646** for storing quality assessment value specific neural network parameter data, and location **648** for storing view category specific neural network parameter data.

In various embodiments, the neural network trainer **502** may be configured to train the neural network **300** shown in Figure **4** based on a plurality of sets of ultrasound images, each set associated with a quality assessment value and an image property, such as a view category.

Referring now to Figure **12**, a flowchart depicting blocks of code for directing the trainer processor **600** shown in Figure **11** to perform neural network training to facilitate ultrasonic image analysis functions in accordance with various embodiments is shown generally at **700**. The blocks of code included in the flowchart **700** may be encoded in the block of codes **660** of the program memory **602** shown in Figure **11** for example.

Referring to Figure **12**, the flowchart **700** begins with block **702** which directs the trainer processor **600** shown in Figure **11** to receive signals representing a plurality of sets of ultrasound training images. In various embodiments, block **702** may direct the trainer processor **600** to receive the signals representing the plurality of sets of ultrasound training images from the training data source **504** via the interface **620** of the I/O interface **612** shown in Figure **11**. In various embodiments, block **702** may direct the trainer processor **600** to store the sets of ultrasound training images in the location **640** of the storage memory **604** of the trainer **502** shown in Figure **11**.

In some embodiments, each set of ultrasound images may be a temporally ordered set of ultrasound images representing a video or cine of a respective subject. In some embodiments, each subject may be a heart of a patient and each set of ultrasound images may be referred as an echocine.

Block **704** then directs the trainer processor **600** to receive signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images. In some embodiments, block **704** may direct the trainer processor **600** to receive the signals representing the quality assessment values from the training data source **504** via the interface **620** of the I/O interface **612** shown in Figure **11**. In various embodiments, the quality assessment values may have been previously provided to the training data source **504**. For example, in some embodiments, the quality assessment values may have been previously provided by an expert who has been trained to determine quality of the sets of ultrasound images. For example, in some embodiments, the quality assessment values may be values between **0**% and **100**% representing whether the set of ultrasound images are suitable for subsequent quantified clinical measurement of anatomical features and/or to assist in diagnosing a medical condition.

Block **704** may direct the trainer processor **600** to store the received quality assessment values in the location **640** of the storage memory **604**. For example, in some embodiments, block **704** may direct the trainer processor **600** to store each of the quality assessment values in association with the set of ultrasound images to which they apply.

Block **706** then directs the trainer processor **600** to receive signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images. In some embodiments, the image properties may each be a view category. In some embodiments, block **706** may direct the trainer processor **600** to receive signals representing view categories from the training data source **504** via the interface **620** of the I/O interface **612** shown in Figure **11**. In various embodiments, the view categories may have been previously provided to the training data source **504**. For example, in some embodiments, the view categories may have been previously provided by an expert who has been trained to determine view categories for the sets of ultrasound images. For example, in some embodiments, the subject imaged in the sets of ultrasound images may be a heart and the view categories may be chosen from the following views: AP**2**, AP**3**, AP**4**, AP**5**, PLAX, RVIF, PSAXA, PSAXM, PSAXPM, PSAXAP, SC**4**, SC**5**, IVC, and SUPRA.

Block **706** may direct the trainer processor **600** to store the received view categories in the location **640** of the storage memory **604**. For example, in some embodiments, block **706** may direct the trainer processor **600** to store each of the view categories in association with the set of ultrasound images to which they apply.

In various embodiments, the training data source **504** may send the sets of ultrasound images in association with the quality assessment values and the image properties and so blocks **702**, **704**, and **706** may be executed concurrently.

Block **708** then directs the trainer processor **600** to train a neural network, the training involving, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network. For example, in some embodiments, the neural network trained at block **708** may be the neural network **300** shown in Figure **4**.

Accordingly, block **708** may direct the trainer processor **600** to train the neural network **300** shown in Figure **4** using each of the sets of ultrasound images stored in the location **640** of the storage memory **604** as inputs and using each of the associated quality assessment values and view categories stored in the location **640** of the storage memory **604** as desired outputs when the associated set of ultrasound images are used as inputs.

In some embodiments, block **708** may direct the trainer processor **600** to train the neural network **300** shown in Figure **4** using batches. For example, in some embodiments, block **708** may direct the trainer processor **600** to randomly select **32** sets of ultrasound images or cine clips from the location **640** of the storage memory **604**, and block **708** may direct the trainer processor **600** to choose **10** consecutive ultrasound images or frames from each set to make a batch such that the batch is filed with **320** frames of images with a dimension or size of **120**x**120**x**1** (in various embodiments, the ultrasound image data may be grayscale and therefore the last channel may have **1** dimension). This batch may be considered an input tensor, with the tensor size is **32**x**10**x**120**x**120**x**1**. In various embodiments, the first dimension **32** may be called the batch size. In some embodiments, a large batch size may help with parallelizing the computation. In some embodiments, batch size may be any number as long as the memory permits and, in some embodiments, **32** may be chosen as the batch size for training.

Block **708** may direct the analyzer processor **100** to feed the input tensor to the neural network **300**, where each ultrasound image first goes through an instance of the commonly defined first feature extracting neural network or DenseNet feature extraction module. The output tensor of the commonly defined first feature extracting neural networks or DenseNet modules may be **32**x**10**xAxBxC, where "AxBxC" denotes the dimensionality of the output feature for each frame. In some embodiments, the output tensor may be of dimension **32**x**10**x**14**x**14**x**34**, for example.

Block **708** then directs the trainer processor **600** to flatten the output tensor into **32**x**10**x(A*B*C), or **32**x**10**x**6664** in some embodiments, for example, so that the second feature extracting neural network **340** (e.g., the LSTM module, in some embodiments) can process it. After the second feature extracting neural network **340** processes the **32**x**10**x(A*B*C) feature tensor, it may produce a **32**x**10**x**128** feature tensor, and block **708** may direct the trainer processor **600** to use the **32**x**10**x**128** feature tensor as inputs for both the quality assessment value specific neural network and view category specific neural network.

Block **708** may direct the trainer processor **600** to compare the predictions made within the quality assessment value specific neural network and view category specific neural network with the respective ground truths, or desired outputs. In various embodiments, the predictions may be compared to the quality assessment values and view categories stored in the location **640** of the storage memory **604**. An initial output of the view category specific neural network may be of dimension **32**x**10**x**14** (classes) and block **708** may direct the trainer processor **600** to determine a mean over the **10** frames for the initial output to generate a tensor of dimension **32**x**14**. An initial output of the quality assessment value specific neural network may be of dimension **32**x**10**x**1** and block **708** may direct the trainer processor **600** to determine a mean over the **10** frames for the initial output to generate a tensor of dimension **32**x**1**.

Block **708** may direct the trainer processor **600** to determine a difference between the view classification predictions (**32**x**14**) and the ground truth (as previously provided by an expert, for example), as measured by the cross-entropy loss function, which produces scalar values, i.e. **32**x**14**->**32**x**1**. In various embodiments, block **708** may direct the trainer processor **600** to average the **32**x**1** values into **1** scalar value representing how well the predictions match the ground truth labels. Similarly, for the quality estimation, the difference may be measured by the binary cross-entropy loss function, which is the cross-entropy loss function working on two classes (i.e., bad quality:**0**, excellent quality:**1**). This also produces a scalar value, i.e., **32**x**1**->**1** representing how well the predictions match the ground truth labels. In various embodiments, a low scalar value representing how well the predictions match the ground truth labels may mean better matching. In various embodiments, the differences may also or alternatively be measured by other types of loss functions such as, for example, an absolute difference loss function or a squared difference loss function.

Block **708** may direct the trainer processor **600** to add these two loss values together and to train the network based on these summed losses. Block **708** may direct the trainer processor **600** to use a back-propagation method, wherein block **708** directs the trainer processor **600** to compute the gradient with respect to the neural network or model parameters (i.e., the weights and bias in every layer) and the gradient is used to update the neural network or model parameters. In various embodiments, the updated parameters may be stored in the locations **642**, **644**, **646**, and **648** of the storage memory **604**.

In various embodiments the flowchart **700** may be executed many times in order to train the neural network **300** shown in Figure **4** adequately. For example, in some embodiments, the plurality of sets of ultrasound training images may include **13400** sets or echo cine clips, and the trainer **502** may be configured to run **100** epochs where each epoch runs through the entire training with batch size **32**.

Accordingly, in some embodiments, the flowchart **700** may be executed **13400**/**32**=**419** times per epoch and **41900** times in total over all of the epochs.

In various embodiments, by adding the loss values together to train the network based on these summed losses, the neural network **300** may be trained more quickly and may provide more accurate results than a neural network which is trained based on loss values provided only by looking at desired quality assessment values or based on loss values provided only by looking at desired view categories. In some embodiments, this may also or alternatively result in a compact neural network that may consume less memory and/or use less battery power for computation.

In some embodiments, the flowchart **700** may include a block for directing the trainer processor **600** to produce signals representing the trained neural network for causing the neural network to be used to predict a quality assessment value and a view category based on an input set of ultrasound images. For example, in some embodiments, a block of codes may direct the trainer processor **600** to transmit the neural network parameter information stored in the locations **642**, **644**, **646**, and **648** of the storage memory **604**, which defines the neural network **300** to the analyzer **14** via the interface **624** and the network **126**.

A block of codes included in the block **170** of the program memory **102** of the analyzer **14** shown in Figure **2** may direct the analyzer processor **100** to receive the neural network parameter information via the interface **124** of the I/O interface **112** and to store the neural network parameter information in the locations **154**, **156**, **158**, and **160** of the storage memory **104**.

Highest quality assessment value

Referring to Figure **3**, in some embodiments, flowchart **200** may include a block of codes for directing the analyzer processor **100** to store an ultrasound image associated with the highest quality assessment value for each view category.

In various embodiments the block may direct the analyzer processor **100** to, for each view category, update/replace an ultrasound image stored in the location **162** of the storage memory **104** such that the ultrasound image stored is an ultrasound image that is associated with the highest quality assessment value, for that view category.

In some embodiments, the block may be executed after blocks **206** and **208** of the flowchart **200** have been executed. Upon analysis of a first set of ultrasound images for a given view category, the block may direct the analyzer processor **100** to, after determining a quality assessment value for each of the ultrasound images included in the first set of ultrasound images and determining a view category for the set of ultrasound images, identify the ultrasound image associated with the highest determined quality assessment value and store the ultrasound image in association with the determined quality assessment value and the determined view category in the location **162** of the storage memory **104**.

Upon analysis of subsequent sets of ultrasound images for the view category, The block may direct the analyzer processor **100** to, for each determined quality assessment value, determine whether the quality assessment value is higher than the quality assessment value stored in association with the ultrasound image and the same view category in the location **162** of the storage memory **104**. The block may direct the analyzer processor **100** to, if the determined quality assessment value is higher than the stored quality assessment value, store the ultrasound image associated with the determined quality assessment in the location **162** of the storage memory **104** in association with the determined quality assessment value and the determined view category. In some embodiments, the block may direct the analyzer processor **100** to replace any previously stored quality assessment value and ultrasound image stored in the location **162** of the storage memory **104** in association with the determined view category with the determined quality assessment value and the associated ultrasound image. In various

embodiments, this may facilitate storage of ultrasound images associated with the highest determined quality assessment values, for each view category, in the location **162** of the storage memory **104**.

In various embodiments, an operator may not even know this is happening, but when it comes to review the high-quality cines afterwards, it may be a very useful tool to find the best quality images for each cine. In various embodiments, an operator may initiate a block of codes included in the program memory **102** for directing the analyzer processor **100** to later retrieve the ultrasound images stored in the location **162** of the storage memory and to produce signals representing the ultrasound images for causing the ultrasound images to be displayed by the display **18**. In various embodiments, in this way, the operator may easily view the best quality images for each view category.

Various embodiments

In some embodiments, a system generally similar to the system **10** shown in Figure **1** and discussed herein may use a neural network having additional and/or alternative architecture to the architecture of the neural network **300** shown in Figure **4** and discussed herein.

In some embodiments, the functionality provided by the quality assessment value specific neural network and the image property specific neural network may be implemented using a combined neural network configured to output both a quality assessment value and a representation of the image property.

While various embodiments have been described herein wherein the image property used in the system **10** is a view category, in some embodiments, the system **10** may use another image property. In such embodiments, the analyzer **14** may be configured to apply a neural network that outputs a quality assessment value and the other image property. Further, in such embodiments, the trainer **502** may be configured to train a neural network that outputs a quality assessment

value and the other image property. For example, in some embodiments, the image property may include a representation of any or all of the elements included in the following list, for example:

- Cardiac
  - Left ventricular ejection fraction (LVEF)
  - Left atrial ejection fraction (LAEF)
  - Strain, both local and global
  - Pericardial Effusion
  - Heart rate
  - Cardiac phase
- FAST (Emergency Medicine)
  - Free Fluid
- Inferior vena cava (IVC)
- Volume Assessment
- Obstetrics
  - Ovarian torsion
  - Endometritis
  - Detection of fetal pole
  - Calculation of gestational age
- Gallbladder
  - Gallstones
- Pulmonary
  - Pneumothorax
  - Pleural Effusion
  - Pneumonia/Consolidation
- Ocular
  - Retinal Detachment
  - Vitreous Hemorrhage
- Musculoskeletal
  - Joint Effusion
  - Tendon Rupture

- Fracture Identification
- Renal
  - Hydronephrosis
  - Nephrolithiasis
- Deep vein thrombosis (DVT)
- Aorta
- Intrauterine pregnancy
  - Intrauterine Pregnancy
  - Fetal Heart Rate
- Soft Tissue
  - Cellulitis
  - Abscess
  - Foreign body
- Scrotal
  - Testicular Torsion
  - Hydrocele
  - Epididymitis

In various embodiments, the system **10** shown in Figure **1** may be used to facilitate analysis of ultrasound images in various subjects. For example, in some embodiments, various tissues/organs may be analyzed using an embodiment of the system **10**. For example, in some embodiments, the system **10** may be used for liver analysis, spine analysis, fat tissue analysis and other tissue/organ analysis etc. For example, in some embodiments, the system **10** may be used for analysis of any or all of the elements in the above list. In various embodiments, procedures for which the system **10** may be used may include, for example:

- Heart valve repair using transesophageal echocardiography
- Nerve blocks
- Vascular access
- Arthrocentesis
- Lumbar puncture

- Paracentesis
- Thoracentesis
- Airway

In various embodiments, a system generally similar to the system **10** shown in Figure **1** may include an analyzer that performs the functionality of the analyzer **14** described herein but that takes a different form. For example, in various embodiments, the analyzer may not be implemented using a mobile device. In some embodiments the analyzer may be implemented within an ultrasound machine, for example. In such embodiments, the ultrasound monitor may provide some of the functionality described herein as provided by the display **18** and/or ultrasound image data may not need to be transferred off of the ultrasound machine.

In various embodiments, the ultrasound machine **16** may take additional or alternative forms to the schematic representation shown in Figure **1**. For example, in some embodiments, the ultrasound machine **16** may be implemented wherein the ultrasound machine and the transducer are one unit and the ultrasound machine produces wireless signals for causing a display to display the ultrasound images. For example, in some embodiments, the ultrasound machine may wirelessly transmit ultrasound data to a mobile device or phone for display. In some embodiments, the mobile device or phone displaying the ultrasound images may act as the analyzer **14** or transmit the ultrasound data to a secondary mobile device acting as the analyzer **14**, for analysis.

In various embodiments the set of ultrasound images analyzed in the system **10** described herein may be a single ultrasound image.

In some embodiments, the trainer may include a user interface and block **704** may direct the trainer processor **600** to receive the quality assessment values and/or

the view category information via the user interface from an expert interacting with the user interface.

In various embodiments, the analyzer **14** may be implemented using an Android mobile device running a customized mobile implementation of the TensorFlow inference engine. In some embodiments, by multi-threading four TensorFlow instances together, the analyzer **14** may be able to execute the flowchart **200** shown in Figure **3** for analyzing images being received at **30** Hz with a latency of under **0**.**4** seconds.

In various embodiments, while three threads are running the first feature extracting neural networks for a set of ultrasound images, a fourth thread may run the rest of the neural network **300** shown in Figure **4** for a previous set of ultrasound images for which the feature representations were already determined. For example, Figure **13** shows a timing diagram **750** of how the threads **752**, **754**, **756**, and **758** may be run concurrently according to various embodiments.

Referring to Figure **13**, three first feature extracting neural network or CNN threads can be seen extracting features from ten consecutive input frames before waking a waiting RNN thread configured to run the rest of the neural network **300** shown in Figure **4**, which then runs the LSTMs, quality assessment value and view category prediction on the buffered features extracted by the CNN threads. The target frame rate for the system may be set at **30** Hz, which can be inferred by the lines **760**, **762**, **764**, **766**, and **768** representing the arrival of input frames. In some embodiments, the mean run-time for the first feature extracting neural networks (including feeding the input, running the network, and fetching the output) may be **28**.**76** ms with a standard deviation of **16**.**42** ms and the mean run time of the rest of the neural network **300** may be **157**.**48** ms with a standard deviation of **21**.**85** ms. Therefore, the mean latency of the feedback may be **352**.**58** plus or minus **38**.**27** ms, when measured from the middle of the ten-frame sequence.

In various embodiments, in order to prevent lag resulting from the build-up of unprocessed frames, the first feature extracting neural network threads and RNN need to finish running before they are requested to process the next batch of data. In some embodiments, to accomplish this reliably, all the per-frame processing must complete within $T_{max,\ first\ feature}$, calculated as follows:

$$T_{max,first\ feature} = (\#\ of\ first\ feature\ threads) * \mathbf{1}/FPS = \mathbf{3}/\mathbf{30} = \mathbf{100}\ ms$$

while the rest of the neural network **300** may need to complete its processing before the features from the next ten frames are extracted:

$$T_{max,RNN} = (buffer\ length) * \mathbf{1}/FPS = \mathbf{10}/\mathbf{30} = \mathbf{333}:\mathbf{33}\ ms$$

With the chosen three first feature extracting neural network threads and one thread for the rest of the neural network **300** configuration, in various embodiments, the application may require few threads while still providing enough tolerance to avoid frame build-up.

In various embodiments, neural networks described herein, including the first feature extracting neural networks shown in Figure **4**, for example, may be implemented by using Keras (https://keras.io/), a high-level neural networks API on top of the Tensorflow (https://www.tensorflow.org/) deep learning library backend in Python. The Keras library may be imported as tf.keras from Tensorflow (i.e., tf).

For the components included in the first feature extracting neural networks, in various embodiments, the convolution operation may be implemented by using the function tf.keras.layers.Conv2D, the batch normalization operation may be implemented by using the function tf.keras.layers.BatchNormalization, the ReLU activation operation may be implemented by using the function tf.keras.layers.ReLU, the dropout operation may be implemented by using the

function tf.keras.layers.Dropout, the concatenation operation may be implemented by using the function tf.keras.layers.concatenate, and the average pooling operation may be implemented by using the function tf.keras.layers.AveragePooling2D. In various embodiments, for the second feature extracting neural network **340** shown in Figure **4**, the LSTM operation may be implemented by using the function tf.keras.layers.LSTM.

While specific embodiments of the disclosure have been described and illustrated, such embodiments should be considered illustrative of the disclosure only and not as limiting the disclosure as construed in accordance with the accompanying claims.

CLAIMS:

1. A computer-implemented method of facilitating ultrasonic image analysis of a subject, the method comprising:

receiving signals representing a set of ultrasound images of the subject;

deriving one or more extracted feature representations from the set of ultrasound images;

determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images;

determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and

producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

2. The method of claim **1** wherein the image property is a view category.

3. The method of claim **2** wherein deriving the one or more extracted feature representations from the ultrasound images comprises, for each of the ultrasound images, deriving a first feature representation associated with the ultrasound image.

4. The method of claim **3** wherein deriving the one or more extracted feature representations comprises, for each of the ultrasound images, inputting the ultrasound image into a commonly defined first feature extracting neural

subnetwork to generate the first feature representation associated with the ultrasound image.

5. The method of claim **4** wherein deriving the one or more extracted feature representations comprises concurrently inputting each of a plurality of the ultrasound images into a respective implementation of the commonly defined first feature extracting neural network.

6. The method of claim **4** wherein the commonly defined first feature extracting neural network includes a convolutional neural network.

7. The method of claim **4** wherein deriving the one or more extracted feature representations comprises inputting the first feature representations into a second feature extracting neural network to generate respective second feature representations, each associated with one of the ultrasound images and wherein the one or more extracted feature representations include the second feature representations.

8. The method of claim **7** wherein the second feature extracting neural network is a recurrent neural network.

9. The method of claim **2** wherein determining the quality assessment value comprises inputting the one or more extracted feature representations into a quality assessment value specific neural network and wherein determining the image property comprises inputting the one or more extracted feature representations into an image property specific neural network.

10. The method of claim **9** wherein inputting the one or more extracted feature representations into the quality assessment value specific neural network comprises inputting each of the one or more extracted feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork and wherein inputting the one

or more extracted feature representations into the image property determining neural network comprises inputting each of the one or more extracted feature representations into an implementation of a commonly defined image property specific neural network.

11. The method of claim **2** wherein producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images comprises producing signals for causing a representation of the quality assessment value and a representation of the image property to be displayed by at least one display in association with the set of ultrasound images.

12. A computer-implemented method of training one or more neural networks to facilitate ultrasonic image analysis, the method comprising:

receiving signals representing a plurality of sets of ultrasound training images;

receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images;

receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images; and

training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties

associated with the set of ultrasound training images as desired outputs of the neural network.

13. The method of claim **12** wherein each of the image properties is a view category.

14. The method of claim **13** wherein the neural network includes a feature extracting neural network, an image property specific neural network, and a quality assessment value specific neural network and wherein:

the feature extracting neural network is configured to take an input set of the plurality of sets of ultrasound training images as an input and to output one or more extracted feature representations;

the image property specific neural network is configured to take the one or more extracted feature representations as an input and to output a representation of an image property associated with the input set of ultrasound training images; and

the quality assessment specific neural network is configured to take the one or more extracted feature representations as an input and to output a quality assessment value associated with the input set of ultrasound training images.

15. The method of claim **14** wherein the feature extracting neural network is configured to, for each of the ultrasound training images included in the input set of ultrasound training images, derive a first feature representation associated with the ultrasound image.

16. The method of claim **15** wherein the feature extracting neural network includes, for each of the ultrasound images included in the input set of ultrasound training images, a commonly defined first feature extracting

neural network configured to take as an input the ultrasound training image and to output a respective one of the first feature representations.

17. The method of claim **16** wherein more than one implementation of the commonly defined first feature extracting neural networks are configured to concurrently generate the first feature representations.

18. The method of claim **16** wherein the commonly defined first feature extracting neural network is a convolutional neural network.

19. The method of claim **16** wherein the feature extracting neural network includes a second feature extracting neural network configured to take as an input the first feature representations and to output respective second feature representations, each associated with one of the ultrasound images included in the input set of ultrasound training images and wherein the one or more extracted feature representations include the second feature representations.

20. The method of claim **19** wherein the second feature extracting neural network is a recurrent neural network.

21. A system for facilitating ultrasonic image analysis comprising at least one processor configured to:

receive signals representing a set of ultrasound images of the subject;

derive one or more extracted feature representations from the set of ultrasound images;

determine, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images;

determine, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and

produce signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images

22. The system of claim **21** wherein the image property is a view category.

23. The system of claim **22** wherein the at least one processor is configured to, for each of the ultrasound images, input the ultrasound image into a commonly defined first feature extracting neural subnetwork to generate a first feature representation associated with the ultrasound image.

24. The system of claim **23** wherein the at least one processor is configured to, for each of the ultrasound images, input the ultrasound image into a commonly defined first feature extracting neural subnetwork to generate the first feature representation associated with the ultrasound image.

25. The system of claim **24** wherein the at least one processor is configured to concurrently input each of a plurality of the ultrasound images into a respective implementation of the commonly defined first feature extracting neural network.

26. The system of claim **24** wherein the at least one processor is configured to input the first feature representations into a second feature extracting neural network to generate respective second feature representations, each associated with one of the ultrasound images and wherein the one or more extracted feature representations include the second feature representations.

27. The system of claim **22** wherein the at least one processor is configured to input the one or more extracted feature representations into a quality assessment value specific neural network and to input the one or more extracted feature representations into an image property specific neural network.

28. The system of claim **27** wherein the at least one processor is configured to input each of the one or more extracted feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork and to input each of the one or more extracted feature representations into an implementation of a commonly defined image property specific neural network.

29. The system of claim **22** wherein the at least one processor is configured to produce signals for causing a representation of the quality assessment value and a representation of the image property to be displayed by at least one display in association with the set of ultrasound images.

30. A system for facilitating ultrasonic image analysis, the system comprising:

means for receiving signals representing a set of ultrasound images of the subject;

means for deriving one or more extracted feature representations from the set of ultrasound images;

means for determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images;

means for determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and

means for producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

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ABSTRACT

Embodiments of a computer-implemented method of facilitating ultrasonic image analysis of a subject are disclosed. The method can involve receiving signals representing a set of ultrasound images of the subject, deriving one or more extracted feature representations from the set of ultrasound images, determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images, determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images. Embodiments of a computer-implemented method of training one or more neural networks to facilitate ultrasonic image analysis is also disclosed. Other apparatuses, methods, systems, and computer-readable media are also disclosed.

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Filer:	Keith M Lim/Jayne Clodfelter
Attorney Docket Number:	CRBN001.002AUS

Filed as Small Entity

Filing Fees for Track I Prioritized Examination - Nonprovisional Application under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY FILING FEE (ELECTRONIC FILING)	4011	1	75	75
UTILITY SEARCH FEE	2111	1	330	330
UTILITY EXAMINATION FEE	2311	1	380	380
REQUEST FOR PRIORITIZED EXAMINATION	2817	1	2000	2000
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	2202	10	50	500
INDEPENDENT CLAIMS IN EXCESS OF 3	2201	1	230	230

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous-Filing:				
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
PROCESSING FEE, EXCEPT PROV. APPLS.	2830	1	70	70
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**3585**

Electronic Acknowledgement Receipt

EFS ID:	37029597
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Customer Number:	20995
Filer:	Keith M Lim/Aimee Kazan
Filer Authorized By:	Keith M Lim
Attorney Docket Number:	CRBN001.002AUS
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Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$3585
RAM confirmation Number	E20198TF52240961
Deposit Account	111410
Authorized User	Aimee Kazan

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37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	TrackOne Request	CRBN001002AUS_Track_1.pdf	118810 fa103a9fb682349c925d9a958e4c776db7379379	no	2
Warnings:					
Information:					
2	Drawings-other than black and white line drawings	CRBN001002AUS_Figs.pdf	185288 acd07711cd47e16d593e50fb74342510de5522a6	no	13
Warnings:					
Information:					
3	Application Data Sheet	ADS_revised.pdf	1256440 b01cae5874535df45834d1fd5a78b7ada4bb277d	no	10
Warnings:					
Information:					
4		Spec_revised.pdf	237991 d97a66e3040a324d3b37ff44776c0d6e87e9f8bd	yes	51

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	42
Claims	43	50
Abstract	51	51

Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	43083 eb0d2d44e162baf53a1de104f57452718586 4d91	no	2

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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

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Electronic Patent Application Fee Transmittal

Application Number:	16557261
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Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Filer:	Keith M Lim/Jayne Clodfelter
Attorney Docket Number:	CRBN001.002AUS

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
LATE FILING FEE FOR OATH OR DECLARATION	2051	1	80	80
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**80**

Electronic Acknowledgement Receipt

EFS ID:	37035730
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Correspondence Address:	KNOBBE MARTENS OLSON & BEAR LLP - 2040 MAIN STREET FOURTEENTH FLOOR IRVINE CA 92614 US 949-760-0404 efiling@knobbe.com
Filer:	Keith M Lim/Wendi Manzanares
Filer Authorized By:	Keith M Lim
Attorney Docket Number:	CRBN001.002AUS
Receipt Date:	30-AUG-2019
Filing Date:	
Time Stamp:	16:38:58
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$80

Caption Health Ex1004

RAM confirmation Number	E20198TG39181953
Deposit Account	111410
Authorized User	Wendi Manzanares

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Fee Worksheet (SB06)	fee-info.pdf	30321 b076a97764dc6790f640f3750d3d2f1e4b445464	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	30321		

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS

CONFIRMATION NO. 6889

20995
KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614

INFORMAL NOTICE

OC000000111049471

Date Mailed: 09/13/2019

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  Purang Abolmaesumi
  Robert Rohling
  Teresa Tsang
  Zhibin Liao
  Amir Abdi

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/ctuazon/

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/557,261

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	30 minus 20 =	* 10	x 50 =	500	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	4 minus 3 =	* 1	x 230 =	230			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 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).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1515		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	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	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	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 found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/557,261	08/30/2019		1595	CRBN001.002AUS	30	4

CONFIRMATION NO. 6889

20995
KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614

FILING RECEIPT

OC000000111049470

Date Mailed: 09/13/2019

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

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

Inventor(s)

Purang Abolmaesumi, Vancouver, CANADA;
Robert Rohling, Vancouver, CANADA;
Teresa Tsang, North Vancouver, CANADA;
Zhibin Liao, Adelaide, AUSTRALIA;
Amir Abdi, Vancouver, CANADA;

Applicant(s)

The University of British Columbia, Vancouver, CANADA;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of PCT/CA2019/051192 08/28/2019
and claims benefit of 62/725,913 08/31/2018

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

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

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

If Required, Foreign Filing License Granted: 09/11/2019

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/557,261**

Projected Publication Date: 03/05/2020

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

ULTRASONIC IMAGE ANALYSIS

Preliminary Class

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

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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

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

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

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

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

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

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

NOT GRANTED

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

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

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	6889

20995 7590 09/24/2019

KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614

EXAMINER	

ART UNIT	PAPER NUMBER
3793	

NOTIFICATION DATE	DELIVERY MODE
09/24/2019	ELECTRONIC

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

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

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

efiling@knobbe.com
jayna.cartee@knobbe.com

Decision Granting Request for Prioritized Examination (Track I)	**Application No.** 16/557,261	**Applicant(s)** Abolmaesumi et al.	
	Examiner BRIAN W BROWN	**Art Unit** OPET	**AIA (FITF) Status** Yes

1. THE REQUEST FILED 30 August 2019 IS **GRANTED** .

The above-identified application has met the requirements for prioritized examination

A. ☑ for an original nonprovisional application (Track I).
B. ☐ for an application undergoing continued examination (RCE).

2. **The above-identified application will undergo prioritized examination**. The application will be accorded special status throughout its entire course of prosecution until one of the following occurs:

A. filing a **petition for extension of time** to extend the time period for filing a reply;

B. filing an **amendment to amend the application to contain more than four independent claims, more than thirty total claims** , or a multiple dependent claim;

C. filing a **request for continued examination** ;

D. filing a notice of appeal;

E. filing a request for suspension of action;

F. mailing of a notice of allowance;

G. mailing of a final Office action;

H. completion of examination as defined in 37 CFR 41.102; or

I. abandonment of the application.

Telephone inquiries with regard to this decision should be directed to BRIAN BROWN at (571)272-5338.

In his/her absence, calls may be directed to Petition Help Desk at (571) 272-3282.

/BRIAN W BROWN/ Petitions Examiner, OPET	

U.S. Patent and Trademark Office
PTO-2298 (Rev. 02-2012)

Please Direct All Correspondence to Customer Number 20995

RESPONSE TO INFORMATIONAL NOTICE

First Inventor	:	Purang Abolmaesumi
App. No.	:	16/557261
Filed	:	August 30, 2019
For	:	ULTRASONIC IMAGE ANALYSIS
Art Unit	:	3793
Conf No.	:	6889

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

Dear Sir:

The above-captioned application was filed without a Declaration and/or Substitute Statement. Enclosed in compliance with 37 CFR 1.53(f) are the following.

(X) Declaration(s) for:

Abolmaesumi, Purang

Rohling, Robert

Tsang, Teresa

Liao, Zhibin

Abdi, Amir

The Commissioner is hereby authorized to charge any additional fees which may be required, now or in the future, or credit any overpayment, to Account No. 11-1410.

/Keith M Lim/
Keith M Lim
Registration No. 68,912
Attorney of Record
Customer No. 20995
(949) 760-0404

31482120

PTO/AIA/01 (08-12)
Approved for use through 01/31/2014. 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

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	ULTRASONIC IMAGE ANALYSIS

As the below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application, or

▩ United States application or PCT international application number 16/557261

filed on August 30, 2019

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Robert Rohling Date (Optional): _____

Signature: _____

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. 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 1 minute 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.

PTO/AIA/01 (08-12)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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LEGAL NAME OF INVENTOR

Inventor: Teresa Tsang Date (Optional): 9/24/2019

Signature: _____

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

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

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U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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Title of Invention	ULTRASONIC IMAGE ANALYSIS

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This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 16/557261 filed on August 30, 2019.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

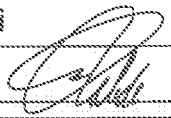
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Amir Abdi Date (Optional): September 24, 2019

Signature: 

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. 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 1 minute 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.

PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
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DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	ULTRASONIC IMAGE ANALYSIS

As the below named inventor, I hereby declare that:

This declaration is directed to:

- ☐ The attached application, or
- ☒ United States application or PCT international application number 16/557261 filed on August 30, 2019.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

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LEGAL NAME OF INVENTOR

Inventor: Zhibin Liao Date (Optional): 2019/09/25

Signature:

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. 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 1 minute 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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PTO/AIA/01 (06-12)
Approved for use through 01/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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This declaration is directed to:

☐ The attached application, or

☒ United States application or PCT international application number 16/557261

filed on August 30, 2019.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

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LEGAL NAME OF INVENTOR

Inventor: Purang Abolmaesumi Date (Optional): Sept 23, 2019

Signature:

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. 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 1 minute 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.

Electronic Acknowledgement Receipt

EFS ID:	37477323
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Customer Number:	20995
Filer:	Keith M Lim/Wendi Manzanares
Filer Authorized By:	Keith M Lim
Attorney Docket Number:	CRBN001.002AUS
Receipt Date:	16-OCT-2019
Filing Date:	30-AUG-2019
Time Stamp:	17:29:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Response to Pre-Exam Formalities Notice	FormalitiesResponse.pdf	17301 30b0d049e6eefe09862e5b3a4fba8448779d321c	no	1

Warnings:

Caption Health Ex1004

Information:					
2	Oath or Declaration filed	Declarations.pdf	1177015 458a8c98f151758baa8c34b176ef6e563be089c6	no	5
Warnings:					
Information:					
			Total Files Size (in bytes):	1194316	

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

PTO/AIA/82A (07-13)
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TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	16/557261
Filing Date	August 30, 2019
First Named Inventor	Abolmaesumi, Purang
Title	ULTRASONIC IMAGE ANALYSIS
Art Unit	3793
Examiner Name	Currently Unassigned
Attorney Docket Number	CRBN001.002AUS

SIGNATURE of Applicant or Patent Practitioner

Signature	/Keith M Lim/	Date (Optional)	2019-11-21
Name	Keith M Lim	Registration Number	68,912
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. 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 3 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.

PTO/AIA/82B (07-13)
Approved for use through 01/31/2018. OMB 0651-0035
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date
16/557,26 1	August 30, 2019

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 20995

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

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

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

The University of British Columbia

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	Brett Sharp	Date (Optional)	
Name	2019.11.07 11:47:53		
Title	Associate Director UBC ULO -08'00'		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. 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 3 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.**

Electronic Acknowledgement Receipt

EFS ID:	37821134
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Customer Number:	20995
Filer:	Keith M Lim/Fabiola Esmerio
Filer Authorized By:	Keith M Lim
Attorney Docket Number:	CRBN001.002AUS
Receipt Date:	21-NOV-2019
Filing Date:	30-AUG-2019
Time Stamp:	16:35:28
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	POA.pdf	257514 031abcc4568f4842fd727bbffcbbe7e146490f81	no	2

Warnings:

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Information:	
Total Files Size (in bytes):	257514

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

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United States Patent and Trademark Office
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www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS

CONFIRMATION NO. 6889

POA ACCEPTANCE LETTER

20995
KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614

OC000000112906968

Date Mailed: 11/26/2019

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 11/21/2019.

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.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/atesfai/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	3793
(Multiple sheets used when necessary)	Examiner	Currently Unassigned
SHEET 1 OF 2	Attorney Docket No.	CRBN001.002AUS

U.S. PATENT DOCUMENTS					
Examiner Initials	Cite No.	Document Number *Number - Kind Code (if known)* Example: 1,234,567 B1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear
	1	7,672,491	03-02-2010	Krishnan et al.	
	2	7,680,308	03-16-2010	Dale	
	3	8,712,157	04-29-2014	Marchesotti et al.	
	4	2005/0020903	01-27-2005	Krishnan et al.	
	5	2006/0147107	07-06-2006	Zhang et al.	
	6	2009/0034808	02-05-2009	Zhou et al.	
	7	2009/0088640	04-02-2009	Park et al.	
	8	2015/0302638	10-22-2015	Jago et al.	
	9	2017/0360401	12-21-2017	Rothberg et al.	
	10	2017/0360402	12-21-2017	De Jonge et al.	
	11	2017/0360403	12-21-2017	Rothberg et al.	
	12	2017/0360411	12-21-2017	Rothberg et al.	
	13	2017/0360412	12-21-2017	Rothberg et al.	
	14	2018/0153505	06-07-2018	Cadieu et al.	
	15	2019/0059851	02-28-2019	Rothberg	
	16	2019/0104949	04-11-2019	Cadieu et al.	
	17	2019/0266716	08-29-2019	Rothberg et al.	

FOREIGN PATENT DOCUMENTS						
Examiner Initials	Cite No.	Foreign Patent Document *Country Code-Number-Kind Code* Example: JP 1234567 A1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear	**T[1]**
	18	WO 2014/097090 A1	06-26-2014	Koninkl Philips NV [NL]		
	19	WO 2017/181288 A1	10-26-2017	Univ British Colombia [CA]		

Examiner Signature	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.

[1] Place a check mark in this area when an English language Translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	3793
(Multiple sheets used when necessary)	Examiner	Currently Unassigned
SHEET 2 OF 2	Attorney Docket No.	CRBN001.002AUS

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[1]
	20	"2019 CES Butterfly Personal Whole Body Ultrasound," (retrieved from the Internet at YOUTUBE "2019 CES Butterfly Personal Whole Body Ultrasound," Sync Media Network https://www.youtube.com/watch?v=m21kXPUi-_g&feature=youtu.be January 11, 2019).	
	21	ABDI A.H. et al., "Automatic quality assessement of echocardiograms using convolutional neural networks: Feasibility on the apical four-chamber view". Trans. Medical Imaging. 2017.	
	22	ABDI A.H. et al., "Quality assessment of echocardiographic cine using recurrent neural networks: Feasibility on five standard view planes". In Proceedings of MICCAI 2017.	
	23	"Healthcare Summit 2017: Spotlight: An Ultrasound In Your Pocket- Forbes Live," (retrieved from the Internet at YOUTUBE "Healthcare Summit 2017: Spotlight: An Ultrasound In Your Pocket- Forbes Live," Forbes Live https://www.youtube.com/watch?v=Pi-ipOXqk8k&feature=youtu.be December 4, 2017).	
	24	HOCHREITER S et al., "Long short-term memory". Neural computation. 1997.	
	25	HUANG G. et al., "Densely connected convolutional networks". In Proceedings of the IEEE conference on CVPR. 2017.	
	26	International Search Report and Written Opinion in PCT Application No. PCT/CA2019/051192 mailed November 8, 2019.	
	27	IOFFE, S. et al., "Batch normalization: Accelerating deep network training by reducing internal covariate shift". In: Proceedings of the 32nd International Conference on Machine Learning. Pp. 448-456. ICML'15, JMLR (2015).	
	28	KIM J. et al, "Deep Convolutional Neural Models for Picture-Quality Prediction", IEEE Signal Processing Magazine, 13 November 2017.	
	29	LU, X. et al., "AutoMPR: Automatic detection of standard planes in 3D echocardiography". In: 5th IEEE International Symposium on ISBI 2008, pp. 1279-1282 (2008).	
	30	NAIR, V. et al., "Rectified linear units improve restricted Boltzmann machines". In: Proceedings of the 27th international conference on machine learning (ICML-10). Pp.807-814 (2010).	
	31	Search Strategy in PCT Application No. PCT/CA2019/051192 mailed November 8, 2019.	
	32	SRI-KAUSHIK PAVANI, et al., "Quality Metric for Parasternal Long Axis B-Mode Echocardiograms," published in Medical Image Computing and Computer Assisted Intervention (MICCAI) in January 2012. Volume 15, part 2, pages 478-485.	

31771034

Examiner Signature	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.	

[1] Place a check mark in this area when an English language Translation is attached.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 June 2014 (26.06.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/097090 A1

(51) **International Patent Classification:**
A61B 8/08 (2006.01) *G06T 7/00* (2006.01)
A61B 8/00 (2006.01) *A61B 8/06* (2006.01)
G01S 7/52 (2006.01)

(21) **International Application Number:**
PCT/IB2013/060908

(22) **International Filing Date:**
13 December 2013 (13.12.2013)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
61/740,595 21 December 2012 (21.12.2012) US

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(54) **Title:** ANATOMICALLY INTELLIGENT ECHOCARDIOGRAPHY FOR POINT-OF-CARE

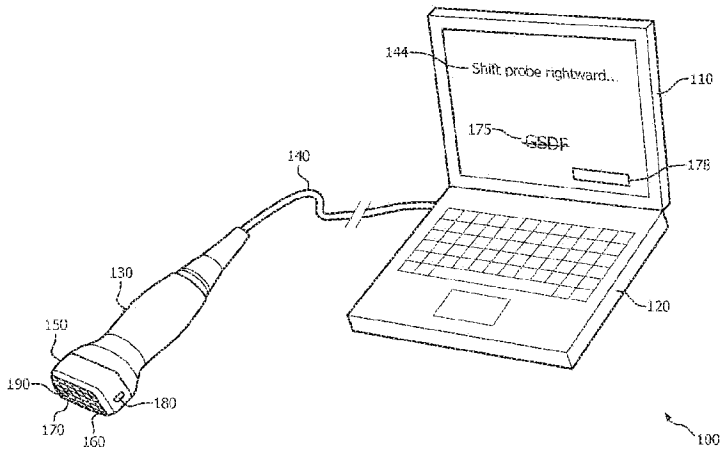


FIG. 1

(57) **Abstract:** An apparatus includes an imaging probe and is configured for dynamically arranging presentation of visual feedback (144) for guiding manual adjustment, via the probe, of a location, and orientation, associated with the probe. The arranging is selectively based on comparisons (321) between fields of view of the probe and respective results of segmenting image data acquired via the probe. In an embodiment, the feedback does not include (175) a grayscale depiction of the image data. Coordinate system transformations corresponding to respective comparisons may be computed. The selecting may be based upon and dynamically responsive to content of imaging being dynamically acquired via the probe.

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Anatomically Intelligent Echocardiography for Point-of-Care

FIELD OF THE INVENTION

The present invention relates to user guidance in adjusting imaging probe location and orientation and, more particularly, to the guidance being visual.

BACKGROUND OF THE INVENTION

Heart failure is a major disease with five million patients in the United States alone and tens of millions worldwide. The individuals at risk of heart failure are estimated at 60 million in the United States only; one million are hospitalized, the rest being in the care of heart failure clinics. Basic information about the heart is needed in the heart failure clinics or general practitioners' offices for patient management. This information includes images as well as quantification data, such as ejection fraction, computed from the image once the image is acquired. Ultrasound is a reliable and cost-effective imaging modality for soft tissue such as the heart.

Acquisition of an ultrasound image requires a skilled sonographer. One parameter the sonographer, or other clinician trained in sonography, optimizes is the field of view. The apical four chamber view is a standard one for routine cardiac checkups. The clinician places the head of the ultrasound probe, or "transducer probe", on the patient. An effective site on the patient's skin for placement of the probe for various views is part of the clinician's training, and the site can vary from patient to patient. For the apical four chamber view the probe is placed over the apex of the heart. The probe also needs to be manually tilted, typically in different directions until the organ is captured for imaging. This is all done interactively, with the clinician viewing the image, which is usually a sonogram, on-screen. Interpreting a sonogram is a skill that must be developed, e.g., through training and practice. The clinician's experience tells him or her, in an ongoing iterative process, how to shift and tilt the probe to achieve an effective acoustic window.

SUMMARY OF THE INVENTION

What is proposed herein below is directed to addressing one or more of the above concerns.

Access to a full ultrasound scan in heart failure clinics and general practitioner's offices is not easy. Making the ultrasound system portable would help. However, although most cardiologists would be able to use a conventional portable ultrasound system, they are generally too busy to carry out this procedure themselves.

Yet, serial imaging, in which images of the heart are taken periodically for example, would improve patient treatment.

What is needed is a point-of-care solution that enables automatic ultrasound-based volumetric measurement of the heart during the patient's regular visit, which would be especially useful in heart failure clinics. A nurse trained in placing ECG leads, but with no training in echocardiography, would operate the portable system and the cardiologist would be provided with the diagnostic images together with automatic measurements such as ventricle size and ejection fraction.

Such a technology would lower the barrier to use of ultrasound data for cardiac diagnostic and follow-up examinations.

In accordance with an aspect of the present invention, an apparatus includes an imaging probe. It further includes a user-guidance processor configured for dynamically arranging presentation of visual feedback for guiding manual adjustment, via the probe, of a location, and orientation, associated with the probe. The arranging is selectively based on comparisons between fields of view of the probe and respective results of segmenting image data acquired via the probe.

In a sub-aspect, the arranging includes presenting the feedback. The feedback includes user instructions on manually maneuvering the probe.

In a further sub-aspect, the feedback does not include a grayscale depiction of image data acquired via the probe.

In another sub-aspect, the apparatus is configured for computing coordinate system transformations corresponding to respective ones of the comparisons.

In a first further sub-aspect, the computing is dynamically based on the results.

In a second further sub-aspect, the selecting is respectively based on magnitudes of translational and rotational components of the transformations.

In a third further sub-aspect, the computing is responsive to respective pauses in the adjusting.

In a relevent sub-aspect, the probe includes a sensor. The apparatus is configured for deciding, based on output of the sensor, that acoustic coupling quality is insufficient and for issuing a user alert upon the decision.

In a related sub-aspect, the segmenting is model-based.

In an associated sub-aspect, the selecting is based upon and dynamically responsive to content of imaging being dynamically acquired via the probe.

In a particular sub-aspect, the imaging probe is or includes an ultrasound imaging probe.

In a more overall sub-aspect, the presenting dynamically guides a user in a procedure for achieving an apical view of a heart.

As an added sub-aspect, at least one of the fields of view is three-dimensional.

In a different sub-aspect, the acquiring of the image data to be segmented occurs respectively from the fields of view.

In a specific sub-aspect, a field of view from among the fields of view has a viewpoint coinciding with the location. The orientation coincides with a viewing orientation of the field of view.

From an implementational sub-aspect, the apparatus further comprises a display and a user-operable console. The apparatus is configured for: a) acquiring the image data via the probe b) the segmenting c) displaying the feedback via the display; and d) portability, as a hand-carriable unit.

In still another sub-aspect, issuing a user alert for halting the adjustment is responsive to content of imaging dynamically acquired via the probe.

As a further sub-aspect, the apparatus is configured for detecting the halting.

In a yet, further sub-aspect, the apparatus is further configured for, responsive to detecting that the halting has occurred, performing the segmenting.

In one other particular sub-aspect, the apparatus is configured for the segmenting in a relatively coarse mode and in a relatively fine mode. It is further configured for making a volumetric measurement based on one or more segments formed as a result of the spatially finer segmenting. Making the measurements is responsive to completion of the spatially finer segmenting.

In still one more sub-aspect, an instruction to halt, as part of the feedback, is subject to an outcome of a comparison between a current location, and current orientation, of the probe and a location and orientation derived from the segmenting.

In a similar sub-aspect, the feedback includes a progressive indicator of overall progress in acquiring a target view.

Details of the novel, real-time, user-pause-driven, acoustic-window identification guidance technology are set forth further below, with the aid of the following drawings, which are not drawn to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one form of portable apparatus in accordance with the present invention;

FIGs. 2A and 2B are flow charts of an exemplary ultrasound clinical procedure in accordance with the present invention;

FIG. 3 is a conceptual diagram of how the apparatus is able to guide, in real time, the placement of the acoustic window;

FIGs. 4A and 4B are diagrams showing examples of schemes for imaging-blockage avoidance that use on-screen guidance images of segments disposed with respect to a field of view of an ultrasonic probe, in accordance with the present invention;

FIG. 5 is a flow chart, and formula list, relating to FIG. 4A;

FIGs. 6A, 6B and 6C are, respectively, exemplary graphs of radiofrequency data used to distinguish lung tissue from heart tissue, and an algorithm used in the distinguishing, in accordance with the present invention;

FIG. 7 is a flow chart representative of an exemplary lung identification algorithm based on a one-dimensional probe; and

FIG. 8 is a flow chart representative of an exemplary lung identification algorithm based on a matrix probe.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 depicts a portable apparatus 100 as one example of an implementation of the novel, real-time, user-pause-driven, acoustic-window identification guidance technology proposed herein. Although shown here in a form factor easily transportable from room to room in a clinical environment, the apparatus 100 may instead be implemented as a stationary device. The apparatus 100 includes a display 110, a user console 120, a transthoracic echocardiography (TTE) probe 130, and a probe cable 140 of extended length as represented by the broken lines in FIG. 1. The display 110 and user console may be similar to those used in a laptop computer. At a total weight of about 10 pounds, the unit 100 can be carried by hand. The description below will assume an ultrasound system, although any kind of hand-steered, imaging-probe-based system is within the intended scope of the

invention. Also, although volumetric quantification and live three-dimensional imaging are features of the embodiment below, what is proposed herein applies also to two-dimensional imaging.

The apparatus 100 is configured for using ultrasound to perform volumetric imaging, such as computing the size of the left ventricle of the heart or computing ejection fraction. The computation results are stored in a memory (not shown). Live imaging acquired via the probe 130, and upon which the computations are based, is also stored in memory. Circuitry (not shown) for standard functions such as dynamic beamforming, scan conversion and image rendering is also included within the apparatus 100. Two or more beamformers can be included for automatic image blockage detection, which is discussed further below. Additional circuitry (not shown) includes a user-guidance processor configured for dynamically presenting visual feedback, i.e., user instructions. They are of a kind specifically for guiding manual adjustment, via the probe 130, of a location and orientation associated with the probe, and accordingly an acoustic window. The processor dynamically arranges the presentation, and selectively arranges it for guiding the user and in conformity with "updates" to respective three-dimensional fields of view. The update is a new field of view, one that is suggested by one or more segments created by segmenting an image in the current field of view of the probe. The model upon which the segmentation is based provides the new field of view, based on an orientation and position of the segment(s). This new field of view, when compared to the current field of view of the probe, serves as the guidepost in notifying the clinician, untrained in sonography, on how to next manipulate the probe 130. The processor issues all instructions to the user on how to manually maneuver the probe 130 to iteratively achieve the optimal acoustic window.

Segmentation need not be as detailed for the above-described "steering" of the field of view as it is for quantification once the target acoustic window is achieved. An example of model-based segmentation that uses coarse and fine meshes is found in commonly-assigned U.S. Patent Publication Number 2009/0202150 to Fradkin et al. ("Fradkin"). The adaptation termination criterion in Fradkin can be set to keep segmentation coarse for field-of-view steering in the present embodiment of apparatus 100, or set to proceed to fine segmentation for volumetric-data-based quantification in the present embodiment. Steering and quantification are discussed further below.

In order to locate an image for segmentation, the apparatus 100 is further configured for performing a generalized Hough transform (GHT). A method for performing

a GHT is discussed in commonly-assigned U.S. Patent Publication No. 2008/0260254 to Schramm et al.

The entire disclosure of both publications is incorporated herein by reference.

The apparatus 100 further has the capability of detecting motion of the probe 130. The user will often pause movement of the probe so that image segmentation can occur. Also, the apparatus 100 will check on whether an instruction to pause, e.g., because the probe 130 is close to attaining a target acoustic window, has yet been followed. In one embodiment, the apparatus 100 includes the increment calculator 80 disclosed in commonly-assigned U.S. Patent No. 5,529,070 to Augustine et al ("Augustine"). The increment calculator 80 is supplied values by means of the probe cable 140 that originate from accelerometers (not shown) residing in the probe 130. Unlike in Augustine, the positional readings need not be matched with image acquisition. So, the increment calculator can be simplified to merely detect movement in location and/or orientation of the probe 130. The accelerometers can be apportioned between the distal and proximal parts of the probe 130, as seen from FIGs. 4, 5 and 5a of Augustine. The entire disclosure in Augustine relating to the accelerometer embodiment is incorporated herein by reference. Alternatively, an example of using electromagnetic (EM) sensors in tracking a medical tool is provided in commonly-owned U.S. Patent No. 7,933,007 to Stanton et al. A similar system which also attaches to the tool an optical sensor is disclosed in commonly-owned U.S. Patent Publication No. 2010/0168556 to Shen et al. Motion may also be sensed by comparing successive real time images as described in commonly-owned U.S. Patent No. 6,299,579 to Peterson et al. All three documents are incorporated herein by reference in their entirety.

The above functions for which the apparatus 100 is configured may be implemented with any suitable and known combination of software, firmware and hardware. The user-guidance processor may be realized, for example, on a device having one or more integrated circuits, or as a suitably programmed computer readable medium.

The probe 130 has a head 150 containing a matrix array 160 that includes transducer elements 170. Although, for simplicity, a relatively small number of elements 170 are shown in FIG. 1, the number might typically be in the thousands. Also, although the array 160 is shown as generally rectangular, it might be square, circular, oval or in another shape. It also might be flat, as in a linear array, or curved, as in a sector array.

Shown for purposes of illustration, on the display 110, is visual feedback 144 of kind specifically for guiding manual adjustment, via the probe 130, of the array's location and orientation. Advantageously, a user untrained in sonography need not rely on grayscale

images, such as sonograms, for guidance. So, there is no reliance on a grayscale display function (GSDF), as represented by the on-screen annotation 175 that is struck out and depicted in FIG. 1. In particular, the visual feedback 144 of the embodiment shown in FIG. 1 does not include a grayscale depiction of image data acquired via the probe 130. Another example of visual feedback 144 is the on-screen overall progress bar 178. It can be annotated with a percentage such as "82%" or it can be progressively filled in and bordered by a frame that represents 100%, i.e., completion.

The probe 130 also has a pair of pause/go indicator lights 180 (one of which is visible in FIG. 1, with the other on the opposite side of the probe) realizable as a red/green light-emitting diodes (LEDs). When green, the light 180 indicates that the user should look to the display 100 for directions and then proceed by moving the probe 130 as instructed. When red, the light 180 indicates that the user should pause movement of the probe 130. Both lights are concurrently the same color.

As an alternative for the lights 180, or as an implementation of additional lights, directional indicator lights can be provided. In this alternative embodiment, when one light is green, the other is red. When green, the light indicates that the user should shift in the direction of the green light beam. The apparatus 100 will already have determined that the probe 130 is validly positioned along the intercostal space between the two ribs currently surrounding the matrix array 160, as discussed further below. Conversely, when red, the light indicates that the user should shift in the opposite direction. Alternatively or in addition, the instruction to shift, and the directionality, may appear on the display 110.

The probe may also incorporate an acoustic coupling quality sensor (not shown). Distributed sparsely among the transducer elements 170, i.e., in replacement of individual elements, are pressure sensors 190 devoted to detecting pressure. Detection is interleaved with image acquisition. When transducer elements 170 in proximity of a pressure sensor 190 are active, and the pressure sensor reading implies lack of pressure, this indicates weak acoustic coupling. More generally, if and when the apparatus 100 decides, based on output of the acoustic coupling quality sensor, that acoustic coupling quality is insufficient, a user alert is issued upon that decision. Visual or auditory user alerts can be provided, via the probe 130 or other parts of the apparatus 100. As an example, the acoustic coupling quality sensor can comprise merely 8 pressure sensors 190 that are disposed among 10,000 transducer elements 170.

FIGs. 2A and 2B depict, by way of illustrative and non-limitative example, a clinical ultrasound procedure 200 demonstrating how the apparatus 100 visually guides a

nurse, or other user, unskilled in sonography. In this embodiment, a four-chamber apical view of the heart for imaging is to be recorded and volumetric cardiac measurements are to be taken and stored. The process is in two stages. In the first stage, the user moves the probe 130 until the imaging detects at least part of the heart, or other organ of interest. In the second stage, the user moves the probe 130, pausing frequently and receiving further instructions shortly after each pause. Sometimes, the apparatus 100 determines that a transition is to be made, from the second stage, back to the first stage. Successful completion of the ultrasound procedure 200 occurs during, i.e., at the end of, the second stage.

Operationally, first, the nurse places the electrocardiogram (ECG) leads on the patient or ultrasound subject, human or animal (step S202). The ECG will serve as part of the cardiac checkup. It also facilitates analysis of the live cardiac imaging that will be recorded. At the outset, the user is instructed generally about the imaging that is to be done, that instructions will be visible on the display 110 and via the lights 180, to stop movement of the probe 130 promptly when instructed, and, when instructed to move the probe, to pause frequently so that the system can take readings (step S204). Also, a stage two flag is cleared as part of the initialization, since the user is initially in stage one of the procedure 200. The user is then instructed to have the patient lie on his or her left side, so that the heart will fall forward in the patient's chest for easier imaging (step S206). The user is instructed to start from the bottom of the rib cage at a point below the left nipple, and to count up to between the fourth and fifth ribs from the bottom of the rib cage (step S208) for a point at which to place the head 150 of the probe 130 for an initial acoustic window. Image acquisition by the probe is live and continuous. The instructions also mention that the probe should be tilted upward to point toward the base of the patient's neck as a first estimate. The instruction now is to: remembering the placement, lift away the probe 130; apply coupling gel around the probe face covering the matrix array 160; and reassume the probe placement as to location, and as to orientation (step S210). If, by a blockage-identification algorithm discussed further below, no ribs are detected (steps S212, S214), a branch back is taken to step S206. Otherwise, if only one rib is detected (step S214), the user is instructed to shift up or down slightly to get between the two ribs (step S216). On-screen, a graphic depiction can be displayed of a probe aimed at one rib being shifted up/down to placement between two ribs. Processing returns to step S212. In this processing loop, and all processing loops that involve issuing a user instruction, the instruction is not listed again if already shown on-screen. If, on the other hand, both ribs are detected, then this aspect of correct probe placement is validated. Query is made as to whether a lung is blocking the current field of view of the probe 130

(step S218). This determination is made by a blockage-identification algorithm discussed further below. If lung tissue is in the field of view (step S218), the user is instructed to have the patient exhale and hold his or her breath (step S220). This might take the lung out of the field of view, since the lung may venture in and out of the field of view with each breath and expiration by the patient. If the lung is detected again and therefore is still blocking the field of view (step S222), the user is instructed to have the patient resume normal breathing (step S224). Since the lung blocking the heart would be the left lung and since the lung is less central on the chest than is the heart, the user is instructed to shift the probe 130 upward, i.e., toward the breastbone (step S226). The pause/go indicator lights 180 on the probe 130 will be green. The user may also be told to tilt the probe 130 slightly to aim more to the left side of the patient, as the probe is shifted up. Return is made to step S212. Alternatively or in addition, the user may be shown an on-screen inverted "V" display by which the user can interactively shift and tilt the probe 130 to avoid the lung. The same "V" display could be used to guide the user to tilt and translate the probe to avoid the ribs. If, on the other hand, after having the patient hold his or her breath (step S220), the lungs are no longer blocking the field of view (step S222), or if the lungs were not initially blocking (step S218), query is made as to whether at least part of the heart is detected in the live imaging by the probe 130 (S228). The Schramm GHT, mentioned above, is utilized for this detecting. Although the left ventricle (LV) may be the part of the heart for which quantification is desired, detecting part of the heart can even involve detecting merely the left atrium, or the mitral valve, for example. A predetermined confidence level must be met in deciding whether the detection has occurred. For example, in the Schramm reference the measure of optimality in determining the set of transformation parameters can be required to meet a predetermined threshold.

If the heart is not detected (S228), the user is instructed to "Shift slowly down away from the breastbone, shift slowly up toward the breastbone, each time to a greater extent." A graphic moving depiction of the pattern may be displayed on the display 110 (step S230). The procedure 200 branches back to step S212.

If, on the other hand, part of the heart is detected (step S228), query is made as to whether the stage two flag, which was cleared during initialization in step S204, is set (step S232). If it is not set (step S232), the user is instructed to pause and wait for instructions (step S234). The pause is needed, because segmentation, even coarse segmentation, requires a short time period, e.g., two seconds. Specifically, the pause/go indicator lights 180 on the probe 130 will turn red and/or the display 110 will show, in red, an instruction to pause. A

short audio beep may also issue. The apparatus 100 detects, via the accelerometers in the probe 130, whether motion of the probe has paused (step S236). Until the movement pauses (step S236), the visual and audio feedback to pause is maintained (step S238). When a pause is detected (step S236), a check is again made as to whether part of the heart is detected (step S240). This precaution is taken to determine whether the user has paused quickly enough to still be imaging part of the heart.

If there no longer exists detection of part of the heart (step S240), the instruction (step S242) is "Slowly backtrack your most recent movement and pause when instructed to regain (partial) view of the heart . . . otherwise shift as instructed." Return is then made to step S212.

On the other hand, if at least part of the heart is still detected (step S240), a coarse image-segmentation of the bodily organ, here the heart, is performed (step S244) using a model (step S245).

Provided that the apparatus 100 has electronic steering capability, query is now made as to whether the entire heart, judging from the segment(s), is within the current field of view of the probe 130 (step S246).

If the entire heart is not within the current field of view (step S246) or if the apparatus 100 lacks an electronic steering capability, a coordinate system transformation is computed (step S247). In particular, the segmenting produces one or more segments of the heart having a location and orientation in the image space of the probe 130. The location and orientation are known from the model. Based on the location and orientation, it is determined what would be an optimal viewpoint and viewing orientation for a geometrically-fixed field of view of the probe that covers the entire heart or heart section, e.g., the left ventricle, being investigated. For example, both the mitral valve and the apex of the heart can be identified by segmentation, and an axis connecting them may be, or may be close to, an optimal viewing orientation for quantification and diagnostic cardiac images. The field of view is geometrically fixed, because it is assumed that the user is untrained in sonography and, for simplicity, is being guided merely to move the probe according to visual instructions. The derived optimal viewpoint and viewing orientation will, in general, differ from the current viewpoint and current orientation of the probe. The viewpoints and viewing orientations are all in the image space of the probe 130. The apparatus 100 computes a coordinate system transformation that would bring the current viewpoint and orientation into coincidence with the derived optimal viewpoint and orientation.

After the transformation is computed, the on-screen overall progress bar 178 is updated (step S248).

The progress is based on the magnitude of the translation component of the transformation and, to a lesser degree or at a later stage, on the magnitude of the rotation component of the transformation.

The length of the progress bar 177 could therefore be, percentage-wise, 100 minus a weighted average of the two components that is non-negative and less than unity.

The same or a similar metric is used by the apparatus 100 to decide whether the current view is sufficiently on target for commencing quantification and optionally live imaging acquisition for storage. Alternatively or in addition, the apparatus 100 can determine, based on the model, whether the heart, or heart section, is entirely or sufficiently within the current field of view of the probe 130 (step S249).

If it is determined in step S249 that the current field of view of the probe 130 is not sufficiently close to the optimal field of view, a decision is made as to whether tilting or shifting predominates as the selection for the next user instruction (step S250). Generally, shifting will predominate if any remains; although, if the remainder is small enough, tilting may be sufficient. The parameters for making the decision can be empirically established. Going forward from this part of the procedure 200, presentation to the user of the visual feedback 144 is dynamically arranged selectively based on a comparison between the current field of view of the probe 130 and the derived optimal viewpoint and viewing orientation from step S247. For example, it is based on the need for shifting and/or tilting, those needs being assessed based on the comparison. The selecting inherently occurs according to which of the user instructions mentioned below issues in the procedure 200. It is noted here that the arranging of the presentation of visual feedback 144 earlier in the procedure 200, such as in the steps S212-S228, is done dynamically and selectively and is based on image content acquired but not on the above-mentioned comparison. Therefore, some but not all of the dynamic, selective arranging of visual feedback 144 within the procedure 200 is based on the comparison.

If shifting predominates (step S250), query is made as to whether the translation indicated would involve crossing a rib to enter an adjoining intercostal space, given the position of the ribs (step S251). The apparatus 100 is aware of the position of the ribs through a blockage-identification algorithm mentioned above in relation to steps S212 and S214 and discussed further herein below. If the translation is not feasible (step S251), the user is accordingly instructed to, after re-applying coupling gel to the probe 130, move

up, or down, the ribcage (step S253). The stage two flag is cleared, and processing returns to step S210. If, on the other hand, the translation is feasible (step S251), the user is instructed to shift slowly in the direction determined by the apparatus 100, pausing frequently (step S254). Thus, this user instruction is among those dynamically and selectively arranged based on the above-mentioned comparison.

If, on the other hand, shifting does not predominate in step S250, the user is instructed to tilt the probe 130 slowly in the determined direction (step S255). The instruction may be "tilt slowly aiming inward toward the breastbone, stopping frequently" or "tilt slowly aiming downward toward the patient's feet, stopping frequently", some combination of these two instructions, etc. This instruction then is among those dynamically and selectively arranged based on the above-mentioned comparison.

Alternatively or in addition, the display 110 may show an interactive graphical depiction of the segmented organ, here segments defining a heart, as a segmented on-screen object with a superimposed, inverted "V" representing the field of view of the probe 130. A second, separate, concurrent depiction may be shown for a "V" in the orthogonal direction. This graphical depiction is discussed further below.

After the instruction for either step S254 or S255 issues, query is made as to whether movement since step S236 has occurred. This can be determined via the accelerometers in the probe 130. If such movement has occurred and if there is no movement now (step S256), the stage two flag is set (step S257), and processing returns to step S212.

If, on the other hand, it is determined in step S249 that the current field of view of the probe 130 is sufficiently close to the optimal field of view, the apparatus 100 issues an instruction to halt (step S258). Specifically, the pause/go indicator lights 180 on the probe 130 will turn red and/or the display 110 will show, in red, an instruction to halt. A short audio beep may also issue. The apparatus 100 detects, via the accelerometers in the probe 130, whether motion of the probe has halted, i.e., paused or terminated (step S260). Until the movement halts (step S260), the visual and audio feedback to halt is maintained (step S262). Once the movement halts (step S260), query is made, as in step S249, as to whether the current view is sufficiently on target for commencing quantification and optionally live imaging acquisition for storage (step S264). If the current view is not, i.e., is no longer, on target (step S264), the progress bar 178 is accordingly shortened to reflect the setback in progress toward completion of the procedure 200 (step S266). An instruction issues for the user to slowly backtrack the most recent probe movement, stopping frequently (step S268). Processing branches to step S257. If, on the other hand, the current view is

sufficiently on target for commencing quantification and optionally live imaging acquisition for storage (step S264), the user is notified to hold the probe still for completion of the procedure 200 (step S270). Fine segmentation is performed for quantification (step S272). The model is utilized for this purpose (step S274). The apparatus 100 starts recording live imaging of the heart or heart section (step S276). If the apparatus 100 includes an electronic steering capability, various views of the heart such as the standard views can be played back from the recording. The apparatus also and makes volumetric measurements from the segmentation (step S278). For example, left ventricle (LV) size is computed, over a heart cycle, by finding the average or maximum length and finding the average or maximum breadth, for example. Likewise, ejection fraction is computed by detecting, over a cardiac cycle, maximum and minimum LV volume, and taking a ratio of the two quantities . The quantification data is stored in memory (step S280).

If, on the other hand, the entire heart is within the current field of view (step S246) and if the apparatus 100 has an electronic steering capability, the progress bar 177 is made to reflect near completion (step S282). An instruction to halt is given in step S284. While movement of the probe 130 is detected (step S286), a user alert to halt is maintained (step S288). Once it is detected that the probe 130 is halted (step S286), query is again made as to whether the entire heart is in the field of view (step S290). If the entire heart is still in the field of view (step S290), processing branches to step S270 to instruct the user to pause for completion of the procedure 200. Otherwise, if the entire heart is no longer within the field of view (step S290), processing branches to step S266 to try to recover the image of the entire heart.

FIG. 3 depicts, conceptually, how the apparatus 100 is able to guide, in real time, placement of the acoustic window. A probe 302 is held by the clinician's hand 304 against the skin 306 of a patient. More specifically, the probe 302 has a head 308 which has a face 310 for placement against the skin 306, separated from the skin only by the acoustic coupling medium such as a specialized gel. Within the head 308 and along the face 310 is a matrix array 312. Extending from the matrix array 312 is a field of view 314. The heart 316 of the patient is partially, here mostly,within the field of view 314, and is being imaged via the probe 302. Since part of the heart 316 is detected with a sufficient level of confidence, the clinician has been instructed to pause and has done so promptly. As a result of image segmentation into segments 318, the apparatus 100 determines, via the model, an orientation 320 that would provide an optimal, or targeted, view of the heart 316 if the probe 302, or some part of the probe such as the matrix array 312, were to assume that orientation from an

appropriate location 318. The model also provides the location 318. For simplicity of explanation, a curved arrow 321 in FIG. 3 starts at a location 322 and orientation 324 of the probe 302. It ends at the model-provided location 318 and model-provided orientation 320 that are derived from the image segmentation. The curved arrow 321 represents comparison of the field of view 314 with the model-provided location and orientation 318, 320. The comparison involves a coordinate system transformation that would bring the model-provided location and orientation 318, 320 into coincidence with the current location 322 and current orientation 324 of the probe 302. The transformation has a translational component 326 and a rotational component 328. Visual feedback 144 in the procedure 200 is selected based on magnitudes of the components 326, 328, as for example in steps S248, S249 and S264 of FIGs. 2A and 2B. Another curved arrow 330 in FIG. 3 shows the clinician's hand 304 maneuvering the probe 302, based on the feedback 144, into an apical view 332.

In the depicted example, the heart 316 is partially outside the current field of view 314. Electronic steering into a favorable field of view corresponding to the apical view 332 still fails to capture imaging content that was out of view prior to the electronic steering. Accordingly, relying on electronic steering in the depicted example to shorten the procedure 200 might compromise the result, depending upon the impact of losing that particular image content.

If, however, FIG. 3 were to be redrawn with the heart 316 completely within the current field of view 314, electronic steering proceeds as described above, provided that the apparatus 100 has an electronic steering capability. Thus, the apical view 332 is achieved without maneuvering the probe 302, that maneuvering being represented by the curved arrow 330. Instead, it is achieved by electronic steering. Although the manual maneuvering of the probe 203 may have been needed earlier in the procedure to achieve detection of part of the heart 316 (step S228), electronic steering can, once the entire heart is in view, alleviate the need for further manual maneuvering of the probe.

Advantageously, the user is guided throughout a procedure for achieving an apical view of the heart.

As mentioned herein above, detecting that the ribs bordering the current intercostal space are within the field of view is part of the validation that the current acoustic window, placed in finding an optimal acoustic window, is valid. User instructions on how to maneuver the probe around the lungs to view the heart are also mentioned herein above.

Echocardiography is challenging as the heart is surrounded by ribs and lung tissue. Ultrasound can hardly penetrate calcified ribs (typically encountered in the apical

view) and lung tissue because of severe acoustic impedance mismatch between them and other soft tissues. In addition, ultrasound absorption in ribs is quite high compared to tissue. Conventionally, optimization of ultrasound image quality is done solely by the user based on real-time-displayed grayscale ultrasound images on the screen. Though experienced users are usually capable of recognizing image degradation and improving image quality accordingly by moving the probe to a better position, less experienced users might acquire compromised images because of inferior hand-eye coordination and less awareness of artifacts. Successful ultrasound scanning strongly relies on training and experience of the user. To help inexperienced or less experienced users acquire meaningful information from the heart using echocardiography, an anatomically intelligent ultrasound system is desired.

Since ultrasound can hardly penetrate a calcified rib, deep echoes of an ultrasound beam hitting a calcified rib are very unlikely to be from tissues under the rib. Rather, they might be picked up by sidelobes. The visual artifact is recognizable by an experience sonographer viewing the (grayscale) sonogram, but can easily be unrecognized by the inexperienced user.

Also, to get good image quality for an inexperienced user, an ultrasound system should be aware of the presence of lung tissue.

One blockage-identification algorithm described below is specialized for detecting lung tissue, and especially rib tissue, blocking the field of view. A second blockage-identification algorithm described below is tailored especially for detecting lung tissue blockage. They are discussed in view of the following drawings.

FIGs. 4A and 4B show examples of schemes for imaging-blockage avoidance that use on-screen guidance images of segments disposed with respect to a field of view of an ultrasonic probe.

Both figures feature a sonogram. The FIG. 4A sonogram is an image slice that runs along the length of a patient; whereas, the FIG. 4B sonogram is an image slice that runs along the width of a patient.

FIG. 4A relates not only to the first algorithm, but also to an interactive display as part of the visual feedback 144.

The matrix array 160 has a current field of view 314 that partially includes ribs 404, 408 and partially (and here almost entirely) includes a heart 412. The first algorithm calculates blockage boundary lines 416, 420 that correspond to the boundary between good ultrasound beams and ones that are bad due to blockage by the ribs 404, 408.

Coherence of channel data is used to detect blockage. Each channel delivers its respective radiofrequency data magnitude associated with its respective fixed transducer element 170 or patch of elements. As ultrasound echoes return, their incident pressures on the elements 170 are sampled quickly and periodically. The samples are delayed with respect to each other according to the line-of-sight travel time geometry of the field point being evaluated. Here, "coherence" means similarity among data recorded by different channels of an array after applying the above-mentioned receiving focusing delays.

One gauge of coherence is a beamsummed-data-based coherence estimation method, such as the one described in U.S. Patent Publication No. 2009/0141957 to Yen et al., the entire disclosure of which is incorporated herein by reference.

The estimation method can be tailored to detecting rib and lung blockage, and is demonstrated below using two beamformers. Let $s_j(r, \Theta)$ denote the (real-valued) channel data at depth r received by the j-th channel after applying the focusing delay, and let C_1 and C_2 denote the set of channels used in the first and the second beamformer, respectively. The output of the k-th (k = 1, 2) beamformer is $b_k(r, \Theta)$, the formula for which is shown in FIG. 5. When all the channel data $s_j(r, \Theta)$ are identical across channels, $b_1(r, \Theta)$ and $b_2(r, \Theta)$ will be highly correlated no matter how C_1 and C_2 are chosen. On the other hand, when the channel data are mainly contributed by scatterers in sidelobe regions, the correlation between b_1 and b_2 can drop significantly if C_1 and C_2 are properly chosen. C_1 and C_2 can be complementary, interleaving apertures. In short, it is possible to distinguish between on-axis signals and off-axis signals based on correlation between b_1 and b_2. The output of the correlator is the correlation coefficient $p(r, \Theta)$ of $b_1(r, \Theta)$ and $b_2(r, \Theta)$ defined as listed in FIG. 5, where w is a real symmetric weighting function. $p(r, \Theta)$ is then lowpass filtered to get a smoothed correlation map $p(r, \Theta)$ which is used for blockage detection. A flow diagram for the algorithm, i.e., the "first algorithm", is shown in FIG. 5. Sums of $s_j(r, \Theta)$ are taken for C_1 (step S510) and for C_2 (step S520). They are correlated to calculate the correlation coefficient $p(r, \Theta)$ (step S530) which is low-pass filtered (step S540) to produce the smoothed correlation map $p(r, \Theta)$ used for blockage detection (step S550). The edge lines are then generated for the inverted "V" display (step S560).

In a specific example, the data is acquired at 32 MHz sampling rate in a pulse-inversion mode using a probe having 80 elements 170. Each frame has 44 beams and the beam density is 0.4944 beam/degree. The center frequency is 1.3 and 2.6 MHz on transmit and on receive, respectively. C_1 = {20-22, 26-28, 32-34, 38-40, 44-46, 50-52, 56-58} and

C_2 = {23-25, 29-31, 35-37, 41-43, 47-49, 53-55, 59-61}. The weighting function w used in the correlator is a 51 (axially or in the r direction) by 1 (laterally or in the Θ direction) boxcar and the smoothing filter is a 501 by 3 boxcar. Due to the periodic structure of the apertures, sensitivity of the correlation coefficient p to off-axis signals varies periodically with the direction of off-axis signals. This periodicity can be alleviated by randomizing sub-aperture sizes while still keeping both apertures complementary.

To verify whether a beam is blocked, a count is made of the number of points with a correlation coefficient *(p)* higher than 0.55 between 72 and 180 mm in depth. If at least 400 points (at 32 MHz sampling rate) in a beam have high coherence, this beam is considered penetrating into tissue. Otherwise it is considered blocked by a rib.

Referring back to FIG. 4A, and counting the 80 channels from left to right, perhaps the 20th channel has the first beam exhibiting high coherence; whereas, the 19th beam does not exhibit high coherence. Thus, the first blockage boundary line 416 is shown in FIG. 4A at the 19th beam. Likewise, if the 59th channel exhibits high coherence, but the 60th channel does not exhibit high coherence, the second blockage boundary line 420 is placed in coincidence with the 59th beam.

The upper bound of the depth range is not critical. 72 mm, much larger than the depth of human ribs in general, can be chosen as the lower bound because high coherence factor values might be present in regions right below a rib due to multiple reflections (or reverberation) and such reflections tend to fade away with depth.

The apertures described do not include channels in both ends of the full aperture. Though apertures can be extended to include those channels, the number of blocked beams might be underestimated if large apertures are used. This is because the correlation coefficient of complementary aperture outputs could still be high if part of the large complementary apertures is not blocked.

Though the embodiment above uses 2D images acquired with a ID probe, the methodology can be applied to matrix probes and therefore 3D volumetric imaging to guide novice users to perform volumetric acquisitions.

FIG. 4A also depicts an image that can be displayed for interactively guiding the clinician. The image of the heart 412 can be implemented as the segment(s) defining the heart by virtue of the coarse segmentation (step S244). The heart 412 is barely but partially outside the field of view 314. As the clinician shifts the probe 302 according to visual feedback 144 on-screen or in the form a green light 180 on the probe, the FIG. 4A image updates in real time. The inverted "V" can easily be made to fully encompass the desired

organ, here a heart. A FIG. 4A image, as part of the visual feedback 144, may supplement steps S212, S214 and S255 described above in connection with FIGs. 2A and 2B.

To optimize probe positioning, the span of V's can be enlarged through the use of an x-plane display.

Analogous to FIG. 4A, FIG. 4B relates not only to the second algorithm, but also to an interactive display as part of the visual feedback 144.

The matrix array 160 has a current field of view 314 that includes a heart 424 and part of a lung 428. The second algorithm calculates a blockage boundary line 432 that corresponds to the boundary between good ultrasound beams and ones that are bad due to blockage by the lung 428.

In the second algorithm, the center frequency of radiofrequency (RF) data acquired in pulse inversion (PI) modes is used as the parameter to distinguish lung tissue from heart tissue.

Sample radiofrequency data with a transmit center frequency of 2.1MHz is shown in FIGs. 6A and 6B. The FIG. 6A graph represents the interrogation of lung tissue; whereas, the FIG. 6B graph represents the interrogation of heart tissue. Lung and heart tissue look more different in pulse inversion imaging that in conventional imaging. For example, lung tissue responded better to lower frequencies.

The FIG. 6A graph resulted from linear response of the lung tissue to self-demodulated signals. With wideband transmission, after nonlinear propagation the summation of the positive and the negative pulse will present a finite signal around 1 MHz, roughly half of the center frequency on transmit, a phenomenon called self-demodulation. Lung tissue responds to this low-frequency signal better than heart tissue. On the other hand, compared to lung tissue, heart tissue tends to favor higher frequency components in a PI mode because its stronger motion results in less perfect cancellation at higher frequencies.

Part of the second algorithm involves estimating the center frequency of the RF data. Let r(n) be a sampled A-line signal and $R(n)$ be its complex envelope. $f_c(n)$, the local center frequency of r(n), is related to $R(n)$ by

$$\arg\{i?(n+1)R^*(n)\} \cong \frac{\arg\{R(n+1)R^*(n-1)\}}{2} \geq \frac{2\pi f_c(n)}{f_s}, \quad (1)$$

where arg{-} denotes phase/argument and f_s is the sampling rate. Estimators of $f_c(n)$ can be derived based on (1). An example of an estimator is:

$$\hat{f}_c(n) \equiv \frac{\arg\left\{\sum_{i=-m}^{i=m} w(i)R(n+i+1)R^*(n+i-1)\right\}}{4\pi} f_s \quad (2)$$

as the estimator. Averaging based on the window function w(i) reduces variance.

In one example, transmitting is at 2.1 MHz in a high resolution mode, the sampling rate is 32 MHz and the beam density is 0.72 beam/degree. One image or frame consists of 64 beams with 2 transmits per beam. The RF echoes in a frame are denoted as $\{r_p(n, \Theta), r_n(n, \theta)\}$, where the subscripts p and n stand for positive and negative pulse on transmit respectively, and n and $\Theta = 6(k)$ (k is the beam index) denote time index and angle respectively.

FIG. 6C shows the flow diagram of first version of the second algorithm, where $r_s(n, \Theta) \equiv r_p(n, \Theta) + r_n(n, \Theta)$, $R_f(n, \Theta) \equiv r_s(n, \theta) \otimes h(n)$, $\otimes$ denotes convolution, and $h(n)$ is a 121-tap single-sided complex bandpass filter between 0.95 and 2.05 MHz. The center frequency map $f_c(n, \Theta)$ is obtained beam by beam based on equation (2) with a 301-tap Hamming window, and then smoothed by a 301 (axially or in the n direction) by 5 (laterally or in the Θ direction) boxcar filter to get $\hat{f}_c f(n, \Theta)$. The last step is to estimate the boundary angle between heart and lung using the smoothed center frequency map $\hat{f}_{c,f}(n, \Theta)$. The steps in FIG. 6C are summation (step S610), complex temporal filtering (step S620), center frequency estimation (step S630), 2D filtering (step S640) and boundary estimation (step S650).

Estimation of the boundary angle involves multiple thresholding. Starting with the first thresholding relation: For a beam (i.e., give a Θ) to qualify as a heart region, the center frequency has to satisfy the following condition:

$$\frac{1}{1501}\sum_{m=0}^{1500} f_c f(n + \pi\iota, \theta) \geq f_{u1} \text{ for all } n \in [1500,2500]. \quad (3)$$

That is, only if the average center frequencies between the 1500th and 3000th points (between 36 mm and 72 mm), between the 1501st and 3001st points, …, and between the 2500th and 4000th points (between 60 mm and 96 mm) are all no lower than f_{u1}, can a beam be considered to be passing through heart tissue. The collection of the index of qualified beams is denoted as the set Ai. For example, $A_1 = \{3,4, \ldots, 32\}$ (noting that the 64 beams are counted from right to left in FIG. 4B and that the first two and last two beams do not qualify because of the spatial smoothing filter) for $f_{u1} = 1.37$ MHz. Accordingly, the boundary angle can be estimated as the average angle over beams 32 and 33, $6(k)$ being an increasing function of k. The blockage boundary line 432 corresponds to the boundary angle.

The lung tissue can never appear on the right side of the heart (from the perspective patient) as long as the probe is correctly positioned, unless the image shown in FIG. 4B is, in effect, flipped. We can therefore always estimate the boundary based on the

leftmost beam satisfying the condition defined in (3). For example, if $A_1 = \{14,15, ..., 32\}$, the boundary angle still could be estimated as the average angle over beams 32 and 33.

Robustness of lung identification can be improved by including additional criteria. The second threshold is used to detect regions with very low center frequency: Given a beam angle Θ, if the center frequency satisfies

$$\frac{1}{501}\sum_{m=-500}^{500} f_c \mathbf{f}(\mathbf{n} + \mathbf{m}, 0) < f_x \text{ for any } n \text{ G } [1750,3750], \quad (4)$$

this beam can be considered passing through lung tissue. The collection of the index of beams satisfying (4) is denoted as A_2. $A_2 = \{3,4, ...,32\}$ in the case shown in **Erreur ! Source du renvoi introuvable.** for $f_1 = 1.27$ MHz and therefore has no conflict with the corresponding A_1.

The third (and the last) threshold is used to detect regions with very high center frequency: Given a beam angle 0(k), if the center frequency satisfies

$$\frac{1}{2001}\sum_{m=-1000}^{1000} f_c \mathbf{f}[\mathbf{n}, \theta(\mathbf{fe} + \mathbf{m})] > f_{u2} \text{ for all } m \; E \; \{-2, -1,0,1,2\}, \quad (5)$$

this beam is considered to be passing through heart tissue. That is, if 5 consecutive beams present very high center frequency, the central beam has a high chance of passing heart tissue. The collection of the index of beams satisfying (5) is denoted as A_3.

In practice, A_1, A_2 and A_3 might not be consistent with each other. For example, the intersection of A_1 and A_2 might be nonempty meaning that some beam could be considered passing both heart and lung tissue. Accordingly, the collections may be prioritized. Specifically A_3 (the very high frequency condition defined in (5)) is given the highest priority and A_1 (the high frequency condition defined in (3)) is given the lowest priority. The "adjusted heart tissue set" is defined as

$$A_h \equiv \{k | k \; E \; A_1 \text{ and } k < I \text{ for any } I \; E \; A_2 \text{ that is larger than } \mathbf{max}(\boldsymbol{A_3})\}, \quad (6)$$

where $\mathbf{max}(\boldsymbol{A_3})$ is the maximum element of A_3 and is defined as $-\infty$ if A_3 is empty. The following is an equivalent definition:

$$A_h \equiv \{k | k \; E \; A_1 \text{ and } k < I \text{ for any } I \in A_2'\} \quad (7)$$

where

$$A_2' \equiv \{I | I \; E \; A_2 \text{ and } I > j \text{ for any } j \; \text{G} A_3\}. \quad (8)$$

The boundary between heart and lung is estimated based on the largest element of A_h. For example, if $A_1 = \{5,6, ...,50\}$, $A_2 = \{3,4, 49,50,51\}$ and $A_3 = \{11,12,13\}$, then $A_2' = \{49,50,51\}$, $A_h = \{5,6, ...,48\}$, and the estimated boundary angle $\hat{\theta}_b$ is the average angle over

beams 48 and 49. An empty A_h indicates lung tissue occupying the whole image. If A_h is not empty,

$$\hat{\theta}_b \equiv \pm_z\{\mathbf{0}[\max(\_4_h)] + \mathbf{0}[\max(\_4_h) + \mathbf{1}]\} = \mathbf{0}[\max(\_4_h)] + \frac{1}{2}\Delta\theta, \quad (9)$$

where $\Delta\Theta = \mathbf{0}(k+\mathbf{1}) - \theta(k)$. Because the 2D smoothing filter deteriorates beams on the sides, it is concluded that no lung tissue appears in the image if $\mathbf{0}[\max(A_h)] \geq$ (beam number) - (half the lateral dimension of the 2D smoothing filter) $= \mathbf{64} - \frac{5-1}{2} = \mathbf{62}$.

The role of f_{u1} is much more important than that of f_l, but occasionally existence of A_2 contributes positively in determining the boundary. To recap, in this first version of the second algorithm, $f_{u1} = \mathbf{1.37}$ MHz, $f_l = \mathbf{1.27}$ MHz, and $f_{u2} = \infty$.

A second version of the second algorithm also pertains to ID probes and for PI data acquired in high resolution mode. As mentioned above, lung tissue responds to low-frequency signal components well in a linear fashion and motion causes less perfect cancellation at higher frequencies in heart tissue in a PI mode. This implies the possibility of performance improvement by replacing $r_s(n, \mathbf{0})$ with a composite signal $r_c(n, \mathbf{0})$ in the signal processing chain shown in FIG. 6C. For this reason, there is a second version of the second algorithm. FIG. 7 shows how $r_c(n, \mathbf{0})$ is formed, where $r_d(n, \mathbf{0}) \equiv r_p(n, \mathbf{0}) - r_n(n, \mathbf{0})$ which is step **S710**, $r_{d,l}(n, \mathbf{0}) \equiv r_d(n, \mathbf{0}) \otimes h_l(n)$ which is step **S720**, step **S730** is identical to step **S610**, $r_{s,h}(n, \mathbf{0}) \equiv r_s(n, \mathbf{0}) \otimes h_h(n)$ which is step **S740**, $r_c(n, \Theta) \equiv w_d r_{d,l}(n, \Theta) + w_s r_{s,h}(n, \Theta)$ which is step **S750**, $h_l(n)$ is a 101-tap real lowpass filter cutting off at 0.8 MHz, and $h_u(n)$ is a 101-tap real highpass filter cutting off at 1.15 MHz. Echoes from lung tissue favor $r_{d,l}(n, \Theta)$ (because it responds to low-frequency components well) and echoes from heart tissue favor $r_{s,h}(n, \Theta)$ (because of more motion). w_d and w_s are weights used to balance the two forces. The signal processing following $r_c(n, \Theta)$ remains the same as that following $r_s(n, \Theta)$ in FIG. 6C. Exemplary parameters are $w_d = \mathbf{1.2}$, $w_s = \mathbf{1}$, $f_{u1} = \mathbf{1.4}$ MHz, $f_l = \mathbf{1.2}$ MHz, and $f_{u2} = \mathbf{1.5}$ MHz.

A matrix probe version of the second algorithm is based on the second version - composite signals are used for center frequency estimation. RF data can be collected, for example, using penetration imaging mode with PI enabled and a center frequency of 2.2 MHz. Lateral and elevational widths can be maximal.

Each volume has 40 (lateral) by 33 (elevational) A-lines on transmit (with 2 transmit events per A-line due to PI acquisition) and 80 by 66 A-lines on receive sampled at 16 MHz because of the 4X beamformer. The four signals of each transmit direction are

summed to get RF echoes $\{r_p(n, \Theta, \phi), r_n(n, \Theta, \phi)\}$ with 40 Θ values and 33 ϕ values. The lateral beam density is 0.41 beam per degree.

FIG. 8 shows the flow diagram of the matrix probe version of the second algorithm, with the temporal sampling rate at 16 MHz. The steps are: subtraction (step S805), low-pass filtering (step S810), summation (step S815), high-pass filtering (step S820), weighted summation (step S825), complex temporal filtering (step S830), center frequency estimation (step S835), 2D filtering (step S840), boundary estimation (step S845), median filtering (step S850) and visualization across planes (step S855). In short, $\phi = \phi(v)$, $r_d(n, \Theta, \phi) \equiv r_p(n, \Theta, \phi) - r_n(n, \Theta, \phi)$, $r_s(n, \Theta, \phi) \equiv r_p(n, \Theta, \phi) + r_n(n, \Theta, \phi)$, $r_{d,l}(n, \Theta, \phi) \equiv \mathbf{r_d(n, \Theta, \phi)} \otimes \mathbf{h_l(n)}$, $\mathbf{r_{s,h}(n, \Theta, \phi)} \equiv \mathbf{r_s(n, \theta, \phi)} \otimes \mathbf{h_h(n)}$, $\mathbf{r_c(n, \theta, \phi)} \equiv w_d r_{d,l}(n, \theta, \phi) + w_s r_{s,h}(n, \theta, \phi)$, $h_l(n)$ is a 51-tap real lowpass filter cutting off at 0.8 MHz, $h_u(n)$ is a 51-tap real highpass filter cutting off at 1.3 MHz, $w_d = 2$, and $w_s = 1$. The complex envelope $Rf(n, \Theta, \phi) \equiv r_c(n, \theta, \phi) \otimes h(\eta)$, where $h(n)$ is a 61-tap single-sided complex bandpass filter between 0.95 and 2.05 MHz. In each elevational plane, the center frequency map $\hat{f}_c(n, \Theta, \phi)$ is obtained beam by beam based on equation (2) with a 151-tap Hamming window, and then smoothed by a 151 (in the n direction) by 3 (in the Θ direction) boxcar filter to get $\hat{f}_{c,f}(n, \Theta, \phi)$.

For boundary estimation, the following are defined:

$$A_{1,v} \equiv \left\{k \mid \frac{1}{751} \sum_{m=0}^{750} \hat{f}_{c,f}(n + m, \theta(k), \phi(v)) \geq f_{u1} \text{ for all } n \in [750,1250]\right\}. \quad (10)$$

$$A_{2,v} \equiv \{k \mid \frac{1}{251} \sum_{m=0}^{250} \hat{f}_{c,f}(n + m, \theta(k), \theta(v)) < f_l \text{ for any } n \in [875,1875]\}, \quad (11)$$

and

$$A_{3,v} \equiv \left\{k \middle| \frac{1}{1001} \sum_{n=1000}^{2000} \hat{f}_c(n, \theta(k + m), \theta(v)) > f_{u2} \text{ for all } m \in \{-1,0,1\}\right\}, \quad (12)$$

where $f_{u1} = 1.38$ MHz. Equivalently $f_l \equiv 0, f_{u2} \equiv \infty$, $A_{2,v}$ and $A_{3,v}$ are empty, and the adjusted heart tissue set $A_{h,v} = A_{1,v}$.

The boundary angle between heart and lung in the v-th plane is

$$\theta_b(v) \equiv \begin{cases} \Theta(1) - \frac{1}{2}\Delta\Theta \text{ if } A_{h,v} \text{ is empty} \\ \Theta(40) + \frac{1}{2}\Delta\Theta \text{ if } \max(A_{h,v}) \geq 40 - \frac{3-1}{2} = 39. \\ \theta[\max(A_{h,v})] + \frac{1}{2}\Delta\Theta \text{ otherwise} \end{cases} \quad (13)$$

A 5-tap median filter (a function of v) in the elevational direction is then applied to $\hat{\theta}_b(v)$ and the output is denoted as $\hat{\theta}_{b,f}(v)$. From the filtered boundary angles

$\hat{\theta}_{b,f}(v)$, a map indicating heart region can be derived to provide cross-plane visualization. To remove outliers around the boundary between heart and lung which appear occasionally, only the largest connected region is displayed. The clinician can use the FIG. 4B display to interactively manipulate the probe 130 so as to avoid the lung, in step S226.

An apparatus includes an imaging probe and is configured for dynamically arranging presentation of visual feedback for guiding manual adjustment, via the probe, of a location, and orientation, associated with the probe. The arranging is selectively based on comparisons between fields of view of the probe and respective results of segmenting image data acquired via the probe. In an embodiment, the feedback does not include a grayscale depiction of the image data. Coordinate system transformations corresponding to respective comparisons may be computed. The selecting may be based upon and dynamically responsive to content of imaging being dynamically acquired via the probe.

In addition to making diagnostic cardiac examination performable by nurses or other clinicians who may be untrained specifically in sonography, the apparatus 100 can guide novice sonographers. The apparatus 100 can feature, for this purpose or this mode, a regular (grayscale) sonogram, along with the visual feedback 144 described herein above. Alternatively, the novel visual feedback 144 of the apparatus 100 can speed up the work flow of trained or experienced sonographers.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

For example, the probe cable 140 may be omitted in a wireless probe embodiment.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. Any reference signs in the claims should not be construed as limiting the scope.

A computer program can be stored momentarily, temporarily or for a longer period of time on a suitable computer-readable medium, such as an optical storage medium or a solid-state medium. Such a medium is non-transitory only in the sense of not being a transitory, propagating signal, but includes other forms of computer-readable media such as register memory, processor cache, RAM and other volatile memory.

A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

What is claimed is:

1. An apparatus comprising:

an imaging probe (130); and

a user-guidance processor configured for dynamically arranging presentation of visual feedback for guiding manual adjustment, via said probe, of a location, and orientation, associated with said probe, said arranging selectively based on comparisons between fields of view (3 14) of said probe and respective results of segmenting image data acquired via said probe.

2. The apparatus of claim 1, said arranging comprising presenting said feedback, said feedback comprising user instructions (144) on manually maneuvering said probe.

3. The apparatus of claim 2, said feedback not comprising (175) a grayscale depiction of image data acquired via said probe.

4. The apparatus of claim 1, wherein said processor is further configured for computing (S247) coordinate system transformations corresponding to respective ones of said comparisons.

5. The apparatus of claim 4, said computing being dynamically based on said results (318, 320).

6. The apparatus of claim 4, the selecting being respectively based on magnitudes of translational and rotational components (326, 328) of said transformations.

7. The apparatus of claim 4, said computing being responsive to respective pauses (S236, S238) in the adjusting.

8. The apparatus of claim 1, said probe comprising a sensor (190), said apparatus configured for deciding, based on output of said sensor, that acoustic coupling quality is insufficient and for issuing a user alert upon the decision.

9. The apparatus of claim 1, said segmenting being model-based (S245).

10. The apparatus of claim 1, the selecting being based upon and dynamically responsive to content of imaging being dynamically acquired via said probe (S249).

11. The apparatus of claim 1, said imaging probe comprising an ultrasound imaging probe.

12. The apparatus of claim 1, configured for the presenting in dynamically guiding a user in a procedure for achieving an apical view (332) of a heart.

13. The apparatus of claim 1, a field of view from among said fields of view being three-dimensional (326, 328).

14. The apparatus of claim 1, the acquiring of the image data to be segmented occurring respectively from said fields of view.

15. The apparatus of claim 1, a field of view from among said fields of view having a viewpoint coinciding with said location (322), said orientation (324) coinciding with a viewing orientation of said field of view.

16. The apparatus of claim 1, further comprising:

a display (110); and

a user-operable console (120),

said apparatus configured for:

acquiring said image data via said probe;

said segmenting;

displaying said feedback via said display; and,

portability, as a hand-carriable unit.

17. The apparatus of claim 1, configured for, responsive to content of imaging dynamically acquired via said probe, issuing a user alert for halting said adjustment (S258).

18. The apparatus of claim 17, configured for detecting said halting (S260).

19. The apparatus of claim 18, further configured for, responsive to detecting that said halting has occurred, performing said segmenting (S272).

20. The apparatus of claim 1, configured for said segmenting in a relatively coarse mode and in a relatively fine mode and for making a volumetric measurement (S278) based on one or more segments formed as a result of the spatially finer segmenting, said making being responsive to completion of said spatially finer segmenting.

21. The apparatus of claim 1, an instruction to halt, as part of said feedback, being subject to an outcome of a comparison (321) between a current location, and current orientation, of said probe and a location and orientation derived from said segmenting.

22. The apparatus of claim 1, said feedback comprising a progressive indicator (178) of overall progress in acquiring a target view.

23. A computer readable medium embodying a computer program for guiding a user handling an imaging probe, said program including instructions executable by a processor to perform a plurality of acts, said plurality comprising the acts of:

dynamically arranging presentation of visual feedback for guiding manual adjustment (330), via said probe of a location, and orientation, associated with said probe, said arranging selectively based on comparisons between fields of view of said probe and respective results of segmenting image data acquired via said probe.

24. A user-guidance device (100) comprising at least one integrated circuit and configured for, via one or more of said at least one integrated circuit:

dynamically arranging presentation of visual feedback for guiding manual adjustment, via an imaging probe, of a location, and orientation, associated with said probe, said arranging selectively based on comparisons between fields of view of said probe and respective results of segmenting image data acquired via said probe.

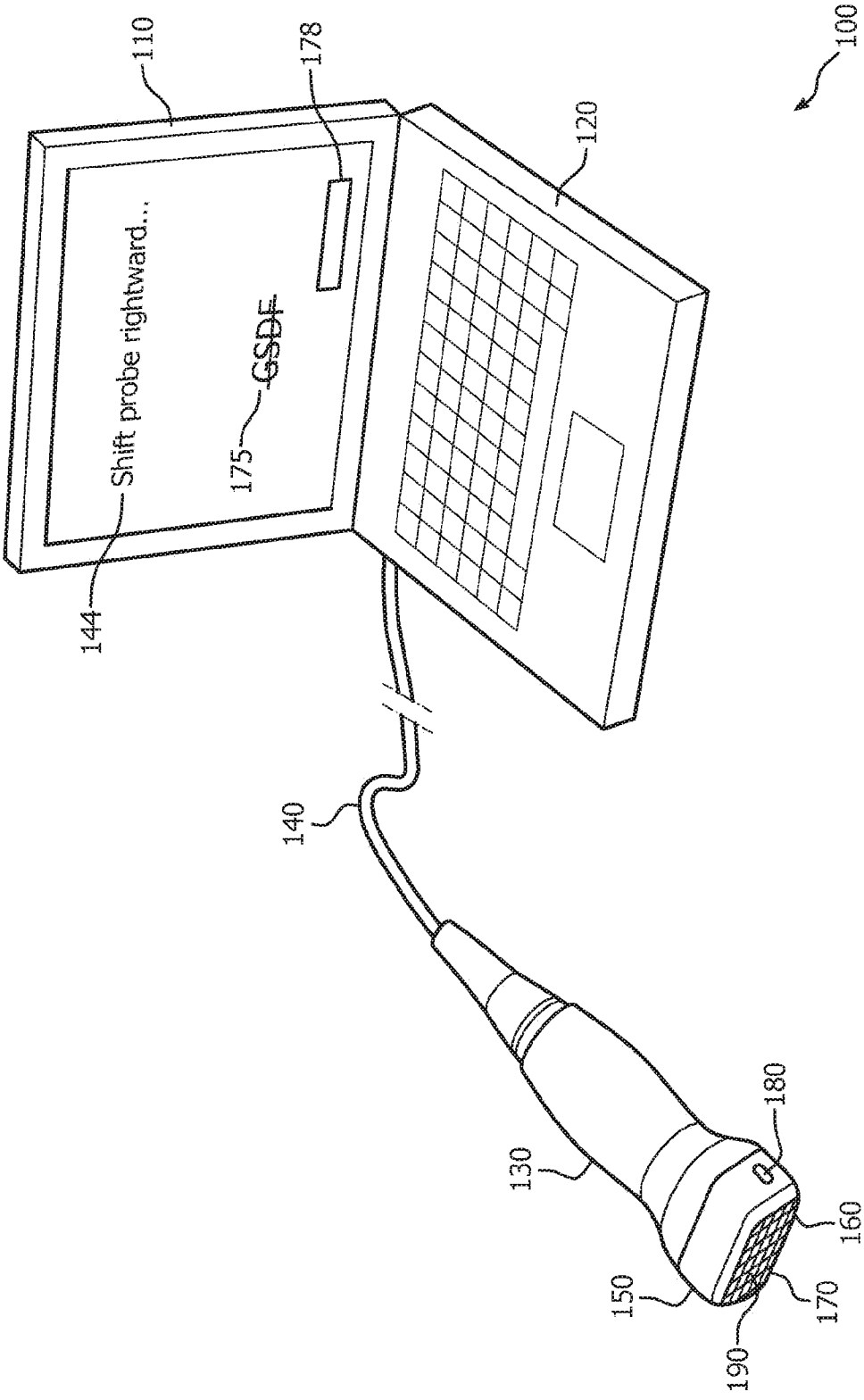

100
110
178
120
Shift probe rightward...
GSDF
175
144
140
130
180
160
150
170
190

FIG. 1

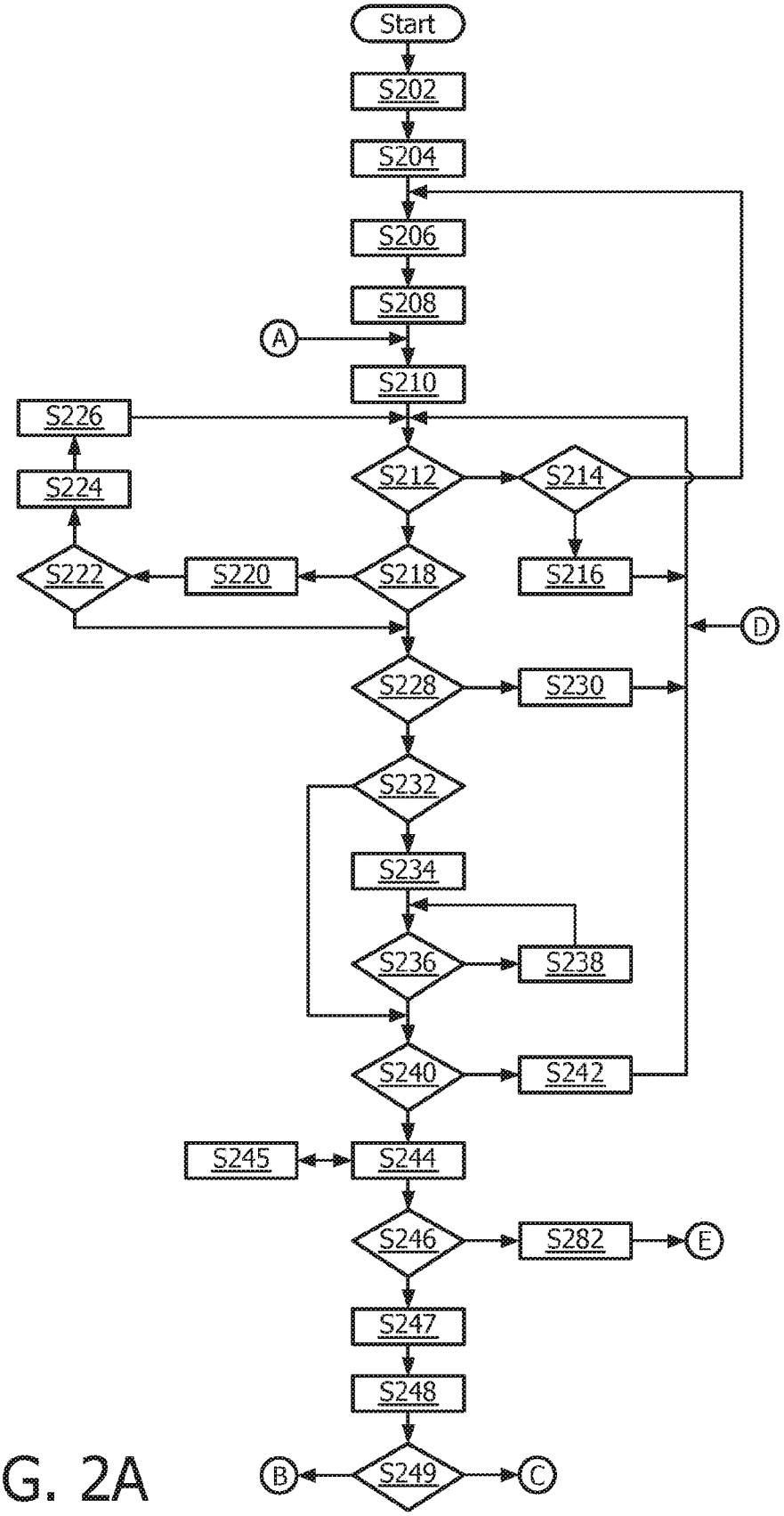

Start
S202
S204
S206
S208
A
S210
S226
S224
S212
S214
S222
S220
S218
S216
D
S228
S230
S232
S234
S236
S238
S240
S242
S245
S244
S246
S282
E
S247
S248
S249
B
C

FIG. 2A

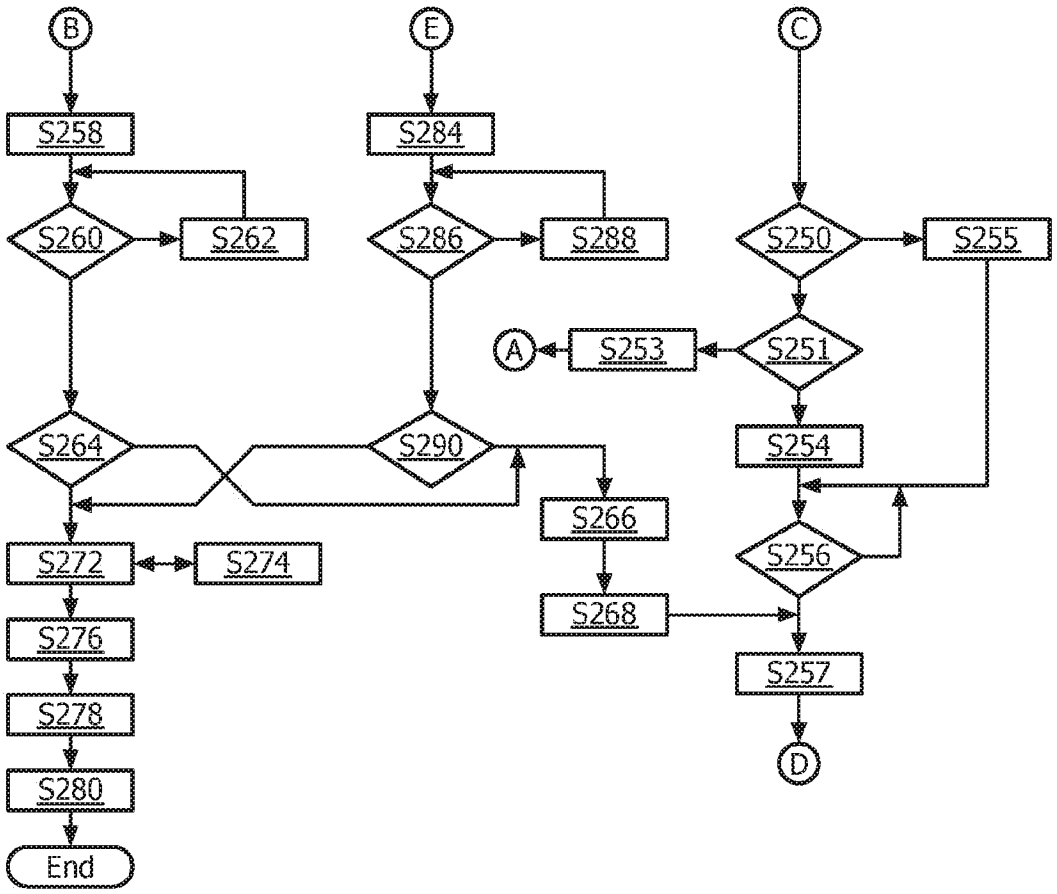

B
E
C
S258
S284
S260
S262
S286
S288
S250
S255
A
S253
S251
S264
S290
S254
S266
S272
S274
S256
S268
S276
S257
S278
S280
D
End

FIG. 2B

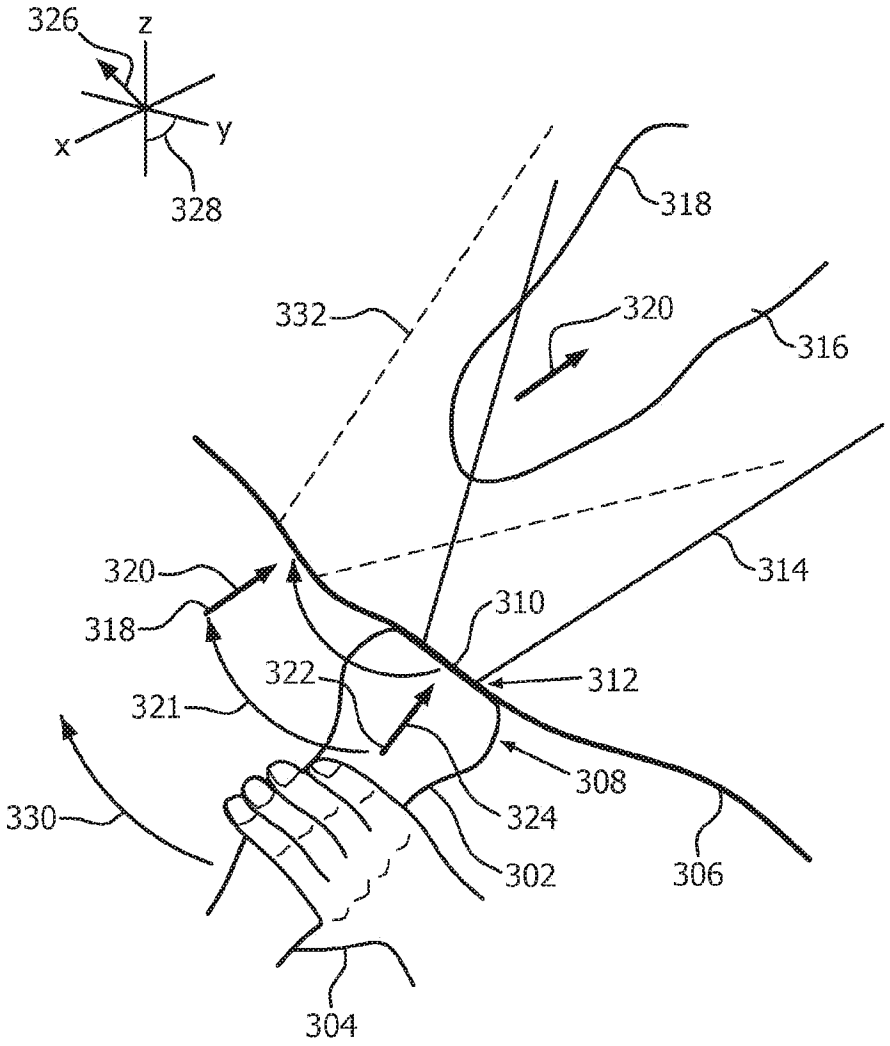

326
z
x
y
328
318
332
320
316
320
314
318
310
322
312
321
308
330
324
302
306
304

FIG. 3

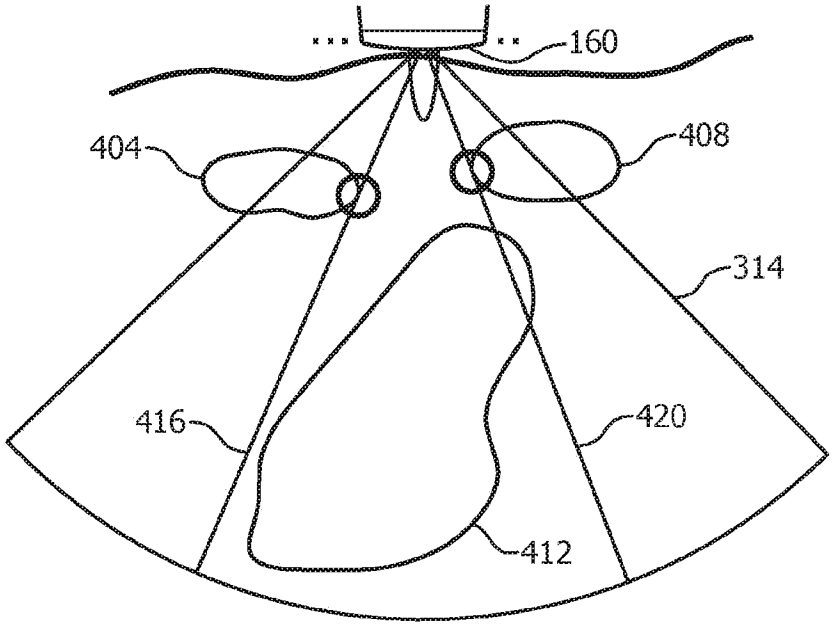


FIG. 4A

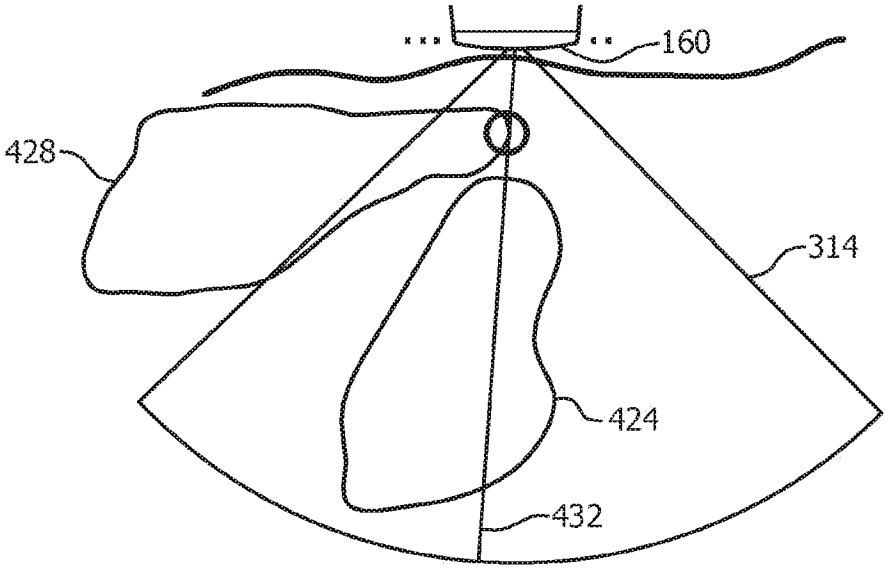


FIG. 4B

$$\rho(r,\theta) \equiv \frac{C[b_1(r,\theta),b_2(r,\theta)]}{\sqrt{C[b_1(r,\theta),b_1(r,\theta)]}\sqrt{C[b_2(r,\theta),b_2(r,\theta)]}}$$

where

$$C[b_k(r,\theta),b_l(r,\theta)] \equiv \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} w(r',\theta')b_k(r+r',\theta+\theta')b_l(r+r',\theta+\theta')dr'd\theta'$$

and where

$$b_k(r,\theta) = \sum_{j\in C_k} s_j(r,\theta)$$

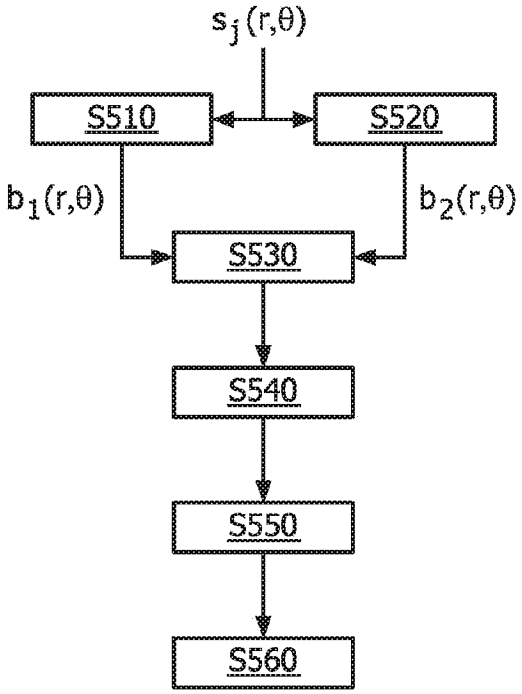


FIG. 5

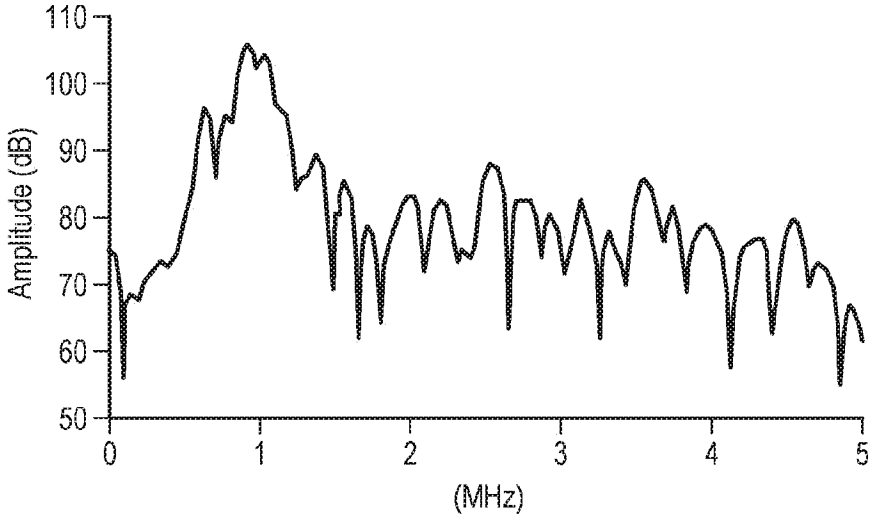

110
100
90
80
70
60
50
Amplitude (dB)
0
1
2
3
4
5
(MHz)

FIG. 6A

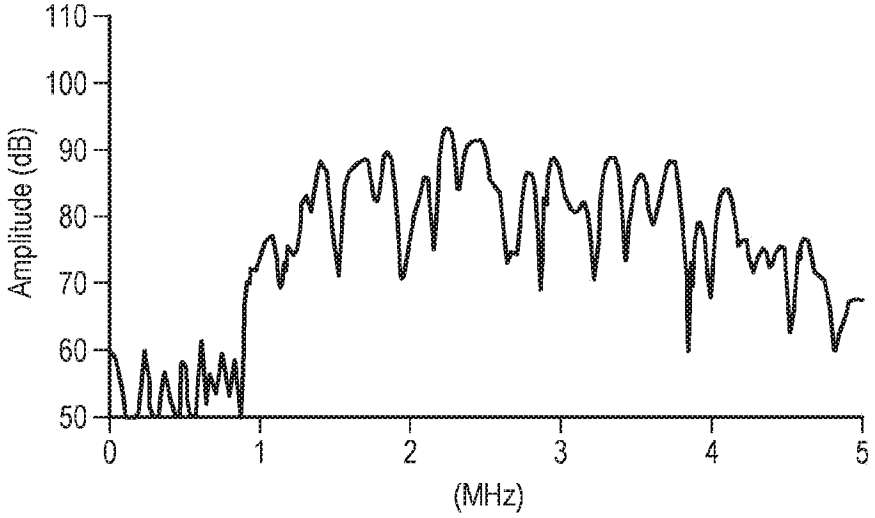

110
100
90
80
70
60
50
Amplitude (dB)
0
1
2
3
4
5
(MHz)

FIG. 6B

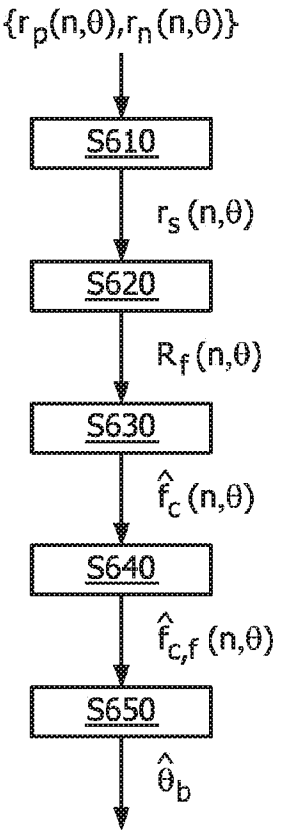

{r_p(n,θ),r_n(n,θ)}
S610
r_s(n,θ)
S620
R_f(n,θ)
S630
f̂_c(n,θ)
S640
f̂_c,f(n,θ)
S650
θ̂_b

FIG. 6C

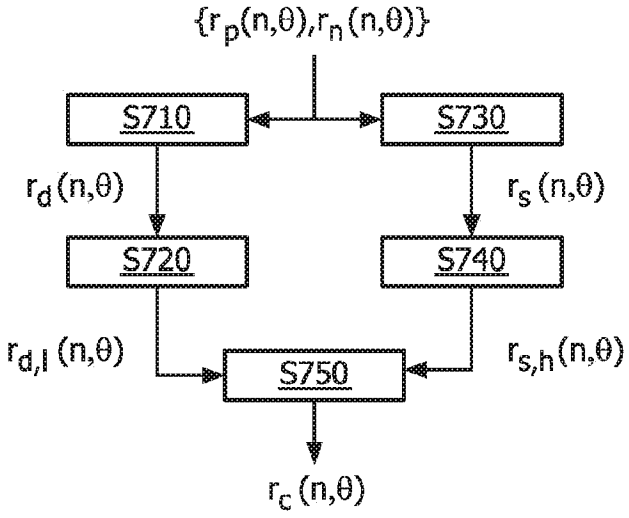

{r_p(n,θ),r_n(n,θ)}
S710
S730
r_d(n,θ)
r_s(n,θ)
S720
S740
r_d,l(n,θ)
r_s,h(n,θ)
S750
r_c(n,θ)

FIG. 7

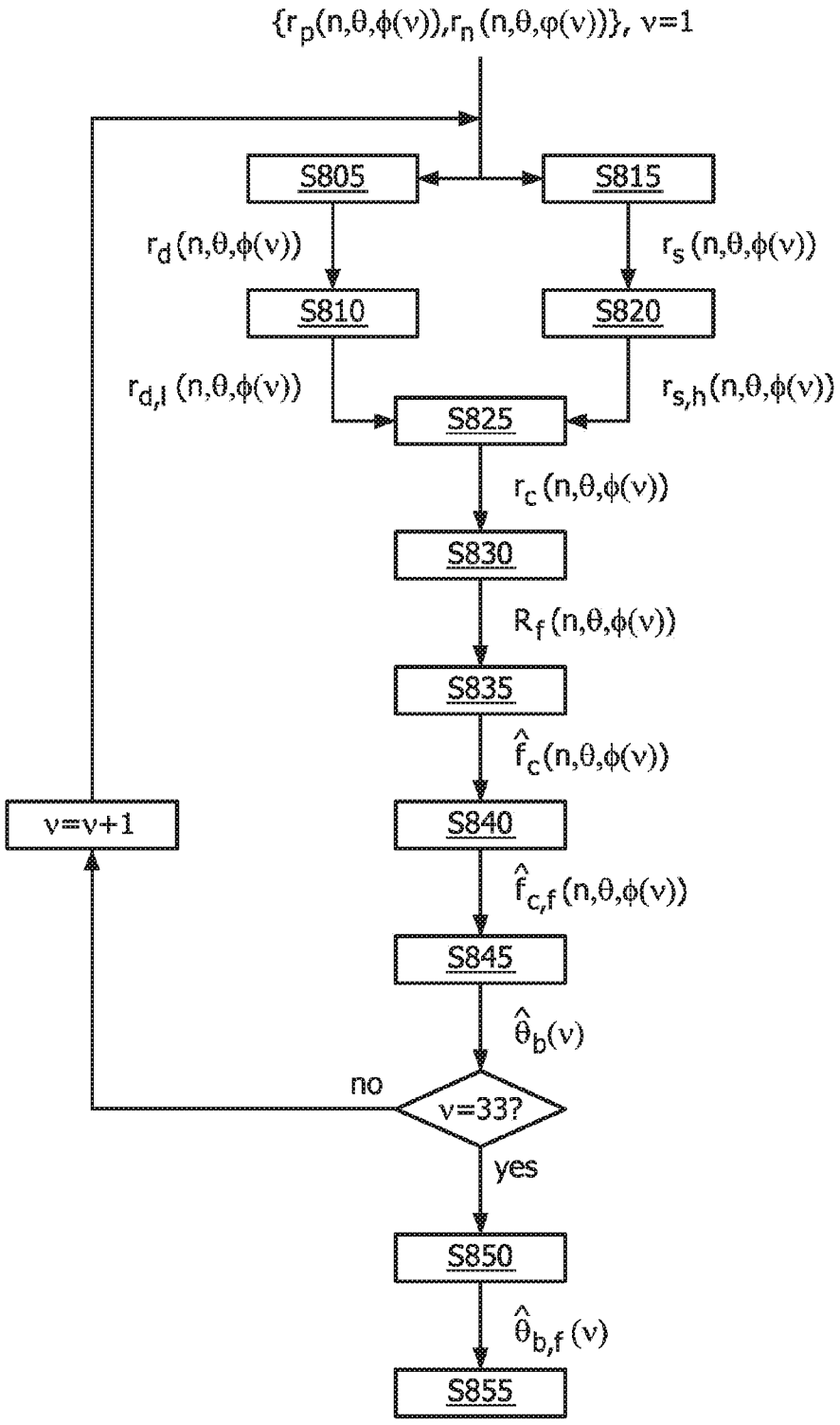

{r_p(n,θ,φ(ν)),r_n(n,θ,φ(ν))}, ν=1
S805
S815
r_d(n,θ,φ(ν))
r_s(n,θ,φ(ν))
S810
S820
r_d,l(n,θ,φ(ν))
r_s,h(n,θ,φ(ν))
S825
r_c(n,θ,φ(ν))
S830
R_f(n,θ,φ(ν))
S835
f̂_c(n,θ,φ(ν))
ν=ν+1
S840
f̂_c,f(n,θ,φ(ν))
S845
θ̂_b(ν)
no
ν=33?
yes
S850
θ̂_b,f(ν)
S855

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/06Q908

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B8/08 A61B8/00 G01S7/52 G06T7/00
ADD. A61B8/Q6

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)
A61B G01S G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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	US 2011/246129 A1 (ISHI KAWA RYO [JP] ET AL) 6 October 2011 (2011-10-06) abstract paragraph [0047] paragraph [0050] - paragraph [0126] paragraph [0135] - paragraph [0140] figures 1-2,4,7A-E, 9A-C, 10-11, 12A-B	1-24
X	JP 2010 088584 A (TOSHIBA CORP; TOSHIBA MEDICAL SYS CORP) 22 April 2010 (2010-04-22) abstract paragraph [0011] - paragraph [0018] paragraph [0036] - paragraph [0041] paragraph [0053] - paragraph [0063] figures 1,5-7	1-3, 10, 11, 14, 15, 23, 24

"/ - "

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"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
30 April 2014	09/05/2014

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, Fax: (+31-70) 340-3016	Artikis, T

1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2013/06Q908

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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A	US 2008/221446 A1 (WASHBURN MICHAEL JOSEPH [US] ET AL) 11 September 2008 (2008-09-11) abstract paragraph [0020] - paragraph [0051] figures 1-6	1-24
A	US 2010/324422 A1 (WANDA KOICHIRO [JP] ET AL) 23 December 2010 (2010-12-23) the whole document	1,23,24

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2013/06Q908

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 2567660 A2	13-03-2013
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		US 2010324422 A1	23-12-2010
		Wo 2010125715 A1	04-11-2010

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(25) Filing Language: English

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(30) Priority Data:
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(74) Agent: **CHARLTON, Graeme H. F.;** Unit 203A - 116 Geary Avenue, Toronto, Ontario M6H 4H1 (CA).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: ECHOCARDIOGRAPHIC IMAGE ANALYSIS

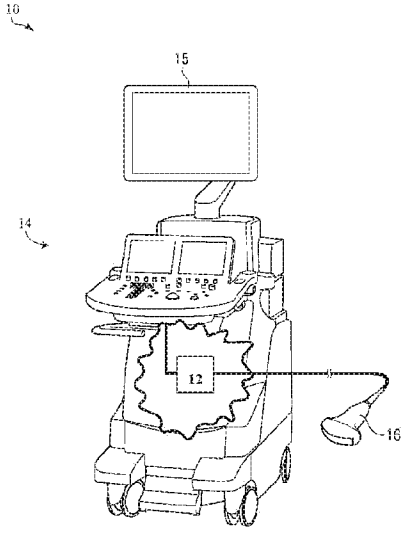


FIG. 1

(57) Abstract: A computer-implemented system for facilitating echocardiographic image analysis is disclosed. The system includes at least one processor configured to receive signals representing a first at least one echocardiographic image, associate the image with a first view category of a plurality of predetermined view categories, determine, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image, and produce signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image. The at least one processor may also be configured to do the above steps for a second at least one echocardiographic and a second view category that is different from the first view category image. Other systems, methods, and computer-readable media are also disclosed.

WO 2017/181288 A1

[Continued on next page]

Caption Health Ex1004

Published:
--- *with international search report (Art. 21(3))*

Caption Health Ex1004

ECHOCARDIOGRAPHIC IMAGE ANALYSIS

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. **62/325,779** entitled "PROCESS FOR IMAGING QUALITY ASSURANCE", filed on April **21, 2016,** which is hereby incorporated by reference herein in its entirety.

BACKGROUND

1. Field

Embodiments of this invention relate to echocardiographic image analysis and more particularly to echocardiographic image analysis for image quality assessment.

2. Description of Related Art

Despite advances in medicine and technology, cardiovascular disease remains the leading cause of mortality worldwide. Cardiac ultrasound, better known as echocardiography (echo), is the standard method for screening, detection, and monitoring of cardiovascular disease. This noninvasive imaging modality is widely available, cost-effective, and may be used for clinical measurement of anatomical features which may then be used for evaluation of cardiac structure and/or function. Some existing echocardiographic systems may be configured to provide feedback regarding general properties of captured images. However, this feedback may not assist echocardiographers in capturing high quality echocardiographic images for use in subsequent quantified clinical measurement of anatomical features.

SUMMARY

In accordance with one embodiment, there is provided a computer-implemented system for facilitating echocardiographic image analysis. The system includes at least one processor configured to, receive signals representing a first at least one echocardiographic image, associate the first at least one echocardiographic

image with a first view category of a plurality of predetermined echocardiographic image view categories, determine, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image, produce signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image, receive signals representing a second at least one echocardiographic image, associate the second at least one echocardiographic image with a second view category of the plurality of predetermined echocardiographic image view categories, said second view category being different from the first view category, determine, based on the second at least one echocardiographic image and the second view category, a second quality assessment value representing a view category specific quality assessment of the second at least one echocardiographic image, and produce signals representing the second quality assessment value for causing the second quality assessment value to be associated with the second at least one echocardiographic image.

In accordance with another embodiment, there is provided a computer-implemented system for training neural networks to facilitate echocardiographic image analysis. The system includes at least one processor configured to: receive signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined echocardiographic image view categories, receive signals representing expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images, and train the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the

neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

In accordance with another embodiment, there is provided a computer-implemented method of facilitating echocardiographic image analysis. The method includes receiving signals representing a first at least one echocardiographic image, associating the first at least one echocardiographic image with a first view category of a plurality of predetermined echocardiographic image view categories, determining, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image, producing signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image, receiving signals representing a second at least one echocardiographic image, associating the second at least one echocardiographic image with a second view category of the plurality of predetermined echocardiographic image view categories, said second view category being different from the first view category, determining, based on the second at least one echocardiographic image and the second view category, a second quality assessment value representing a view category specific quality assessment of the second at least one echocardiographic image, and producing signals representing the second quality assessment value for causing the second quality assessment value to be associated with the second at least one echocardiographic image.

In accordance with another embodiment, there is provided a computer-implemented method of training neural networks to facilitate echocardiographic image analysis. The method includes receiving signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined

echocardiographic image view categories, receiving signals representing expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images, and training the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

In accordance with another embodiment, there is provided a computer readable medium having stored thereon codes which when executed by at least one processor cause the at least one processor to perform any of the above methods.

In accordance with another embodiment, there is provided a system for facilitating echocardiographic image analysis. The system includes means for receiving signals representing a first at least one echocardiographic image, means for associating the first at least one echocardiographic image with a first view category of a plurality of predetermined echocardiographic image view categories, means for determining, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image, means for producing signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image, means for receiving signals representing a second at least one echocardiographic image, means for associating the second at least one echocardiographic image with a second view category of the plurality of predetermined echocardiographic image view categories, said second view category being different from the first view

category, means for determining, based on the second at least one echocardiographic image and the second view category, a second quality assessment value representing a view category specific quality assessment of the second at least one echocardiographic image, and means for producing signals representing the second quality assessment value for causing the second quality assessment value to be associated with the second at least one echocardiographic image.

In accordance with another embodiment, there is provided a system for training neural networks to facilitate echocardiographic image analysis. The system includes means for receiving signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined echocardiographic image view categories, means for receiving signals representing expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images, and means for training the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

Other aspects and features of embodiments of the invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the invention,

Figure 1 is a schematic view of a system for facilitating echocardiographic image analysis in accordance with various embodiments of the invention;

Figure 2 is a schematic view of an echocardiographic image analyzer of the system of Figure 1 including a processor circuit in accordance with various embodiments of the invention;

Figure 3 is a flowchart depicting blocks of code for directing the analyzer of the system of Figure 1 to perform image analysis functions in accordance with various embodiments of the invention;

Figure 4 is a representation of an exemplary image file that may be used in the system shown in Figure 1;

Figure 5 is a flowchart depicting blocks of code that may be included in the flowchart of Figure 3 in accordance with various embodiments of the invention;

Figure 6 is a representation of an exemplary view category determining neural network that may be used in the system shown in Figure 1;

Figure 7 is a representation of an exemplary view category record that may be used in the system shown in Figure 1;

Figure 8 is a representation of an exemplary image quality assessment neural network that may be used in the system shown in Figure 1;

Figure 9 is a representation of an exemplary common neural network record that may be used in the system shown in Figure 1;

Figure 10 is a representation of an exemplary view category specific neural network record that may be used in the system shown in Figure 1;

Figure 11 is a flowchart depicting blocks of code that may be included in the flowchart of Figure 3 in accordance with various embodiments of the invention;

Figure 12 is a representation of an exemplary quality assessment record that may be used in the system shown in Figure 1;

Figure 13 is a representation of a display that may be presented by a display of a user interface system included in the system shown in Figure 1 in accordance with embodiments of the invention;

Figure 14 is a schematic view of a system for training neural networks to facilitate echocardiographic image analysis in accordance with various embodiments of the invention;

Figure 15 is a schematic view of a neural network trainer of the system of Figure 1 including a processor circuit in accordance with various embodiments of the invention;

Figure 16 is a flowchart depicting blocks of code for directing the trainer of the system of Figure 14 to perform image assessment neural network training functions in accordance with various embodiments of the invention;

Figure 17 is a representation of an exemplary training image file that may be used in the system shown in Figure 1;

Figure 18 is a representation of an exemplary expert quality assessment record that may be used in the system shown in Figure 1;

Figure 19 is a schematic view of a system for facilitating echocardiographic image analysis in accordance with various embodiments of the invention;

Figure 20 is a representation of an exemplary view category determining neural network that may be used in the system shown in Figure 1; and

Figure 21 is a representation of an exemplary image quality assessment neural network that may be used in the system shown in Figure 1.

DETAILED DESCRIPTION

Referring to Figure 1, according to one embodiment of the invention, there is provided a system 10 for facilitating echocardiographic image analysis. The system 10 includes a computer-implemented echocardiographic image analyzer 12 in communication with a user interface system 14 and a transducer 16. In the embodiment shown, the analyzer 12 is also in communication with a network 126 and the user interface system 14 includes a display 15. In various embodiments, the system 10 may be incorporated within an ultrasound machine or scanner. For example, in various embodiments, the system 10 may be included in an ultrasound machine generally similar to a Philips™ IE33 Ultrasound machine or a mobile ultrasound machine made by Clarius™.

In operation, an operator of the system 10, who may be for example, an echocardiographer, technician, or sonographer, may manipulate the transducer 16 on or around a patient, and the analyzer 12 may communicate with the transducer 16 and receive signals representing echocardiographic images of the patient. The analyzer 12 may store representations of the echocardiographic

images in memory and/or output representations of the images on the display **15.** The analyzer **12** may determine a quality assessment value representing a quality assessment of at least one echocardiographic image and produce signals for causing the quality assessment value to be associated with the at least one echocardiographic image. For example, the analyzer **12** may be configured to produce signals for causing the display **15** to display a sequence of echocardiographic images captured by the analyzer **12** in near real-time, in association with the determined quality assessment value for the images. In some embodiments, the quality assessment value may be determined for a single image. In some embodiments, the quality assessment value may be determined for a sequence of images or video, which may be referred to herein as an echo cine.

In various embodiments, this near real-time feedback to the operator may help the operator improve their skills and/or improve image quality for subsequently captured images. For example, in some embodiments, the operator may, in response to viewing a low quality assessment value on the display **15,** adjust positioning of the transducer and/or adjust image capture parameters, such as, for example, depth, focus, gain, frequency, and/or another parameter which may affect image quality in the system **10.** The operator may make such adjustments until a high quality assessment value is provided on the display **15,** for example, at which point the operator may be confident that the echocardiographic images captured are suitable for subsequent quantified clinical measurement of anatomical features and/or to assist in diagnosing a medical condition or a characteristic of the heart.

In various embodiments, the operator may wish to capture echocardiographic images for various views or anatomical planes since multiple views may be required in order to perform certain quantified clinical measurement of anatomical features and/or to assist in diagnosing a medical condition or a characteristic of the heart. In some embodiments, the views required for certain measurements

or diagnoses may be chosen from standard 2D echocardiographic views. For example, the operator may wish to capture echocardiographic images of multiple standard 2D echocardiographic views to facilitate image analysis to determine ejection fraction for the patient's heart. For example, in some embodiments, a 2D Method of Simpson may be used to determine ejection fraction, which requires images from AP2 (apical 2-chamber view) and AP4 (apical 4-chamber view).

In various embodiments, some of the desirable characteristics for each of the different views may differ and so it may be desirable to determine quality assessment values for the echocardiographic images in different ways, depending on what view the echocardiographic images are meant to represent. Accordingly, the analyzer 12 may be configured to associate each set of echocardiographic images with a view category of a plurality of predetermined echocardiographic image view categories and to select and apply a function to the set of images to determine the quality assessment value wherein the function selected depends on the view category associated with the set of images. In some embodiments, the analyzer 12 may be configured to automatically determine the view category to associate with the set of images by analyzing the set of images. In some embodiments, the analyzer 12 may be configured to receive operator input (via the user interface system 14, for example), which sets the view category with which to associate the image.

Applying the function to a set of images may involve inputting the set of images into a view category specific image assessment neural network which is configured to output a view category specific quality assessment value. The quality assessment value may represent an assessment of suitability of the associated set of echocardiographic images for quantified clinical measurement of anatomical features.

Image Analyzer - Processor Circuit

Referring now to Figure 2, a schematic view of the analyzer 12 of the system 10 shown in Figure 1 according to an embodiment is shown. As discussed above, in various embodiments, the analyzer 12 may be included in an ultrasound machine, for example.

Referring to Figure 2, the analyzer 12 includes a processor circuit including an analyzer processor 100 and a program memory 102, a storage memory 104, and an input/output (I/O) interface 112, all of which are in communication with the analyzer processor 100. In various embodiments, the analyzer processor 100 may include one or more processing units, such as for example, a central processing unit (CPU), a graphical processing unit (GPU), and/or a field programmable gate arrays (FPGA). In some embodiments, any or all of the functionality of the analyzer 12 described herein may be implemented using one or more FPGAs.

The I/O interface 112 includes an interface 120 for communicating with the transducer 16 and an interface 122 for communicating with the user interface system 14 shown in Figure 1. In some embodiments, the I/O interface 112 may also include an interface 124 for facilitating networked communication through the network 126. In some embodiments, any or all of the interfaces 120, 122, or 124 may facilitate a wireless or wired communication.

In some embodiments, the I/O interface 112 may include a network interface device or card with an input/output for connecting to the network 126, through which communications may be conducted with devices connected to the network 126, such as the neural network trainer (as shown at 502 in Figure 14), for example.

In some embodiments, each of the interfaces shown in Figure 2 may include one or more interfaces and/or some or all of the interfaces included in the I/O interface 112 may be implemented as combined interfaces or a single interface.

In some embodiments, where a device is described herein as receiving or sending information, it may be understood that the device receives signals representing the information via an interface of the device or produces signals representing the information and transmits the signals to the other device via an interface of the device.

Processor-executable program codes for directing the analyzer processor **100** to carry out various functions are stored in the program memory **102.** Referring to Figure **2**, the program memory **102** includes a block of codes **160** for directing the analyzer **12** to perform image capture functions and analysis functions and a block of codes **162** for directing the analyzer processor **100** to perform image reconstruction functions. In this specification, it may be stated that certain encoded entities such as applications or modules perform certain functions. Herein, when an application, module or encoded entity is described as taking an action, as part of, for example, a function or a method, it will be understood that at least one processor (e.g. the analyzer processor **100)** is directed to take the action by way of programmable codes or processor-executable codes or instructions defining or forming part of the application.

The storage memory **104** includes a plurality of storage locations including location **140** for storing image data, location **142** for storing view category data, location **144** for storing view category neural network parameter data, location **146** for storing image assessment neural network parameter data, and location **148** for storing determined quality assessment value data. In various embodiments, the plurality of storage locations may be stored in a database in the storage memory **104.**

In various embodiments, the blocks of codes **160** and **162** may be integrated into a single block of codes and/or each of the blocks of code **160** and **162** may include one or more blocks of code stored in one or more separate locations in program memory **102.** In various embodiments, any or all of the locations **140,**

142, 144, and 146 may be integrated and/or each may include one or more separate locations in the storage memory 104.

Each of the program memory 102 and storage memory 104 may be implemented as one or more storage devices including random access memory (RAM), a hard disk drive (HDD), a solid-state drive (SSD), a network drive, flash memory, a memory stick or card, any other form of non-transitory computer-readable memory or storage medium, and/or a combination thereof. In some embodiments, the program memory 102, the storage memory 104, and/or any portion thereof may be included in a device separate from the analyzer 12 and in communication with the analyzer 12 via the I/O interface 112, for example.

In various embodiments, other device components described herein, such as memory, program memory, blocks of code, storage memory, locations in memory, and/or I/O interfaces, may be implemented generally similarly to as described above for the analyzer 12.

Image analysis

Referring now to Figure 3, a flowchart depicting blocks of code for directing the analyzer processor 100 shown in Figure 2 to perform image analysis functions in accordance with one embodiment is shown generally at 200. The blocks of code included in the flowchart 200 may be encoded in the block of codes 160 of the program memory 102 shown in Figure 2 for example.

Referring to Figure 3, the flowchart 200 begins with block 202 which directs the analyzer processor 100 shown in Figure 2 to receive signals representing at least one echocardiographic image. In various embodiments, block 202 may direct the analyzer processor 100 to obtain image data via the transducer 16. For example, block 202 may direct the analyzer processor 100 to execute blocks included in the block of codes 162 of the program memory 102, to cause the analyzer processor 100 to receive signals representing at least one

echocardiographic image from the transducer **16** shown in Figure **1** via the interface **120** of the I/O interface. The blocks in the block of codes **162** of the program memory **102** may direct the analyzer processor **100** to interpret raw ultrasound echo waveforms received from the transducer **16** into fully formed images. The block of codes **162** may direct the analyzer processor **100** to use an image reconstruction algorithm to filter the waveforms, amplify the waveforms, time delay and sum the waveforms, demodulate the summed waveforms, and/or compress amplitudes of the summed waveforms. The block of codes **162** may direct the analyzer processor **100** to finally perform a scan-conversion of the waveforms to derive an image in Cartesian coordinates with pixels of known size in millimeters.

Block **202** may direct the analyzer processor **100** to store a representation of the received at least one echocardiographic image in the location **140** of the storage memory **104.**

In some embodiments, the analyzer **12** may be configured to receive and analyze respective sequences of echocardiographic images (echo cines). Accordingly, block **202** may direct the analyzer processor **100** to receive a sequence of images. Block **202** may direct the analyzer processor **100** to store a set of image files representing the sequence of images in the location **140** of the storage memory **104.** An exemplary image file which may be included in the set of image files received at block **202** is shown at **240** in Figure **4.**

Referring to Figure **4**, the image file **240** includes an image identifier field **242** for storing a unique identifier for identifying the image data stored in the image file **240**, an image group identifier field **243** for storing an identifier common to a set of image files which are to be analyzed together (e.g. frames of an echo cine), and an image data field **244** for storing information representing an image. In some embodiments, for example, the image file **240** may store a PNG file type representation of the echocardiographic image.

In some embodiments, block **202** may direct the analyzer processor **100** to receive and store a plurality of image files generally similar to the image file **240** shown in Figure **4** in the location **140** of storage memory **104** for analysis together during execution of block **206** of the flowchart **200** shown in Figure **3**. For example, in some embodiments, the analyzer **12** may be configured to analyze a sequence of **20** images during execution of block **206** of the flowchart **200** and so block **202** may direct the analyzer processor **100** to store the received images as groups of **20** image files, each generally similar in format to the image file **240** shown in Figure **4** and sharing a common value in their image group identifier fields.

Referring back to Figure **4**, block **204** then directs the analyzer processor **100** to associate the at least one echocardiographic image received at block **202** with a view category of a plurality of predetermined echocardiographic image view categories. In some embodiments, block **204** may direct the analyzer processor **100** to associate the at least one echocardiographic image with the view category by storing in the location **142** of the storage memory **104** a view category record that associates the view category with the received at least one echocardiographic image.

In various embodiments, associating the at least one echocardiographic image with a particular view category may assist with subsequent quality assessment of the echocardiographic images which may be performed at block **206** of the flowchart **200** shown in Figure **3**. In some embodiments, the view category that is associated with the at least one echocardiographic image may be associated with a function which can be applied to the at least one echocardiographic image to assess the quality of the at least one echocardiographic image. For example, in some embodiments, different analyses may be applied to a set of echocardiographic images, depending on which view category set of echocardiographic images falls within.

In some embodiments, the view categories with which the echocardiographic images may be associated may be chosen from a plurality of standard view categories. For example, the standard view categories may include the following 2D echocardiographic imaging plane views: AP2 (apical 2-chamber view), AP3 (apical 3-chamber view), AP4 (apical 4-chamber view), PSAXA (parasternal short axis at aortic valve level view) and PSAXPM (parasternal short axis at papillary muscle level view). In various embodiments, the standard view categories may include further or alternative view categories, such as, for example, any or all of the following 2D echocardiographic imaging plane view categories: parasternal long axis (PLAX), apical 5 chamber (AP5), subcostal view, aortic arch, or right parasternal. In various embodiments, with any of these views, an operator may switch the system 10 to Doppler and obtain 2D Color Doppler or Power Doppler, Continuous Wave Doppler and Duplex Doppler. In various embodiments, each view category may be associated with a different function for assessing quality of images.

In some embodiments, the block 204 may direct the analyzer processor 100 to determine which of the plurality of predetermined view categories the at least one echocardiographic image falls within before associating the image with the view category.

For example, in some embodiments, this determination may be made automatically, such as by applying a function to the received at least one echocardiographic image. Referring to Figure 5, there is shown at 260 a flowchart representing blocks of codes which may be included in the block 204 of the flowchart 200 shown in Figure 3, in accordance with various embodiments. The blocks of codes included in the flowchart 260 may direct the analyzer processor 100 to apply one or more view categorization functions to the at least one echocardiographic image received at block 202 to determine which of a

plurality of predetermined view categories the at least one echocardiographic image falls within.

Referring to Figure 5, the flowchart 260 begins with block 262 which directs the analyzer processor 100 to receive signals representing parameters defining an image view category determining neural network. The image view category determining neural network may be configured to take the at least one echocardiographic images received at block 202 as an input and to output an indication of what image view category should be associated with the input at least one echocardiographic image.

Block 262 may direct the analyzer processor 100 to receive parameters defining the image view category determining neural network from the location 144 of the storage memory shown in Figure 2, for example. The parameters defining the view category determining neural network may have been previously determined during training of the neural network and stored in the location 144 of the storage memory 104.

In some embodiments, a neural network trainer (for example, as shown at 502 in Figure 14) may have previously determined architecture and weight and bias values for the view category determining neural network. Blocks of code included in the block of codes 160 of the program memory 102 may have previously directed the analyzer processor 100 to receive signals representing the architecture and weight and bias values via the interface 124 of the I/O interface 112 and to store a view category neural network record representing the architecture and the weight and the bias values in the location 144 of the storage memory 104.

In some embodiments, the view category neural network record stored in the location 144 of the storage memory may represent a neural network having convolutional layers, max-pooling layers, one or more fully connected layers, one

or more Long Short Term Memory (LSTM) layers, and a softmax layer acting as an output layer and having outputs which represent a likelihood that an input set of echocardiographic images falls within a particular view category. In some embodiments, the softmax outputs may indicate whether a set of echocardiographic images falls within one of the following standard 2D echocardiographic views, for example: AP2, AP3, AP4, PSAXA, or PSAXPM. An exemplary view category determining neural network that may be represented by the view category neural network record stored in the location 144 of the storage memory, in accordance with some embodiments, is shown at 900 in Figure 6. The view category determining neural network takes as input, a sequence of 20 echocardiographic images, and outputs respective indicators that represent respective likelihoods that an input sequence of 20 echocardiographic images fall within a particular view category.

Referring back to Figure 5, block 264 of the flowchart 260 then directs the analyzer processor 100 to apply the view category determining neural network defined by the parameters received at block 262 to the at least one echocardiographic image received at block 202 of the flowchart 200 shown in Figure 3. Block 264 may direct the analyzer processor 100 to use the image data fields 244 of the 20 image files stored in the location 140 of the storage memory 104 at block 202 as input data for the view category determining neural network defined by the view category neural network record taken from the location 144 of the storage memory 104.

In some embodiments, the output of the neural network may be a softmax output which provides respective indicator values representing whether the set of images received at block 202 are AP2, AP3, AP4, PSAXA, and PSAXPM. In one embodiment, these indicator values may be 0.11, 0.05, 0.7, 0.11, 0.03, respectively, for example. In various embodiments, although the indicator values sum to 1.00, these values may not represent true probabilities that the at least

one image received is of a particular view, as there may be a possibility that the at least one image is none of the views.

In some embodiments, block **264** of the flowchart **260** shown in Figure **5** may direct the analyzer processor **100** to use a **GPU** included in the analyzer processor **100** to perform the neural network calculations. In some embodiments, use of the **GPU** instead of a general **CPU** may reduce the execution time for block **264**.

Referring to Figure **5**, block **266** of the flowchart **260** then directs the analyzer processor **100** to associate the at least one echocardiographic image received at block **202** of the flowchart **200** shown in Figure **3** with a view category based on the output of the neural network. In some embodiments, block **266** may direct the analyzer processor **100** to associate the at least one echocardiographic image with a view category that corresponds to the highest softmax output determined at block **264** of the flowchart **260** shown in Figure **5**. For example, with a softmax output which provides respective indicators for **AP2**, **AP3**, **AP4**, **PSAXA**, and **PSAXPM** of **0.11**, **0.05**, **0.7**, **0.11**, **0.03**, block **266** may direct the analyzer processor **100** to determine which output is the largest (i.e., the **AP4** view category output) and to associate the images with that output.

Block **266** may direct the analyzer processor **100** to associate the at least one echocardiographic image received at block **202** of the flowchart **200** shown in Figure **3** with the **AP4** view category by generating a view category record **300** as shown in Figure **7** and storing the view category record **300** in the location **142** of the storage memory **104**. Referring to Figure **7**, the view category record **300** includes a view category identifier field **302** for storing an identifier for identifying the view category to be associated with the echocardiographic images and an image group identifier field **304** for storing an identifier for identifying the images with which the view category is to be associated.

In some embodiments, block **204** of the flowchart **200** shown in Figure **3** may not include the blocks depicted in the flowchart **260,** but rather an operator of the system **10** shown in Figure **1** may input a view category by which the operator wishes to have the received echocardiographic images assessed. For example, in some embodiments, the operator may input a desired view category using an input device such as a keyboard and/or pointer or mouse of the user interface system **14.** In such embodiments, block **204** may direct the analyzer processor **100** to receive operator input representing the view category via the interface **122** of the I/O interface **112** shown in Figure **2.** Block **204** may direct the analyzer processor **100** to, in response to receiving the input, generate and store a view category record in the location **142** of the storage memory **104** associating the received at least one echocardiographic image with the view category that the operator provided as input.

Referring back to Figure **3,** after block **204** has been executed, the at least one echocardiographic image received at block **202** may now be associated with a view category.

The flowchart **200** continues at block **206,** which directs the analyzer processor **100** to determine, based on the at least one echocardiographic image received at block **202** and the view category associated with the echocardiographic image, a quality assessment value representing a view category specific quality assessment of the at least one echocardiographic image.

In some embodiments, each of the view categories may be associated with a function which can be applied by the analyzer to the received at least one echocardiographic image to generate the quality assessment value. In some embodiments, block **206** may direct the analyzer processor **100** to select a function to apply to the at least one echocardiographic image based on the view category associated with the received at least one echocardiographic image.

In various embodiments, applying the function may involve applying a neural network to the at least one echocardiographic image. A neural network is a non-linear model and so, in some embodiments, by using a neural network to analyze the echocardiographic images, the analyzer **12** may facilitate better functioning, for example, when there is variability in the echocardiographic image data than may be possible when analysis of the echocardiographic image relies on an average template or atlas with average shape.

Referring to Figure **2**, in various embodiments, a plurality of sets of parameters, each set defining a neural network, may be stored in the location **146** of the storage memory **104** shown in Figure **2** and each of the sets of parameters may be associated with a view category to indicate that the set of parameters defines a neural network that is to be applied to echocardiographic images which are associated with that view category.

In some embodiments, the parameters may define neural network architectures and may include weight and bias values for the neural networks. A neural network trainer (for example, as shown at **502** in Figure **14**) may have previously determined the neural network architecture and/or the weight and bias values for each of the neural networks and provided these values to the analyzer **12**. Blocks of code included in the block of codes **160** of the program memory **102** may have previously directed the analyzer processor **100** to receive signals representing the neural network architecture and the weight and bias values via the interface **124** of the I/O interface **112**, for example, and to store this information in image assessment neural network records in the location **146** of the storage memory **104**.

For example, in some embodiments, the image assessment neural network records stored in the location **146** of the storage memory **104** may represent the neural network shown at **360** in Figure **8**. Referring to Figure **8**, the neural network **360** includes **5** image quality assessment neural networks, each

including the same shared layers **362** but including a different set of view category specific layers **370, 372, 374, 376,** and **378.** In various embodiments, the shared layers **362** and the view category specific layers **370, 372, 374, 376,** and **378** may each be considered neural networks and it will be understood that a neural network may include more than one neural network within. Each of the **5** image quality assessment neural networks takes as an input a sequence of **20** echocardiographic images **380** and outputs a view category specific quality assessment value.

The neural network **360** shown in Figure **8** is a deep neural network and a regression model, consisting of convolutional (conv), pooling (pool), and Long Short Term Memory (LSTM) layers, and in various embodiments, may be simultaneously trained to estimate the quality of a sequence of **20** echocardiographic images for any of five standard **2D** echocardiographic views, **AP2, AP3, AP4, PSAXA**, and **PSAXPM** by generating respective view category specific quality assessment values.

The neural network architecture, depicted in Figure **8,** represents a multi-stream network, i.e., five regression models that share weights across the first few common shared layers **362.** Each stream of the network has its own view-specific layer **370, 372, 374, 376,** and **378** and has been trained based on the mean absolute error loss function, via a stochastic gradient-based optimization algorithm, to minimize the absolute difference between normalized quality assessment values assigned by a trained echocardiographer to training images, as discussed further below, and the generated quality assessment values.

In the embodiment shown, all conv layers have kernels with the size of **3X3,** which may, for example, follow the VGG architecture discussed in Simonyan, K., Zisserman, **A.:** Very Deep Convolutional Networks for Large-Scale Image Recognition. International Conference on Learning Representations (ICRL) pp. **1-14 (2015),** with the number of kernels doubling for deeper conv layers, i.e., from

8 to 32 kernels. In some embodiments, the conv layers may extract hierarchical features in the image, with the first three shared layers 362 modeling high level spatial correlations, and the next two conv layers of the view category specific layers 364 focusing on view-specific quality features. In some embodiments, activation functions of the conv layers may be Rectified Linear Units (ReLUs).

Referring still to Figure 8, in various embodiments, the pool layers of the neural network 360 may be 2X2 max-pooling with a stride of 2 to facilitate selection of superior invariant features and divide the input feature-map size in half in both dimensions to reduce feature variance and train more generalized models. The conv and pool layers are applied to each image of an input echo cine, independently.

The output feature map of the last pool layer is flattened and sent to an LSTM unit, a type of Recurrent Neural Networks (RNN) that uses a gated technique to selectively add or remove information from the cell state. Each set of view category specific layers 370, 372, 374, 376, and 378 in the neural network 360 shown in Figure 8 uses a single LSTM cell to analyze 20 feature-sets corresponding to the 20 consecutive input images. The LSTM layer uses hard sigmoid functions for inner and output activations.

In some embodiments, the image assessment neural network records stored in the location 146 of the storage memory 104 which represent the neural network 360 may include a common neural network record representing the shared layers 362 and a plurality of different view category specific neural network records representing the sets of view category specific layers 370, 372, 374, 376, and 378.

A representation of a portion of an exemplary common neural network record for storing a set of parameters defining the shared layers 362 of the neural network 360 shown in Figure 8, is shown at 320 in Figure 9. Referring to Figure 9, the

common neural network record **320** includes first, second, third, fourth, fifth and sixth sets of fields **324**, **326**, **328**, **330**, **332**, and **334** defining the parameters for the six layers of the shared layers **362** of the neural network **360** shown in Figure **8**. For ease of reference, not all kernel fields of the common neural network record **320** are shown in Figure **9** and the content of the kernels is shown as [...], though it will be understood that there are **8** kernels in layer **1**, **16** kernels in layer **3** and **32** kernels in layer **5** and that each kernel field stores a **3X3** matrix of values.

A representation of a portion of an exemplary view category specific neural network record for storing a set of parameters defining the set of view category specific layers **374** of the neural network **360** shown in Figure **8**, is shown at **340** in Figure **10**. Referring to Figure **10**, the view category specific neural network record **340** includes a view category identifier field **342** for storing a view category identifier identifying which view category the record is associated with and seventh, eighth, ninth, and tenth sets of fields **344**, **346**, **348**, and **350** for storing parameters defining the set of view category specific layers **374** of the neural network **360** shown in Figure **8**. For ease of reference, not all kernel fields are shown in Figure **10** and the content of the kernels and LSTM parameters are shown as [...], though it will be understood that there are **32** kernels in layer **7** and **32** kernels in layer **9** and that each kernel field stores a **3X3** matrix of values and the LSTM parameter fields store values defining the parameters of the LSTM.

Additional neural network records representing the sets of shared layers **370**, **372**, **376** and **378** having generally the same format as the view category specific neural network record **340** shown in Figure **10** may also be stored in the location **146** of the storage memory **104**. Thus, each of the image view categories **AP2**, **AP3**, **AP4**, **PSAXA**, and **PSAXPM** may be associated with a view category specific neural network record stored in the location **146** of the storage memory **104**.

In various embodiments, splitting the neural network 360 into a common portion and view category specific portions may facilitate more efficient training of the neural networks. In some embodiments, splitting the neural network 360 into a common portion and view category specific portions may result in requiring fewer learning parameters than would be required if using fully separate neural networks, which may help facilitate easier transferring of a neural network to a new machine, and/or may reduce memory usage.

Referring now to Figure 11, there is shown at 400 a flowchart representing blocks of codes which may be included in the block 206 of the flowchart 200 shown in Figure 3, in accordance with various embodiments. The blocks included in the flowchart 400 may direct the analyzer processor 100 to determine which of the sets of quality assessment parameters is associated with the same view category as the at least one echocardiographic image received at block 202 and to apply a function based on that set of quality assessment parameters.

The flowchart 400 begins with block 402 which directs the analyzer processor 100 to determine that a set of assessment parameters of the sets of assessment parameters stored in the location 146 is associated with the same view category that is associated with the at least one echocardiographic image received at block 202.

For example, in some embodiments, block 402 may direct the analyzer processor 100 to read "AP4" from the view category identifier field 302 of the view category record 300 associated with the echocardiographic image files received at block 202. Block 402 may direct the analyzer processor 100 to read the view category specific neural network records from the location 146 of the storage memory to find a view category specific neural network record that includes the same view category identifier of "AP4" and is therefore associated with the same view category. Accordingly, block 402 may direct the analyzer processor 100 to determine that the view category specific neural network record

340 includes the view category identifier of "AP4" and is therefore associated with the same view category that is associated with the at least one echocardiographic image received at block 202.

Block 404 then directs the analyzer processor 100 to, in response to determining that the set of assessment parameters is associated with the same view category, apply a function based on the set of assessment parameters to the at least one echocardiographic image received at block 202. In some embodiments, block 404 may direct the analyzer processor 100 to apply the neural network defined by the parameters included in the common neural network record 320 and the view category specific neural network record 340 to the image data in the image files received at block 202.

Block 404 may direct the analyzer processor 100 to read the image files received at block 202 from the location 140 of the storage memory 104 and to read the common neural network record 320 and the view category specific neural network record 340 from the location 146 of the storage memory, and to input the image data from the image files into a neural network that includes the shared layers 362 and the view category specific layers 374 shown in Figure 8, which are defined by the common neural network record 320 and the view category specific neural network record 340, to generate or determine a view category specific quality assessment value as an output of the neural network.

In some embodiments, the quality assessment value may represent a suitability for a quantified clinical measurement. In some embodiments, the quality assessment value may represent an estimate of an expected score which would be provided by an expert to the input at least one echocardiographic image. The estimate may be based on the training of the neural network wherein an expert provided quality assessment values for various echocardiographic images.

In some embodiments, the quality assessment value may be a score with criteria and/or a range that varies depending on the view category with which the neural network is associated. In some embodiments, the expert which provided the quality assessment values with which the neural network was trained may have determined the quality assessment values as an aggregation of scores derived using semi-quantitative evaluation of component structures and parameter optimization features such as centering, depth, gain, axis, focus, frequency or another parameter optimization feature or image capture parameter. Accordingly, in various embodiments, the quality assessment value may represent an estimate of an expected aggregation of scores derived using semi-quantitative evaluation of component structures and parameter optimization features such as centering, depth, gain, axis, focus, frequency or another parameter optimization feature or image capture parameter.

For example, in some embodiments, an expert may have, for each at least one echocardiographic image that they assessed, determined for each component in the at least one echocardiographic image, a component quality score of up to **2** points based on the following observations: **0** points) the structure was not imaged or was inadequate for assessment; **1** point) the structure was adequately viewed; **2** points) the view was optimized for the structure. In some embodiments, the component score may act as a clinical plane assessment value representing an expert opinion whether the associated echocardiographic training image was taken in an anatomical plane suitable for a quantified clinical measurement of anatomical features. The expert may have, for each at least one echocardiographic image that they assessed, determined parameter optimization scores as follows: appropriate centering (1 point), correct depth setting (**0.5** points), proper gain (**0.5** points), correct axis (1 point), and correct depth of focus (**0.5** points). In various embodiments, the quality assessment value may represent a sum of the above-noted scores.

As discussed above, in some embodiments, images for the different view categories may include a different set of components and quality assessment values may be determined using different criteria. For example, for the AP2 view category, the left ventricle (LV), left atrium (LA), and mitral valve (MV) may each be assigned a component quality score, which may be summed with scores for centering, depth, and gain to determine the quality assessment value. For the AP3 view category, the aortic valve (AV), MV, LA, LV, and septum may each be assigned a component quality score, which may be summed with scores for centering, depth, and gain to determine the quality assessment value. For the AP4 view category, the LV, right ventricle (RV), LA, right atrium (RA), MV, and TV may each be assigned a component quality score, which may be summed with scores for centering, depth, and gain to determine the quality assessment value. For the PSAXA view category, the AV and leaflets may each be assigned a component quality score, which may be summed with scores for centering, depth, and gain to determine the quality assessment value. For the PLAXPM the papillary muscles may be assigned a component quality score, which may be summed with scores for centering, depth, gain, and axis to determine the quality assessment value.

In some embodiments, the quality assessment values for all views may be normalized to the same scale, which may be, for example, between 0 and 1 or between 0 and 5.

Referring back to Figure 11, in some embodiments, block 404 of the flowchart 400 may direct the analyzer processor 100 to apply the neural network such that the quality assessment value and associated at least one echocardiographic image may be viewed in real-time or near-real time for the operator. For example, in some embodiments, block 404 may direct the analyzer processor 100 to apply the neural network and determine a quality assessment value in less than about 3 seconds. In some embodiments, block 404 may direct the analyzer processor 100 to apply the neural network and determine a quality

assessment value in less than about 1 second. In some embodiments, block 404 may direct the analyzer processor 100 to apply the neural network and determine a quality assessment value in less than about 0.33 ms. In some embodiments, for an input echo cine of 20 images of 200x200 pixels, a quality assessment value may be determined in about 10 ms, which may be suitable for real-time or near real-time deployment. In some embodiments, block 404 may direct the analyzer processor 100 to use a GPU included in the analyzer processor 100 to apply the neural network. In some embodiments, use of the GPU instead of just a general CPU may reduce the time it takes to execute the block 404 and may thus facilitate real-time or near-real time image analysis.

Referring back to Figure 3, the flowchart 200 continues at block 208 which directs the analyzer processor 100 to produce signals representing the quality assessment value determined at block 206, for causing the quality assessment value to be associated with the at least one echocardiographic image received at block 202.

In some embodiments, block 208 may direct the analyzer processor 100 to produce signals for causing the quality assessment value to be stored in the location 148 of the storage memory 104. For example, in some embodiments, block 208 may direct the analyzer processor 100 to store a quality assessment record 420 as shown in Figure 12 in the location 148 of the storage memory 104, wherein the quality assessment record 420 includes an image group identifier field 422 for storing the group identifier which identifies the group of images for which the quality assessment was made and a quality assessment value field 424 for storing the quality assessment that was generated at block 404 of the flowchart 400.

In some embodiments, block 208 may direct the analyzer processor 100 to produce signals for causing a representation of the quality assessment value to be transmitted to the display 15 of the user interface system 14 for causing the

display to display the quality assessment value in association with the received at least one echocardiographic image. In some embodiments, this may assist one or more operators of the system **10** in capturing subsequent echocardiographic images. For example, in some embodiments, block **208** may direct the analyzer processor **100** to communicate with the user interface system **14** of the system **10** shown in Figure **1** via the interface **122** of the I/O interface **112** shown in Figure **2** to cause a display **440** as shown in Figure **13** to be presented on the display **15** of the user interface system **14.**

Referring to Figure **13,** the display **440** includes a representation **442** of the quality assessment value determined at block **206** shown in association with a representation **444** of the at least one echocardiographic image received at block **202**.

In some embodiments, block **208** may direct the analyzer processor **100** to transmit the quality assessment value and associated at least one echocardiographic image to another device for storage and/or further analysis. For example, in various embodiments, block **208** may direct the analyzer processor **100** to transmit a representation of the image files stored at block **202** and the quality assessment record generated at block **208** to an archive device in a picture archiving and communication system (PACS) via the interface **124** and the network **126,** for example.

In various embodiments, once block **208** has been executed, the analyzer processor **100** may be directed to return to block **202** to receive further echocardiographic images. In some embodiments, the flowchart **200** may be executed continuously such that the display **440** shown in Figure **13** is updated with near real-time updates of images or image sequences and associated quality assessment values. In some embodiments, an operator may adjust image capture parameters of the system **10** and/or adjust positioning of the transducer until the operator sees a desired quality assessment value.

In some embodiments, the operator may make adjustments until a quality assessment value of greater than a predetermined threshold value is achieved. In some embodiments, for example, where the quality assessment value has been normalized to a possible range of 0-5 the threshold value may be about 3.0.

In some embodiments, there may be a maximum achievable quality assessment value for a given patient and the maximum achievable quality assessment value may be dependent on the patient, given their anatomy and/or echogenicity, for example. For example, in some embodiments where the quality assessment value has been normalized to a possible range of 0-5, for many patients, the maximum achievable quality assessment value for a given view category may be about 3.0. In some embodiments, the operator may make various adjustments until a near maximum achievable quality assessment value on a given patient has been achieved.

In some embodiments, after capturing images associated with a desired quality assessment value for a first view category, the operator of the system 10 may wish to capture images for a different view category and so reposition the transducer and/or reconfigure the system 10. For example, in some embodiments, the operator may, after capturing images of the AP4 view category, wish to capture images of one or more of the AP2, AP3, PSAXA, and PSAXPM view categories to facilitate quantified clinical measurement of anatomical features and/or to assist in diagnosing a medical condition or a characteristic of the heart. For example, in some embodiments, the operator may, after capturing at least one image of the AP4 view category, wish to capture at least one image of the AP2 view category to facilitate quantified clinical measurement of anatomical features for determining an ejection fraction.

Accordingly, the operator may reposition the transducer 16 shown in Figure 1 and/or adjust image receiving parameters to cause the flowchart 200 to be

executed one or more further times, but with echocardiographic images which are of different view categories and are to be analyzed using different parameters. In various embodiments, the analyzer **12** being configured as described above to switch between analyses of varying view categories may facilitate ease of use and/or efficient capture of subsequent high quality images of different view categories.

Neural network trainer

As discussed above, in various embodiments, a neural network trainer may first train neural networks to determine the architecture and/or parameters to be used by the neural networks at block **204** and/or block **206** of the flowchart **200** shown in Figure **3**. Referring to Figure **14**, there is shown a system **500** for facilitating training of neural networks. The system includes a neural network trainer **502** in communication with a training image source **504** and a user interface system **506**. In some embodiments, the neural network trainer **502** may also be in communication with the analyzer **12** via the network **126**.

The training image source **504** stores echocardiographic images and associated view category information which indicates what view category each of the images falls within. For example, in some embodiments, the training image source **504** may include a server computer for storing and archiving medical electronic images, such as, for example, an archive device from a picture archiving and communication system (PACS).

The neural network trainer **502** may be configured to retrieve and/or receive the echocardiographic images, which may act as echocardiographic training images, from the training image source **504**. In some embodiments, the neural network trainer **502** may, after receiving the training images, produce signals representing the echocardiographic training images and associated view categories to cause the user interface system **506** to present the echocardiographic images and the

view categories to one or more experts, such as, echocardiographers or physicians trained in echocardiography.

The experts may then provide respective quality assessment values for each of the echocardiographic images. For example, in some embodiments, the neural network trainer may be configured to produce signals for causing the user interface system **506** to present the experts with a set of echocardiographic training images and an indication of what view category the set of echocardiographic training images is to be assessed as. An echocardiographer may assess the set of echocardiographic training images and provide a quality assessment value representing a suitability of the set of images for a quantified clinical measurement. The neural network trainer **502** may store the quality assessment value in memory in association with the assessed set of echocardiographic training images.

After quality assessment values have been received and associated with each set of echocardiographic training images, the neural network trainer **502** may train neural networks using the echocardiographic training images as inputs and the associated expert quality assessment values as desired outputs to determine sets of neural network parameters defining the neural networks, wherein at least a portion of each of the neural networks is associated with one of the image view categories.

In some embodiments, the neural network trainer **502** may also train a view category determining neural network to determine sets of neural network parameters defining the view category determining neural network. The view category determining neural network may be generally as described above with reference to block **262** of the flowchart **260** shown in Figure **5**, configured to receive one or more echocardiographic images as an input, and having a softmax layer as an output layer having outputs which represent whether the input echocardiographic images fall within a particular view category.

In some embodiments, the neural network trainer **502** may produce signals representing the parameters defining the trained neural networks for causing the parameters to be provided to a system or device configured to apply the neural networks. For example, in some embodiments, the neural network trainer **502** may transmit the neural network parameters to the analyzer **12** via the network **126** shown in Figure **14.** Alternatively, in some embodiments, the neural network trainer **502** may produce signals for causing the sets of neural network parameters to be stored in removable memory which may be provided to the analyzer **12.**

The analyzer **12** may use the sets of neural network parameters to facilitate analysis of echocardiographic images, generally as described above with reference to the flowchart **200** shown in Figure **3.**

Neural network trainer - Processor circuit

Referring now to Figure **15,** a schematic view of the neural network trainer **502** of the system **500** shown in Figure **14** according to an embodiment is shown. In various embodiments, the neural network trainer **502** may be incorporated in one or more computers, for example.

Referring to Figure **15,** the neural network trainer **502** includes a processor circuit including a trainer processor **600** and a program memory **602,** a storage memory **604,** and an I/O interface **612,** all of which are in communication with the trainer processor **600.**

The I/O interface **612** includes an interface **620** for communicating with the training image source **504** and an interface **622** for communicating with the user interface system **506** shown in Figure **14.** In some embodiments, the I/O interface **612** also includes an interface **624** for facilitating networked communication with the analyzer **12** through the network **126.**

Processor-executable program codes for directing the trainer processor **600** to carry out various functions are stored in the program memory **602.** The program memory **602** includes a block of codes **660** for directing the neural network trainer **502** to perform neural network training functions.

The storage memory **604** includes a plurality of storage locations including location **640** for storing training image data, location **642** for storing expert assessment data, location **644** for storing image assessment neural network parameter data and location **646** for storing view category neural network parameter data.

Training the neural networks

Referring now to Figure **16,** a flowchart depicting blocks of code for directing the trainer processor **600** shown in Figure **15** to perform image assessment neural network training functions in accordance with one embodiment is shown generally at **700.** The blocks of code included in the flowchart **700** may be encoded in the block of codes **660** of the program memory **602** shown in Figure **15** for example.

Referring to Figure **16,** the flowchart **700** begins with block **702** which directs the trainer processor **600** shown in Figure **15** to receive signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined echocardiographic image view categories. In some embodiments, block **702** may direct the trainer processor **600** to receive echocardiographic training images from the training image source **504** shown in Figure **14.** For example, in some embodiments, block **702** may direct the trainer processor **600** to receive sets of associated image files, which may represent respective sequences of images or videos and include common image group

identifiers, from the training image source **504**. Each set of image files may make up an echo cine, which is associated with a view category.

An exemplary training image file that may be received at block **702** is shown at **740** in Figure **17**. The training image file **740** includes an image identifier field **742** for storing a unique identifier for identifying an image included in the file, an image group identifier field **744** for storing an identifier common to a set of image files which include images that are to be analyzed together, a view category identifier field **746** for storing an identifier for identifying the view category within which the image falls and by which the image should be analyzed, and an image data field **748** for storing information representing the image.

Block **702** may direct the trainer processor **600** to store the training image files received at block **702** in the location **640** of the storage memory **604**.

After block **702** of the flowchart **700** shown in Figure **16** has been executed, the location **640** of the storage memory **604** shown in Figure **17** may store a large number of image files, each having generally similar format to the training image file **740** shown in Figure **17**. For example, in some embodiments, about **2,500** echo cines of about **40** images each (about **500** echo cines of each view category) may be stored in the location **640** of the storage memory **604** and therefore about **100,000** training image files generally similar to the training image file **740** shown in Figure **17** may be stored in the location **640** of the storage memory **104**.

Referring back to Figure **16**, block **704** directs the trainer processor **600** to receive signals representing expert quality assessment values representing view category specific quality assessments of the echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the received sets of echocardiographic training images.

In some embodiments, the neural network trainer **502** may cause the echocardiographic training images to be presented to an expert and the expert may provide the expert quality assessment values. For example, block **704** may direct the trainer processor **600** to transmit the training image files to the user interface system **506** via the interface **622** of the I/O interface **612** shown in Figure **15** to cause a display of the user interface system **506** to present one or more experts with the echocardiographic images and an indication of what view category the images are to be assessed as.

In some embodiments, the echocardiographers may be directed to provide a quality assessment value representing a suitability of the images for a quantified clinical measurement. For example, the echocardiographers may be directed to provide a quality assessment value, which represents an aggregation of scores derived using semi-quantitative evaluation of component structures and parameter optimization features such as centering, depth, gain, axis, focus, frequency or another parameter optimization feature or image capture parameter, generally as described above, with reference to flowchart **400** shown in Figure **11**.

Block **704** may direct the trainer processor **600** to receive signals representing the expert quality assessment values and to store representations of the received expert quality assessment values in the location **642** of the storage memory **604.** For example, in some embodiments, block **704** may direct the trainer processor **600** to receive representations of expert quality assessment records from the user interface system **506** and to store the expert quality assessment records in the location **642** of the storage memory. An exemplary expert quality assessment record that may be received at block **704** and stored in the location **642** of the storage memory **604** is shown at **780** in Figure **18.**

Referring to Figure **18**, the expert quality assessment record **780** includes an image group identifier field **782** for storing the group identifier which identifies the set of images for which the expert quality assessment was made and an expert quality assessment value field **784** for storing the view category specific expert quality assessment value provided by the expert.

Referring back to Figure **16**, the flowchart **700** continues at block **706** which directs the trainer processor **600** shown in Figure **15** to train neural networks using the echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

In some embodiments, block **706** may direct the trainer processor **600** to train the neural network **360** shown in Figure **8** to determine values to be included in a common neural network record and view category specific neural network records stored in the location **644** of the storage memory **104**. In various embodiments, the common neural network record stored in the location **644** may have a generally similar format to that of the common neural network record **320** shown in Figure **9** and each of the view category specific neural network records stored in the location **644** of the storage memory **604** may have a generally similar format to that of the view category specific neural network record **340** shown in Figure **10**.

In some embodiments, the sequences of images received at block **702** may include a different number of images than can be analyzed by the neural network to be applied. For example, in some embodiments, the neural network **360** shown in Figure **8** may be configured to take as an input **20** images and the sequences of images received at block **702** may include more than **40** images each. Accordingly, in some embodiments, before training the neural networks,

block 706 may direct the trainer processor 600 to split one or more groups of echocardiographic images received at block 702 into subsets.

For example, block 706 may direct the trainer processor 600 to split each sequence of images into one or more groups of 20 image files each. In order to do this, block 706 may direct the trainer processor 600 to change the value stored in the image group identifier field for each file. Block 706 may further direct the trainer processor 600 to generate and store further expert quality assessment records as necessary such that each of the new groups of images is associated with the same quality assessment value as the original sequence of images.

Due to the storage length of heart cycles and different frame acquisition rates, number of images per cardiac cycle may vary for different image sequences. Accordingly, in some embodiments the neural network may be defined to take as input a static sequence size of nearly half the average heart cycle in the echocardiographic images received at block 702 (for example, in some embodiments 20 images), to capture the quality distribution of the echo imaging view categories. In various embodiments, by choosing a static sequence size of about half the average heart cycle, images in each sequence may not be synced with the heart cycle and this may, in some embodiments, help to ensure that the estimated quality assessment value provided after training for a given input sequence may be independent of the starting phase of the cardiac data.

Block 706 may direct the trainer processor 600 to, for each 20 image sequence of images having a common group identifier value, select a set of layers of the neural network 360 shown in Figure 8 to train, and to train those layers. For example, for a 20 image sequence associated with the AP4 view category, block 706 may direct the trainer processor 600 to train the neural network including the shared layers 362 and the AP4 view category specific layers 374. Block 706 may direct the trainer processor 600 to use the 20 images as inputs and to use the expert quality assessment value from an associated expert quality

assessment record stored in the location 642 of the storage memory 604 as the desired output.

In some embodiments, block 706 may direct the trainer processor 600 work towards optimizing network hyper-parameters by cross-validation to try to ensure that the network can sufficiently learn the distribution of all view categories without overfitting to the training data. In some embodiments, after finalizing the network architecture, the network may be trained on all of the images stored in the location 640 of the storage memory 604.

In various embodiments, the shared layer 362 and the view category specific layers 370, 372, 374, 376, and 378 may be trained simultaneously. In some embodiments, batch training may be used and each batch may consist of eight sequences (or groups of images) from each view, for example, wherein each sequence is a set of 20 consecutive gray-scale images of 200x200 pixels, with no preprocessing applied to the images.

In some embodiments, the neural networks may be trained using the adam optimizer with hyper-parameters as suggested by Kingma, D.P., Ba, J.L.: Adam: a Method for Stochastic Optimization, International Conference on Learning Representations 2015 pp. 1-15 (2015). The weight of the conv layers may be initialized randomly from a zero-mean Gaussian distribution. To try to prevent the neural network from overfitting on the training data, ℓ_2 norm regularization may be added to the weights of the conv kernels. In some embodiments, Keras deep learning library with TensorFlow™ backend, may be used to train and test the models.

In some embodiments, to prevent co-adaptation of features and overfitting on the training data, a dropout layer with the dropout probability of 0.5 may be used after the third pooling layer.

After training has been completed, the sets of parameters stored in the location **646** of the storage memory **104** may represent a trained echocardiographic image quality assessment neural network that includes shared layers and a plurality of view category specific layers.

Referring back to Figure **16,** in some embodiments, the flowchart **700** may include a further block **708** which directs the trainer processor **600** to produce signals representing the parameters defining the trained neural networks for causing the parameters to be provided to a system or device configured to apply the neural networks. In some embodiments, for example, block **708** may direct the trainer processor **600** to retrieve the neural network records from the location **644** and to produce signals representing the records for causing the records to be provided to the analyzer **12.**

For example, in some embodiments, block **708** may direct the trainer processor **600** to retrieve the common neural network record and the view category specific neural network records stored in the location **644** and transmit signals representing the records to the analyzer **12** via the interface **624** and the network **126.** Alternatively, in some embodiments, block **708** may direct the trainer processor **600** to cause the records to be stored in removable memory which may be provided to the analyzer **12.**

The analyzer **12** may be configured as described above to receive the neural network records and to perform image assessment by applying the neural networks represented thereby.

In some embodiments, the block of codes **660** of the program memory **602** shown in Figure **16** may include a block that directs the trainer processor **600** to train a view category determining neural network that is configured to take as an input at least one echocardiographic image and to output an indication of what view category should be associated with the input at least one echocardiographic

image. The block may use the image data from the training image files stored in the location **640** of the storage memory **104** as inputs and indications of the associated view categories (as determined by the view category identifiers included in the image files) as desired outputs.

The neural network may include convolutional layers, max-pooling layers, and fully connected layers, the fully connected layers including a softmax layer as an output layer having outputs which represent respective determinations that an input set of echocardiographic images fall within a particular view category. In some embodiments, the block may direct the trainer processor **600** to store parameters defining the trained neural network in a view category determining neural network record in the location **648** of the storage memory **604.**

Embodiments using distributed processing and/or separate devices

In some embodiments, separation of the neural network trainer **502,** the training image source **504,** and the analyzer **12** into different computers or systems may facilitate control of and access to information. This may be particularly desirable with the systems described herein where personal and/or confidential information may be managed. Further, in some embodiments, separation of the neural network training from the analysis, for example, may allow different or faster computers to train the neural network.

In some embodiments, the functionality of aspects of the system **10** and/or the system **500** may be further modularized and/or distributed between different devices. For example, in some embodiments, a system **800** as shown in Figure **19** may perform generally similar functions to the system **10** shown in Figure **1.** The system **800** includes a user interface system **802** generally similar to the user interface system **14** shown in Figure **1,** and a transducer **804** generally similar to the transducer **16** shown in Figure 1. The system **800** also includes a scanner **806** and an image analyzer **808** which are in communication with one another via a network **810** and configured to together perform generally similar

functions to the analyzer **12** described above. The scanner **806** may be configured to receive signals from the transducer and generate and store echocardiographic images in memory generally as described above. The scanner **806** may be configured to send the echocardiographic images to the image analyzer **808** which is configured to receive the images from the scanner **806** and generally perform image analysis steps as described above with reference to the flowchart **200** shown in Figure **3**. The image analyzer **808** may be configured to send signals to the scanner **806** for causing the scanner **806** to cause representations of the echocardiographic images and associated quality assessment values to be displayed on the display of the user interface system **802**.

In some embodiments, the functionality of any or all of the devices included in the systems **10**, **500**, and/or **800** as shown in Figures **1**, **13**, and **18** may be performed by multiple devices which are in communication with one another via a network. In such embodiments, the devices may be distributed in a cloud computing context, for example. For example, in some embodiments, a system that functions generally similar to the system **800** shown in Figure **19** may include a mobile device, such as a smart phone, acting similar to the user interface system **802**, in communication with a scanner generally similar to the scanner **806**, via a wireless connection, for example. An image analyzer acting as the image analyzer **808** may be remotely located in comparison to the scanner and the mobile device and may be in communication with the scanner **806** and/or the mobile device via a network connection, for example, over the Internet. In some embodiments, allowing the image analyzer **808** to be remotely located and accessible via a network, may facilitate the use of low cost or fast computing resources to carry the load of intensive processing during training and/or application of the neural networks.

In some embodiments, execution of block **206** may be performed by more than one analyzer device. For example, in some embodiments a first analyzer may apply the shared layers of an image quality assessment neural network to the received at

least one echocardiography image and then send the output of the shared layers to a second analyzer, which may apply one of the view specific layers to the received output. In such embodiments, the shared layers may act as a small neural network. In some embodiments, the shared layers may facilitate data compression. In some embodiments, the first analyzer may be in communication with the second analyzer via a network connection, such as, for example, an Internet connection. In some embodiments, the first analyzer may be implemented on a mobile device and the second analyzer may be in the cloud. In various embodiments, using a neural network with common shared layers may facilitate compressing the echocardiographic image data before sending the data to the second analyzer and may reduce the bandwidth needed to transfer data to the second analyzer.

In some embodiments, the first analyzer may use the shared layers of a neural network to generate a coarse quality score, and a finer quality score may be calculated by a larger architecture which is deployed in the cloud, for example, and uses the output of the shared layers.

Stored image analysis

In some embodiments, the analyzer **12** may be used to analyze stored images, rather than echocardiographic images received in real-time or near real-time. For example, in some embodiments, the analyzer **12** may be in communication with an image source, which may, for example, be implemented as a PACS. In some embodiments, the analyzer **12** may be in communication with the image source via a network, such as, the Internet, for example. In some embodiments, the analyzer **12** may be integrated with the image source as a single device.

In some embodiments where the analyzer **12** is used to analyze stored images from an image source, block **202** may direct the analyzer processor **100** to receive at least one echocardiographic image from the image source. Blocks 204 and 206 may direct the analyzer processor 100 to perform functions generally as described above. In some embodiments, block **208** may direct the

analyzer processor **100** to produce signals for causing the quality assessment value to be stored in association with the at least one echocardiographic image at the image source. In some embodiments, using the analyzer **12** to analyze stored echocardiographic images from an image source may facilitate use of the previously captured echocardiographic images for later quantified clinical measurement of anatomical features and/or to assist in diagnosing a medical condition or a characteristic of the heart.

Embodiments using integrated devices

In some embodiments, the functionality of some or all of the neural network trainer **502,** the training image source **504** and/or the analyzer **12** of the systems **500** and **10** may be provided by a single integrated device or system, for example. By way of example, in various embodiments, aspects of the neural network trainer **502** and the analyzer **12** may be integrated, such that a single device performs the neural network training and the analysis. In some embodiments, some of the blocks of code may be altered and/or omitted to facilitate the execution of the functionality of the processes described herein by one or more integrated device or system. In some embodiments, a system including such integrated devices may provide advantages such as, for example, reduction in implementation and/or operating costs.

3D representations

In some embodiments, block **202** may direct the analyzer processor **100** to receive or derive one or more **3D** model representations of the patient's heart from the signals received from the scanner **16.** In such embodiments, each of the **3D** model representations may represent one or more echocardiographic images which may be derived or extracted from the **3D** model representation by taking slices or planar sections from the **3D** model, for example. In such embodiments, the flowchart **200** may be executed to analyze echocardiographic images derived or extracted from the **3D** model representation.

Various embodiments

In some embodiments, echocardiographers may have previously provided the expert quality assessment values, and the training image source **504** may store respective expert quality assessment values in association with each of the images. In such embodiments, block **704** may direct the trainer processor **600** to receive the expert quality assessment values from the training image source **504.**

Certain embodiments of the systems **10, 500,** and **800** have been described above, wherein a plurality of images, in some embodiments a sequence of **20** images, for example, are analyzed together to generate a single quality assessment value. In various embodiments, analyzing more than one image together may facilitate determining accurate and contextualized quality assessment values.

However, in some embodiments, the systems **10, 500,** or **800** may be configured to analyze a single image at a time. In such embodiments, the flowchart **200** shown in Figure **3**, or a generally similar flowchart, may be executed to determine a quality assessment value for a single image received at block **202** of the flowchart **200.** In various embodiments, analyzing a single image at a time may facilitate fast processing of the flowchart **200** and/or real-time or near real-time feedback for the operator. In embodiments where a single image is analyzed at a time, the systems **10, 500,** and/or **800** may be configured to train and/or apply functions or neural networks to the single image to determine quality assessment values of each image. In such embodiments, different neural networks from those shown in Figures 6 and 8, as defined by different neural network records, may be trained and applied.

For example, an exemplary view category determining neural network that may be trained and/or applied to a single echocardiographic image to determine a view category to be associated with the echocardiographic image, in accordance with some embodiments, is shown at **950** in Figure **20.** In some embodiments, the neural network **950** may be configured to take as input an image having a size of

200x200 pixels, and may include one convolutional layer with 12 kernels of each 11x11 pixels, one pooling layer with a kernel of 3x3 and stride of 2, one convolutional layer with 24 kernels of each 7x7 pixels, one pooling layer with a kernel of 3x3 and stride of 2, one convolutional layer with 48 kernels of each 3x3 pixels, one pooling layer with a kernel of 3x3 and stride of 2, a fully connected layer with 2048 outputs, a fully connected layer with 1024 outputs, and a fully connected layer with 5 outputs.

An exemplary image assessment neural network that may be trained and/or applied to a single echocardiographic image to determine a quality assessment value for the echocardiographic image, in accordance with some embodiments, is shown at 980 in Figure 21.

While specific embodiments of the invention have been described and illustrated, such embodiments should be considered illustrative of the invention only and not as limiting the invention as construed in accordance with the accompanying claims.

CLAIMS:

1. A computer-implemented system for facilitating echocardiographic image analysis, the system comprising at least one processor configured to:

receive signals representing a first at least one echocardiographic image;

associate the first at least one echocardiographic image with a first view category of a plurality of predetermined echocardiographic image view categories;

determine, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image;

produce signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image;

receive signals representing a second at least one echocardiographic image;

associate the second at least one echocardiographic image with a second view category of the plurality of predetermined echocardiographic image view categories, said second view category being different from the first view category;

determine, based on the second at least one echocardiographic image and the second view category, a second quality assessment value representing a view category specific quality assessment of the second at least one echocardiographic image; and

produce signals representing the second quality assessment value for causing the second quality assessment value to be associated with the second at least one echocardiographic image.

2. The system of claim 1 wherein the first quality assessment value represents an assessment of suitability of the first at least one echocardiographic image for quantified clinical measurement of anatomical features and wherein the second quality assessment value represents an assessment of suitability of the second at least one echocardiographic image for quantified measurement of anatomical features.

3. The system of claim 1 or 2 wherein the at least one processor is configured to:

produce signals for causing a representation of the first quality assessment value to be transmitted to at least one display for causing the at least one display to display the first quality assessment value in association with the first at least one echocardiographic image, to assist one or more operators of an echocardiographic device in capturing at least one subsequent echocardiographic image; and

produce signals for causing a representation of the second quality assessment value to be transmitted to the at least one display for causing the at least one display to display the second quality assessment value in association with the second at least one echocardiographic image, to assist the one or more operators in capturing at least one subsequent echocardiographic image.

4. The system of any one of claims 1 to 3 wherein the at least one processor is configured to:

apply one or more view categorization functions to the first at least one echocardiographic image to determine that the first at least one echocardiographic image falls within the first view category; and

apply one or more view categorization functions to the second at least one echocardiographic image to determine that the second at least one echocardiographic image falls within the second view category.

5. The system of any one of claims **1** to **4** wherein the first at least one echocardiographic image comprises a plurality of echocardiographic images and wherein the at least one processor is configured to determine the first quality assessment value by determining a single quality assessment value representing a view category specific assessment of the plurality of echocardiographic images.

6. The system of any one of claims **1** to **5** wherein each of the plurality of predetermined echocardiographic image view categories is associated with a respective set of assessment parameters and wherein the at least one processor is configured to:

determine that a first set of assessment parameters of the sets of assessment parameters is associated with the first view category;

in response to determining that the first set of assessment parameters is associated with the first view category, apply a first function based on the first set of assessment parameters to the first at least one echocardiographic image;

determine that a second set of assessment parameters of the sets of assessment parameters is associated with the second view category; and

in response to determining that the second set of assessment parameters is associated with the second view category, apply a second function based on the second set of assessment parameters to the second at least one echocardiographic image.

7. The system of claim 6 wherein each of the sets of assessment parameters includes:

a set of common assessment parameters, which are common to each of the sets of assessment parameters; and

a set of view category specific assessment parameters, which are unique to the set of assessment parameters.

8. The system of claim 6 or 7 wherein each of the sets of assessment parameters is a set of neural network parameters that defines a neural network having a plurality of layers including an input layer configured to receive one or more echocardiographic images and an output layer configured to output one or more quality assessment values and wherein the at least one processor is configured to:

apply the first function based on the first set of assessment parameters to the first at least one echocardiographic image by inputting the first at least one echocardiographic image into the neural network defined by the first set of assessment parameters; and

apply the second function based on the second set of assessment parameters to the second at least one echocardiographic image by inputting the second at least one echocardiographic image into the neural network defined by the second set of assessment parameters.

9. The system of claim 8 wherein the at least one processor is configured to train the neural networks by:

receiving signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of the plurality of predetermined echocardiographic image view categories;

receiving signals representing respective expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images; and

training the neural networks using the plurality of echocardiographic training images as inputs and the associated expert quality assessment values as desired outputs to determine the sets of neural network parameters defining the neural networks.

10. The system of claim 9 wherein each of the expert quality assessment values represents an assessment of suitability of the associated echocardiographic image for quantified clinical measurement of anatomical features.

11. The system of claim 9 or 10 wherein the at least one processor is configured to derive each of the expert quality assessment values at least in part from a clinical plane assessment value representing an expert opinion whether the associated echocardiographic training image was taken in an anatomical plane suitable for quantified clinical measurement of anatomical features.

12. The system of any one of claims 9 to 11 wherein each of the sets of neural network parameters includes:

a set of common neural network parameters, which are common to each of the sets of neural network parameters; and

a set of view category specific neural network parameters, which are unique to the set of neural network parameters; and

wherein the at least one processor is configured to, for each echocardiographic training image:

select one of the sets of view category specific neural network parameters based on the predetermined echocardiographic image view category associated with the echocardiographic training image; and

using the echocardiographic training image as an input and the associated expert quality assessment values as a desired output, train a neural network defined by the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters to update the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters.

13. A computer-implemented system for training neural networks to facilitate echocardiographic image analysis, the system comprising at least one processor configured to:

receive signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined echocardiographic image view categories;

receive signals representing expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images; and

train the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

14. The system of claim **13** wherein each of the expert quality assessment values represents an assessment of suitability of the associated echocardiographic image for quantified clinical measurement of anatomical features.

15. The system of claim **13** or **14** wherein the at least one processor is configured to derive each of the expert quality assessment values at least in part from a clinical plane assessment value representing an expert opinion whether the associated echocardiographic training image was taken in an anatomical plane suitable for a quantified clinical measurement of anatomical features.

16. The system of any one of claims **13** to **15** wherein each of the sets of neural network parameters includes:

a set of common neural network parameters, which are common to each of the sets of neural network parameters; and

a set of view category specific neural network parameters, which are unique to the set of neural network parameters; and

wherein the at least one processor is configured to, for each echocardiographic training image:

select one of the sets of view category specific neural network parameters based on the predetermined echocardiographic image view category associated with the echocardiographic training image; and

using the echocardiographic training image as an input and the associated expert quality assessment value as a desired output, train a neural network defined by the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters to update the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters.

17. A computer-implemented method of facilitating echocardiographic image analysis, the method comprising:

receiving signals representing a first at least one echocardiographic image;

associating the first at least one echocardiographic image with a first view category of a plurality of predetermined echocardiographic image view categories;

determining, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image;

producing signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image;

receiving signals representing a second at least one echocardiographic image;

associating the second at least one echocardiographic image with a second view category of the plurality of predetermined echocardiographic image view categories, said second view category being different from the first view category;

determining, based on the second at least one echocardiographic image and the second view category, a second quality assessment value representing a view category specific quality assessment of the second at least one echocardiographic image; and

producing signals representing the second quality assessment value for causing the second quality assessment value to be associated with the second at least one echocardiographic image.

18. The method of claim 17 wherein the first quality assessment value represents an assessment of suitability of the first at least one echocardiographic image for quantified clinical measurement of anatomical features and wherein the second quality assessment value represents an assessment of suitability of the second at least one echocardiographic image for quantified measurement of anatomical features.

19. The method of claim 17 or 18 wherein:

producing the signals representing the first quality assessment value comprises producing signals for causing a representation of

the first quality assessment value to be transmitted to at least one display for causing the at least one display to display the first quality assessment value in association with the first at least one echocardiographic image, to assist one or more operators of an echocardiographic device in capturing at least one subsequent echocardiographic image; and

producing the signals representing the second quality assessment value comprises producing signals for causing a representation of the second quality assessment value to be transmitted to the at least one display for causing the at least one display to display the second quality assessment value in association with the second at least one echocardiographic image, to assist the one or more operators in capturing at least one subsequent echocardiographic image.

20. The method of any one of claims **17** to **19** wherein:

associating the first at least one echocardiographic image with the first view category comprises applying one or more view categorization functions to the first at least one echocardiographic image to determine that the first at least one echocardiographic image falls within the first view category; and

associating the second at least one echocardiographic image with the second view category comprises applying one or more view categorization functions to the second at least one echocardiographic image to determine that the second at least one echocardiographic image falls within the second view category.

21. The method of any one of claims **17** to **20** wherein the first at least one echocardiographic image comprises a plurality of echocardiographic images and wherein determining the first quality assessment value

comprises determining a single quality assessment value representing a view category specific assessment of the plurality of echocardiographic images.

22. The method of any one of claims 17 to 21 wherein each of the plurality of predetermined echocardiographic image view categories is associated with a respective set of assessment parameters and wherein:

determining the first quality assessment value comprises:

determining that a first set of assessment parameters of the sets of assessment parameters is associated with the first view category; and

in response to determining that the first set of assessment parameters is associated with the first view category, applying a first function based on the first set of assessment parameters to the first at least one echocardiographic image; and

determining the second quality assessment value comprises:

determining that a second set of assessment parameters of the sets of assessment parameters is associated with the second view category; and

in response to determining that the second set of assessment parameters is associated with the second view category, applying a second function based on the second set of assessment parameters to the second at least one echocardiographic image.

23. The method of claim 22 wherein each of the sets of assessment parameters includes:

a set of common assessment parameters, which are common to each of the sets of assessment parameters; and

a set of view category specific assessment parameters, which are unique to the set of assessment parameters.

24. The method of claim 22 or 23 wherein each of the sets of assessment parameters is a set of neural network parameters that defines a neural network having a plurality of layers including an input layer configured to receive one or more echocardiographic images and an output layer configured to output one or more quality assessment values and wherein:

applying the first function based on the first set of assessment parameters to the first at least one echocardiographic image comprises inputting the first at least one echocardiographic image into the neural network defined by the first set of assessment parameters; and

applying the second function based on the second set of assessment parameters to the second at least one echocardiographic image comprises inputting the second at least one echocardiographic image into the neural network defined by the second set of assessment parameters.

25. The method of claim 24 further comprising training the neural networks, said training comprising:

receiving signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of the plurality of predetermined echocardiographic image view categories;

receiving signals representing respective expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images; and

training the neural networks using the plurality of echocardiographic training images as inputs and the associated expert quality assessment values as desired outputs to determine the sets of neural network parameters defining the neural networks.

26. The method of claim **25** wherein each of the expert quality assessment values represents an assessment of suitability of the associated echocardiographic image for quantified clinical measurement of anatomical features.

27. The method of claim **25** or **26** further comprising deriving each of the expert quality assessment values at least in part from a clinical plane assessment value representing an expert opinion whether the associated echocardiographic training image was taken in an anatomical plane suitable for quantified clinical measurement of anatomical features.

28. The method of any one of claims **25** to **27** wherein each of the sets of neural network parameters includes:

a set of common neural network parameters, which are common to each of the sets of neural network parameters; and

a set of view category specific neural network parameters, which are unique to the set of neural network parameters; and

wherein training the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values comprises, for each echocardiographic training image:

selecting one of the sets of view category specific neural network parameters based on the predetermined echocardiographic image view category associated with the echocardiographic training image; and

using the echocardiographic training image as an input and the associated expert quality assessment values as a desired output, training a neural network defined by the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters to update the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters.

29. A computer-implemented method of training neural networks to facilitate echocardiographic image analysis, the method comprising:

receiving signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined echocardiographic image view categories;

receiving signals representing expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images; and

training the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

30. The method of claim **29** wherein each of the expert quality assessment values represents an assessment of suitability of the associated echocardiographic image for quantified clinical measurement of anatomical features.

31. The method of claim **29** or **30** further comprising deriving each of the expert quality assessment values at least in part from a clinical plane assessment value representing an expert opinion whether the associated echocardiographic training image was taken in an anatomical plane suitable for a quantified clinical measurement of anatomical features.

32. The method of any one of claims **29** to **31** wherein each of the sets of neural network parameters includes:

a set of common neural network parameters, which are common to each of the sets of neural network parameters; and

a set of view category specific neural network parameters, which are unique to the set of neural network parameters; and

wherein training the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values comprises, for each echocardiographic training image:

selecting one of the sets of view category specific neural network parameters based on the predetermined echocardiographic image

view category associated with the echocardiographic training image; and

using the echocardiographic training image as an input and the associated expert quality assessment value as a desired output, training a neural network defined by the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters to update the set of common neural network parameters and the selected one of the sets of view category specific neural network parameters.

33. A computer readable medium having stored thereon codes which when executed by at least one processor cause the at least one processor to perform the method of any one of claims **17** to **32.**

34. A system for facilitating echocardiographic image analysis, the system comprising:

means for receiving signals representing a first at least one echocardiographic image;

means for associating the first at least one echocardiographic image with a first view category of a plurality of predetermined echocardiographic image view categories;

means for determining, based on the first at least one echocardiographic image and the first view category, a first quality assessment value representing a view category specific quality assessment of the first at least one echocardiographic image;

means for producing signals representing the first quality assessment value for causing the first quality assessment value to be associated with the first at least one echocardiographic image;

means for receiving signals representing a second at least one echocardiographic image;

means for associating the second at least one echocardiographic image with a second view category of the plurality of predetermined echocardiographic image view categories, said second view category being different from the first view category;

means for determining, based on the second at least one echocardiographic image and the second view category, a second quality assessment value representing a view category specific quality assessment of the second at least one echocardiographic image; and

means for producing signals representing the second quality assessment value for causing the second quality assessment value to be associated with the second at least one echocardiographic image.

35. A system for training neural networks to facilitate echocardiographic image analysis, the system comprising:

means for receiving signals representing a plurality of echocardiographic training images, each of the plurality of echocardiographic training images associated with one of a plurality of predetermined echocardiographic image view categories;

means for receiving signals representing expert quality assessment values representing view category specific quality assessments of the plurality of echocardiographic training images, each of the expert quality assessment values provided by an expert echocardiographer and associated with one of the plurality of echocardiographic training images; and

means for training the neural networks using the plurality of echocardiographic training images and the associated expert quality assessment values to determine sets of neural network parameters defining the neural networks, at least a portion of each of said neural networks associated with one of the plurality of predetermined echocardiographic image view categories.

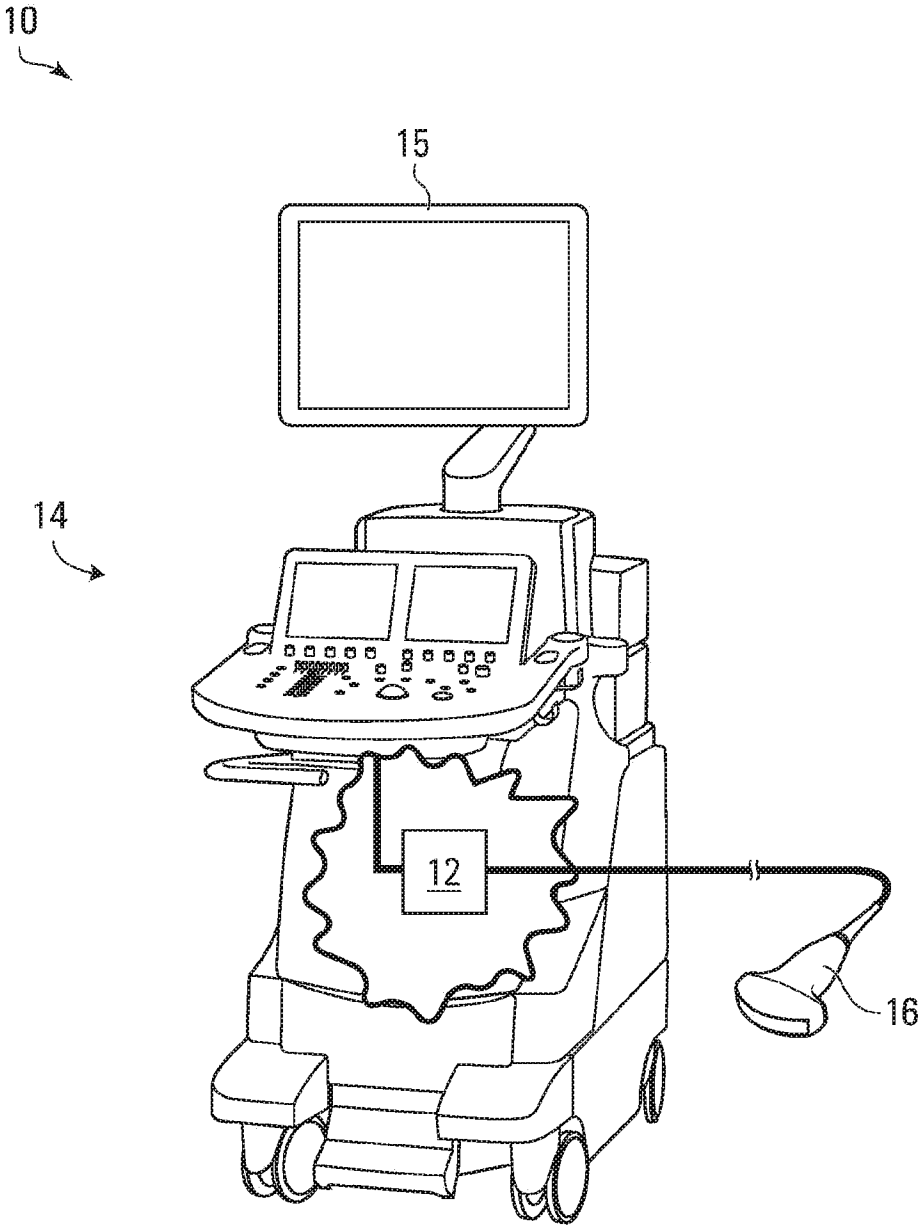


FIG. 1

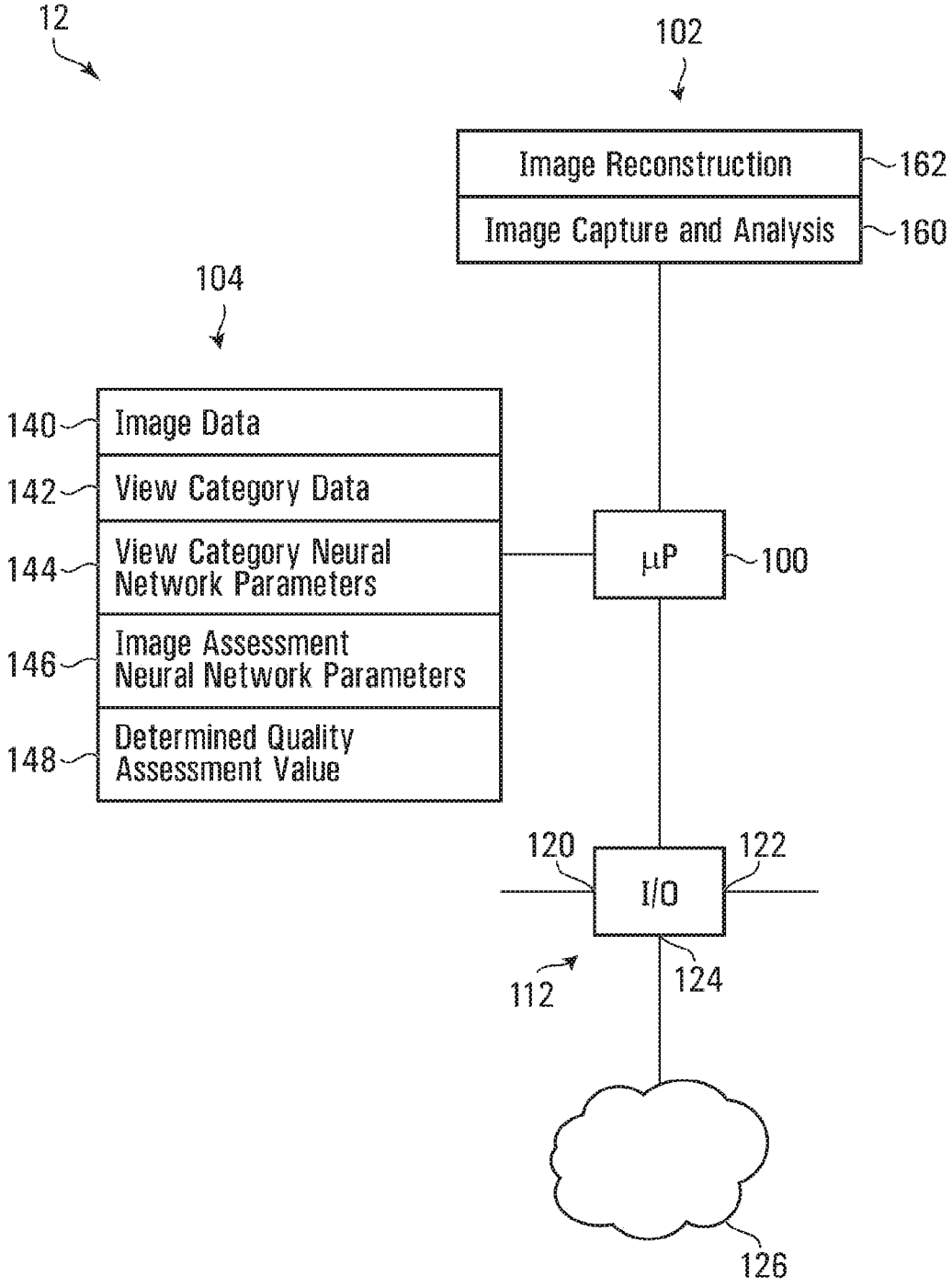

12
102
Image Reconstruction
162
Image Capture and Analysis
160
104
140
Image Data
142
View Category Data
144
View Category Neural Network Parameters
146
Image Assessment Neural Network Parameters
148
Determined Quality Assessment Value
μP
100
120
122
I/O
112
124
126

FIG. 2

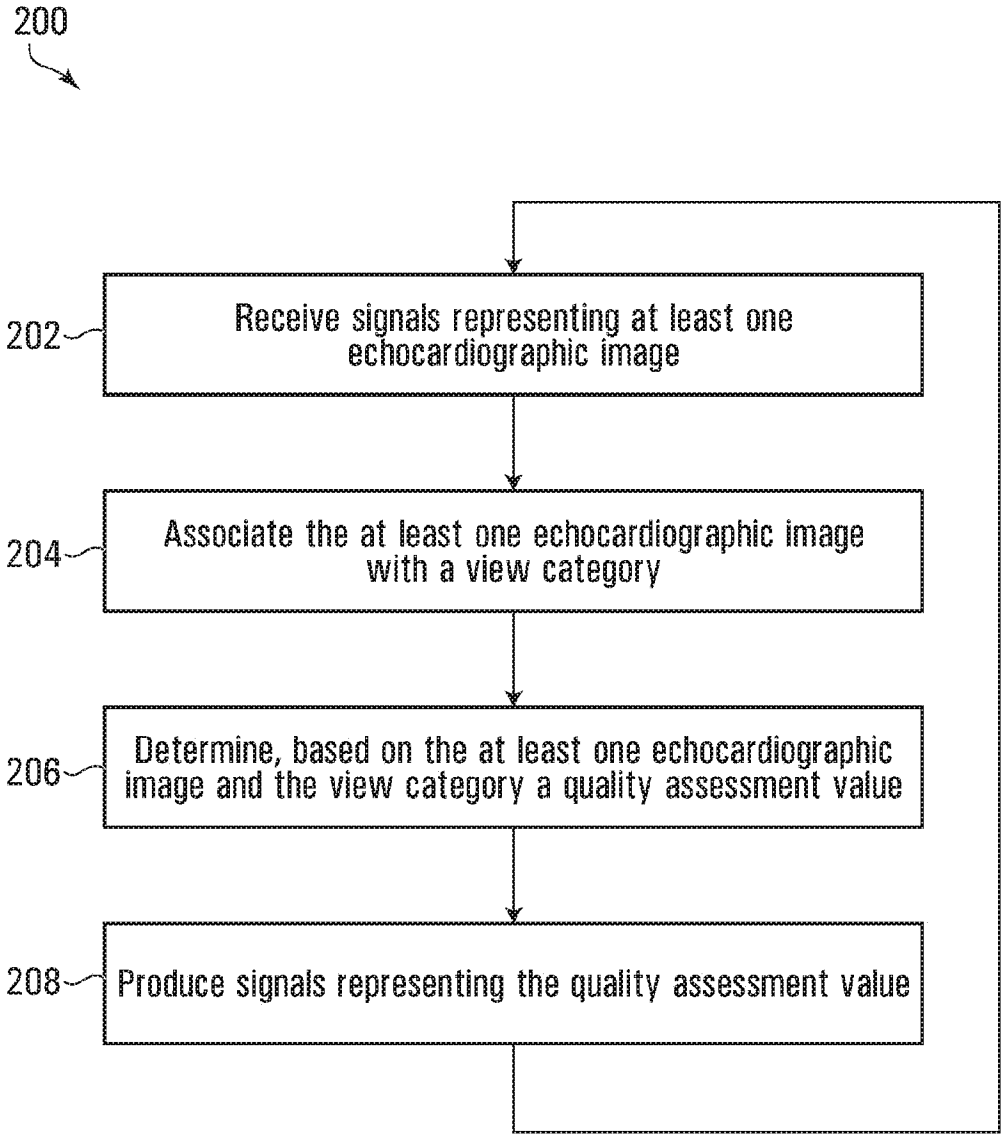

200
202
Receive signals representing at least one echocardiographic image
204
Associate the at least one echocardiographic image with a view category
206
Determine, based on the at least one echocardiographic image and the view category a quality assessment value
208
Produce signals representing the quality assessment value

FIG. 3

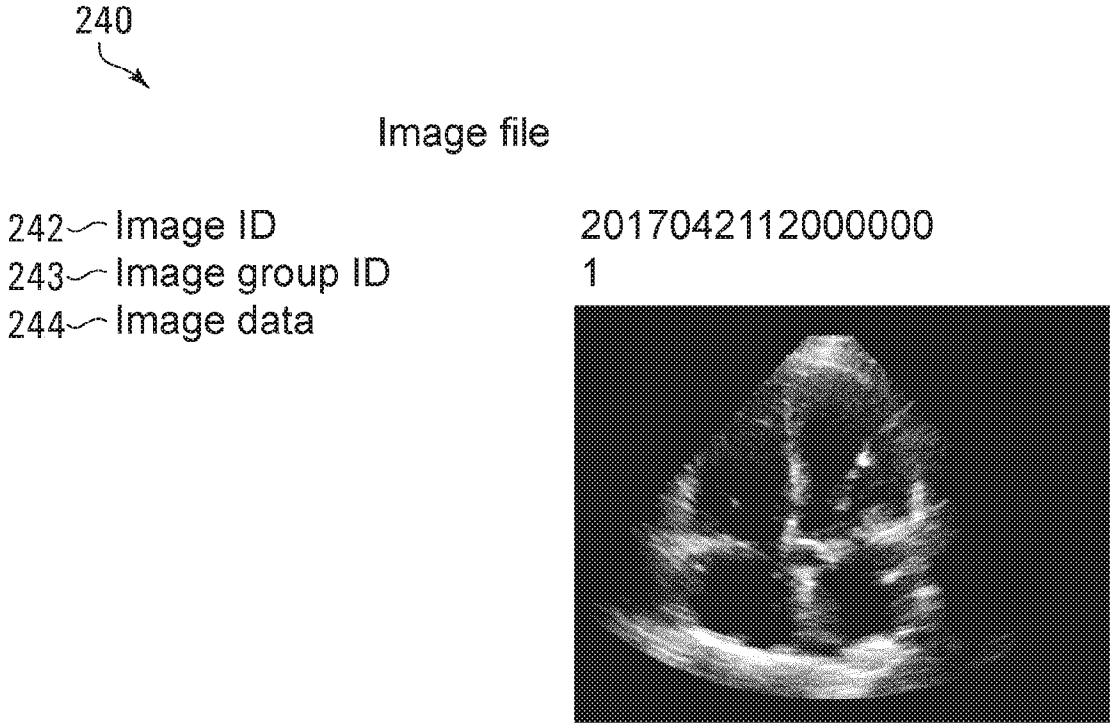

240
Image file
242 Image ID
2017042112000000
243 Image group ID
1
244 Image data

FIG. 4

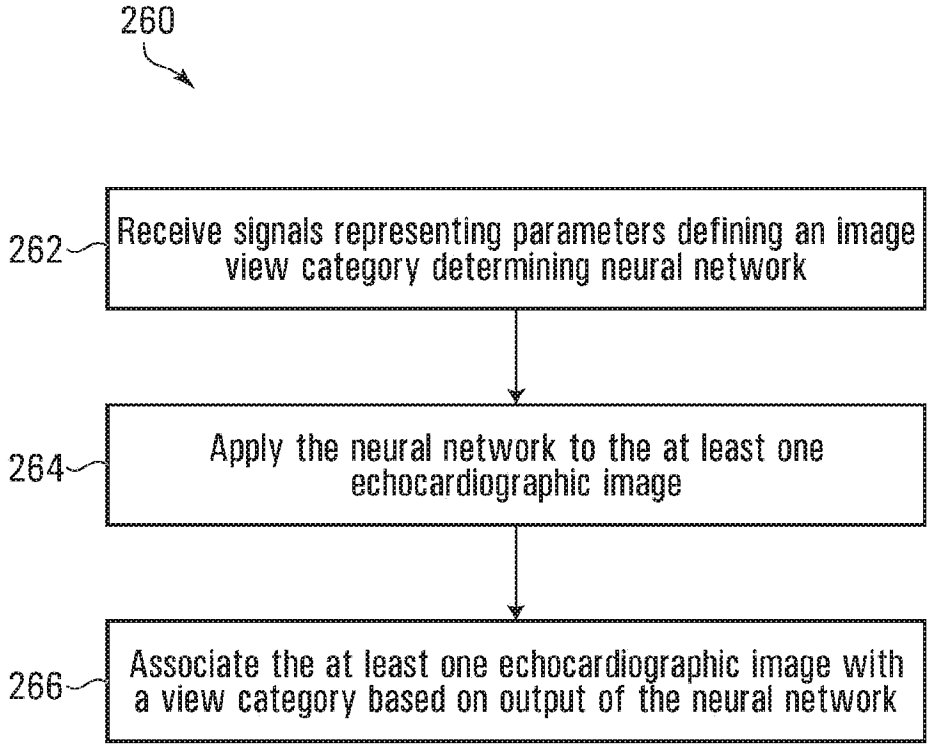

260
262
Receive signals representing parameters defining an image view category determining neural network
264
Apply the neural network to the at least one echocardiographic image
266
Associate the at least one echocardiographic image with a view category based on output of the neural network

FIG. 5

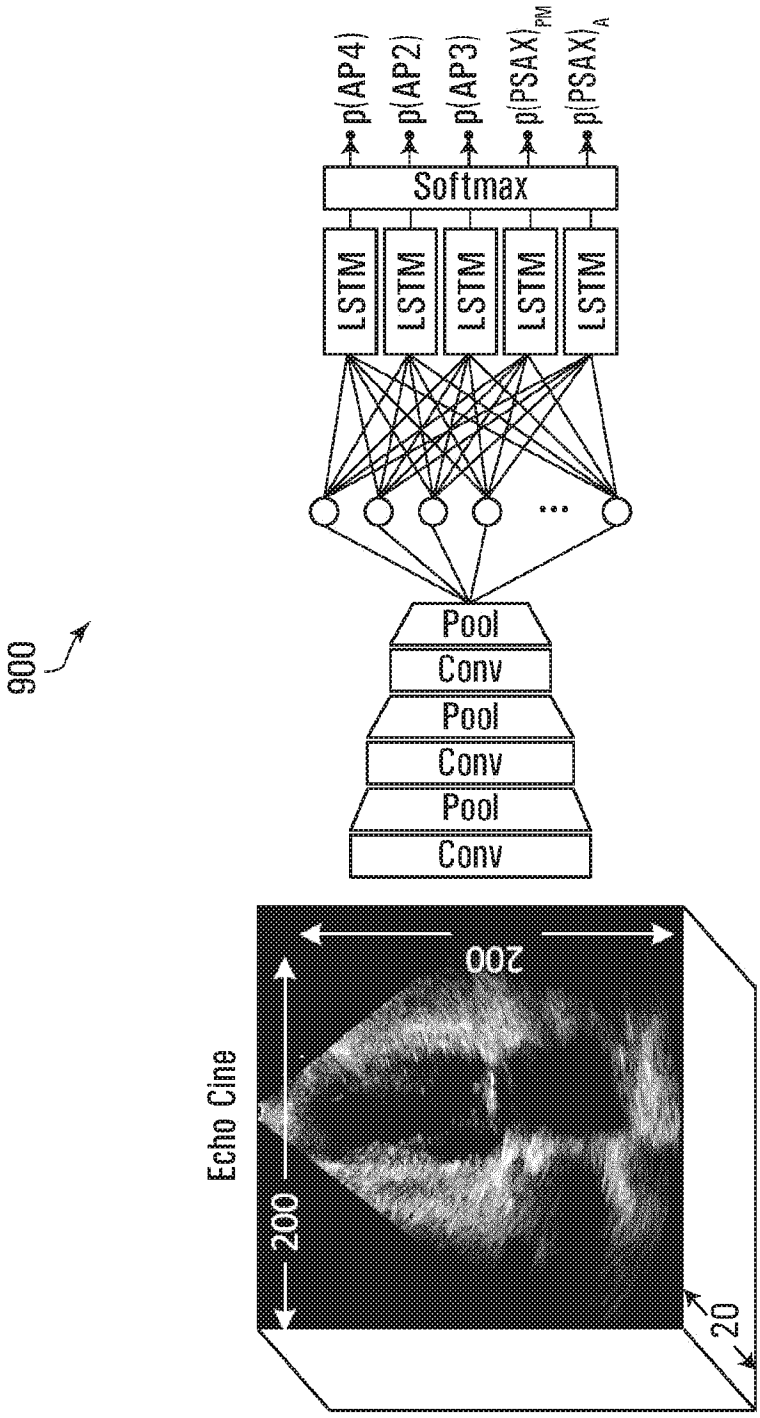

900
Echo Cine
200
200
20
Conv
Pool
Conv
Pool
Conv
Pool
...
LSTM
LSTM
LSTM
LSTM
LSTM
Softmax
p(AP4)
p(AP2)
p(AP3)
p(PSAX)PM
p(PSAX)A

FIG. 6



View category record

302	View category ID	AP4
304	Image group ID	1

FIG. 7

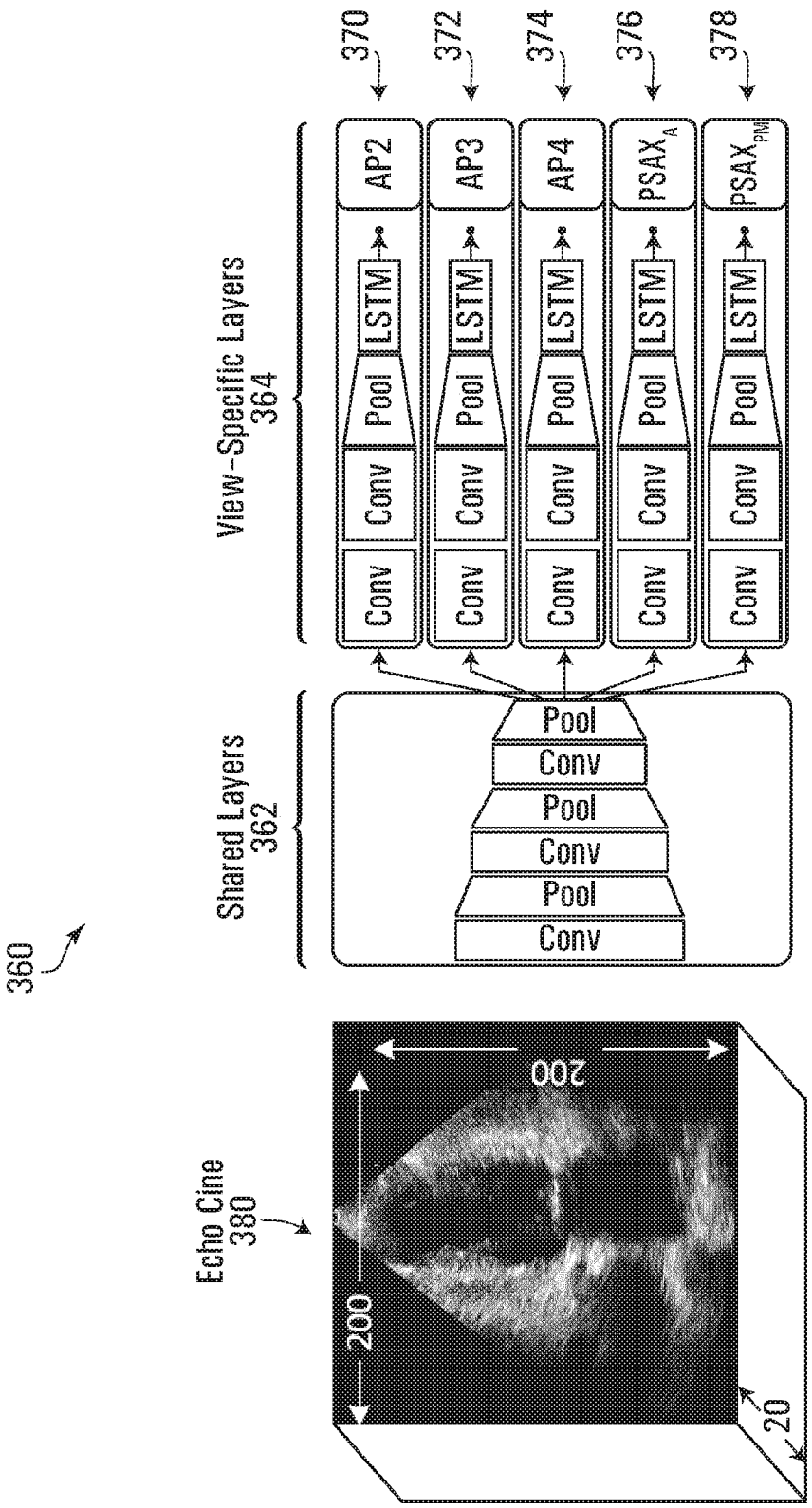

360
Echo Cine
380
200
200
20
Shared Layers
362
Conv
Pool
Conv
Pool
Conv
Pool
View-Specific Layers
364
Conv
Conv
Pool
LSTM
370
AP2
372
AP3
374
AP4
376
PSAX$_A$
378
PSAX$_{PM}$

FIG. 8

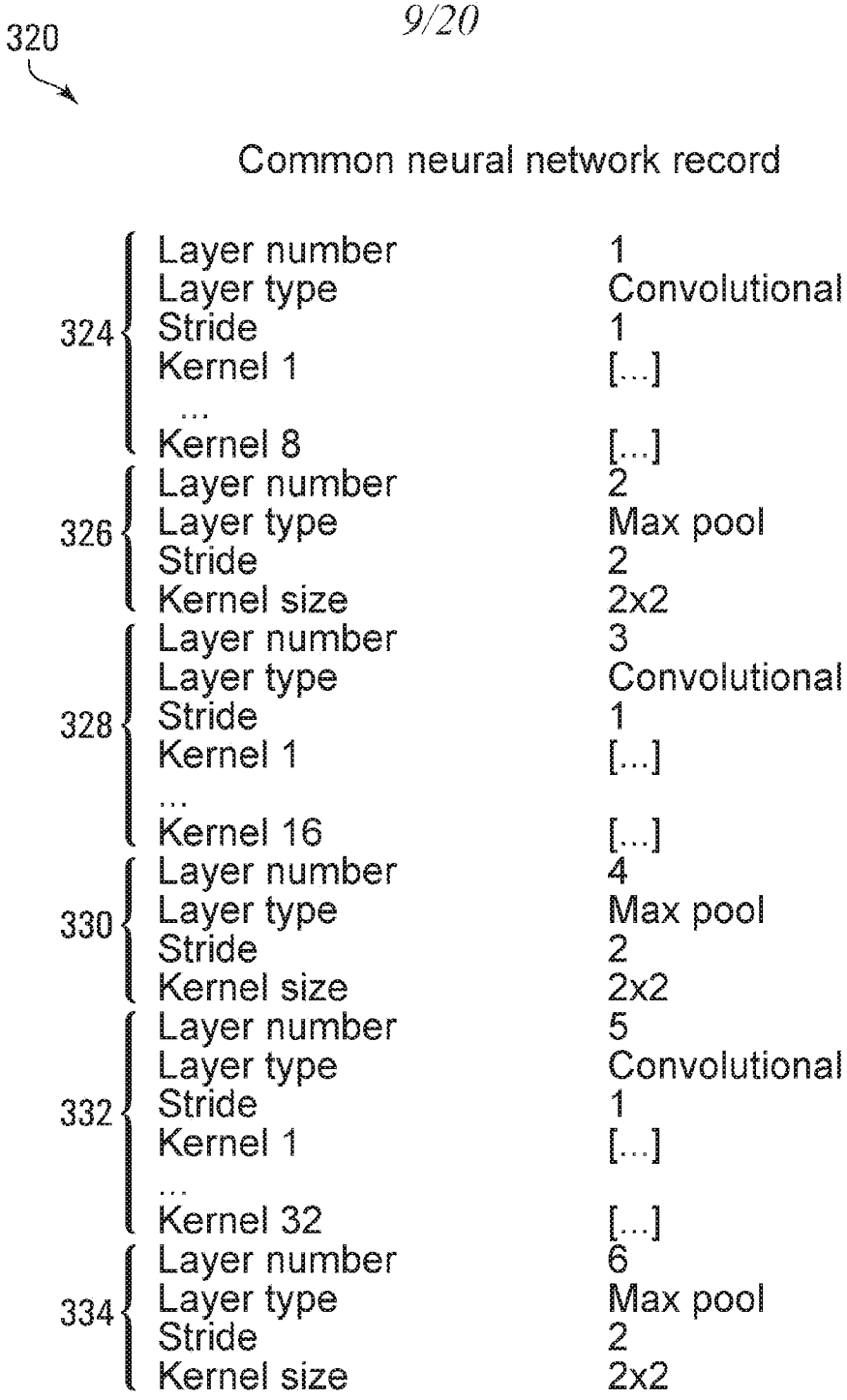

320
Common neural network record
324
Layer number 1
Layer type Convolutional
Stride 1
Kernel 1 [...]
...
Kernel 8 [...]
326
Layer number 2
Layer type Max pool
Stride 2
Kernel size 2x2
328
Layer number 3
Layer type Convolutional
Stride 1
Kernel 1 [...]
...
Kernel 16 [...]
330
Layer number 4
Layer type Max pool
Stride 2
Kernel size 2x2
332
Layer number 5
Layer type Convolutional
Stride 1
Kernel 1 [...]
...
Kernel 32 [...]
334
Layer number 6
Layer type Max pool
Stride 2
Kernel size 2x2

FIG. 9

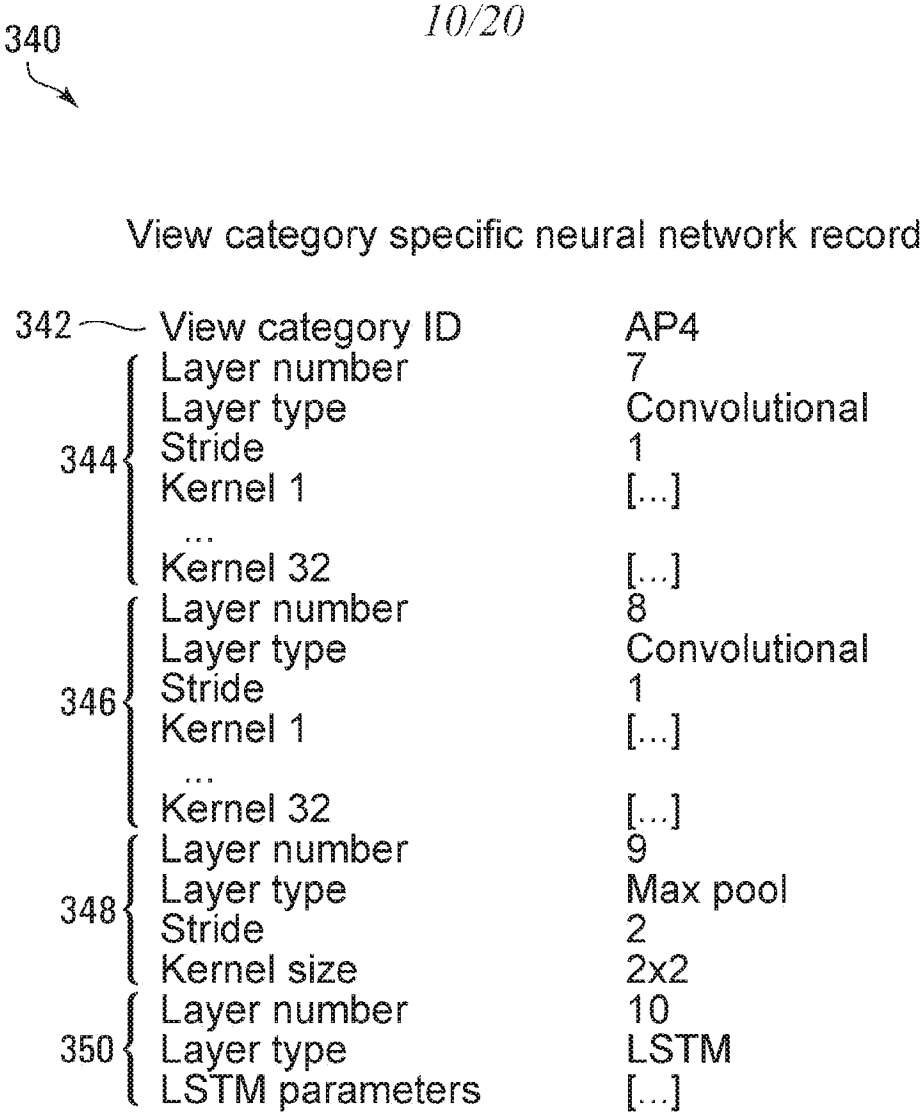

340
View category specific neural network record
342
View category ID
AP4
344
Layer number
7
Layer type
Convolutional
Stride
1
Kernel 1
[...]
...
Kernel 32
[...]
346
Layer number
8
Layer type
Convolutional
Stride
1
Kernel 1
[...]
...
Kernel 32
[...]
348
Layer number
9
Layer type
Max pool
Stride
2
Kernel size
2x2
350
Layer number
10
Layer type
LSTM
LSTM parameters
[...]

FIG. 10

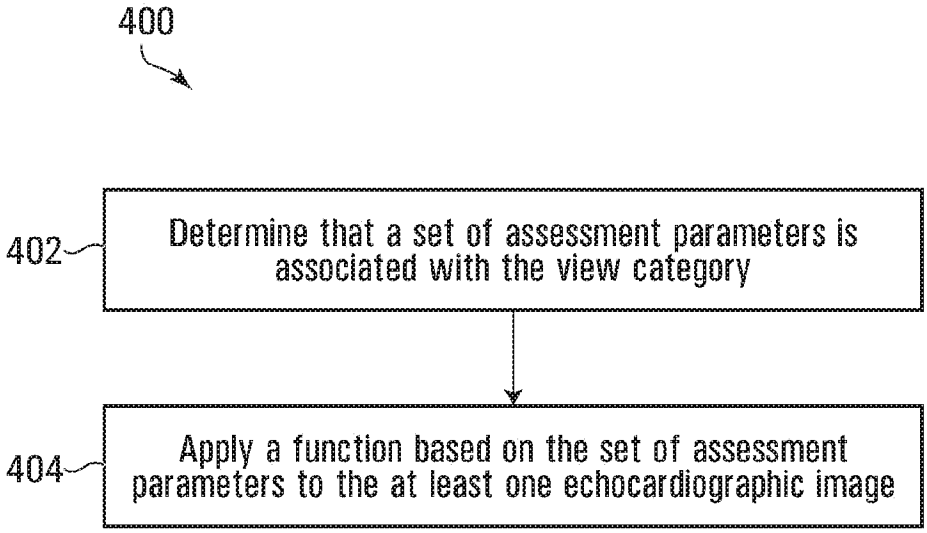

400
402
Determine that a set of assessment parameters is associated with the view category
404
Apply a function based on the set of assessment parameters to the at least one echocardiographic image

FIG. 11

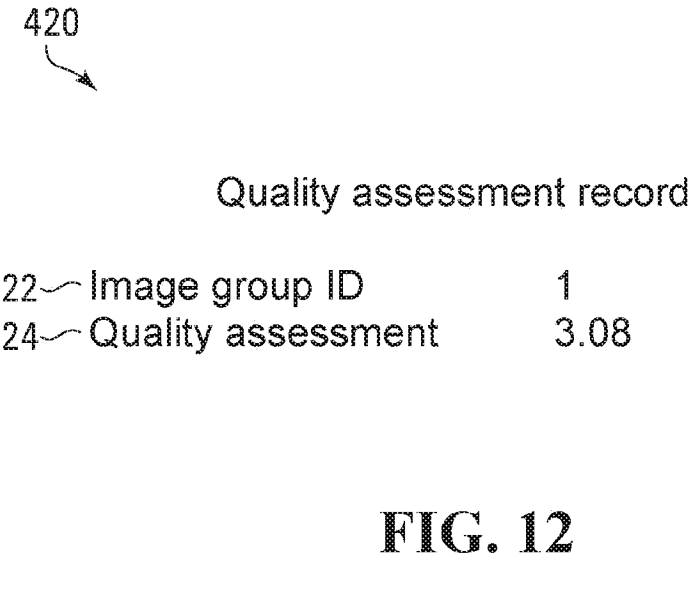

420
Quality assessment record
422 Image group ID 1
424 Quality assessment 3.08

FIG. 12

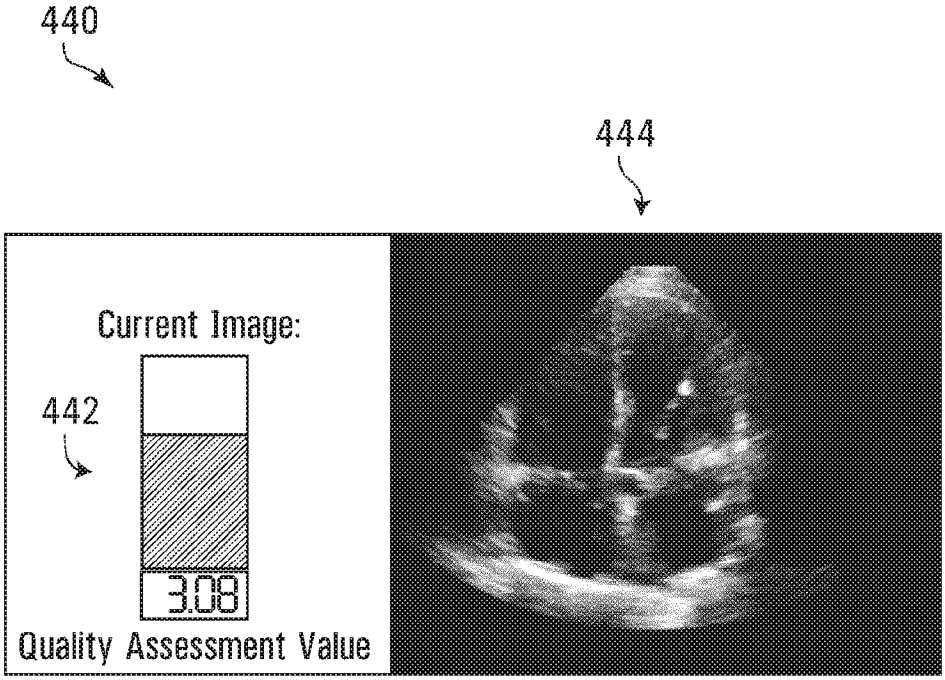


FIG. 13

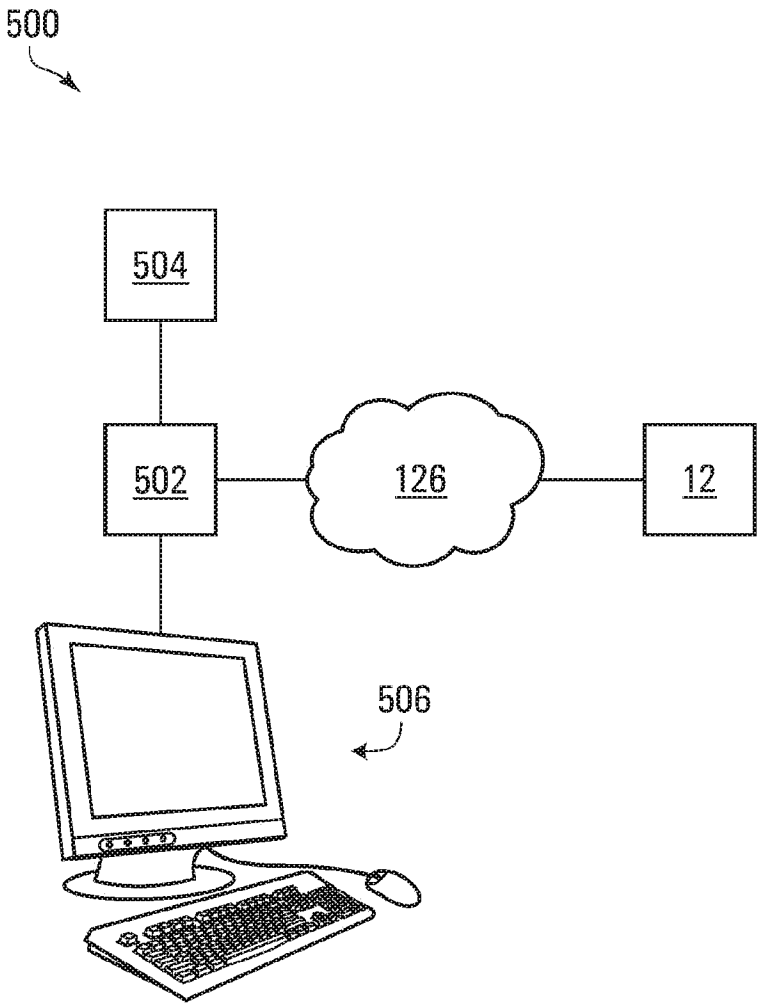


FIG. 14

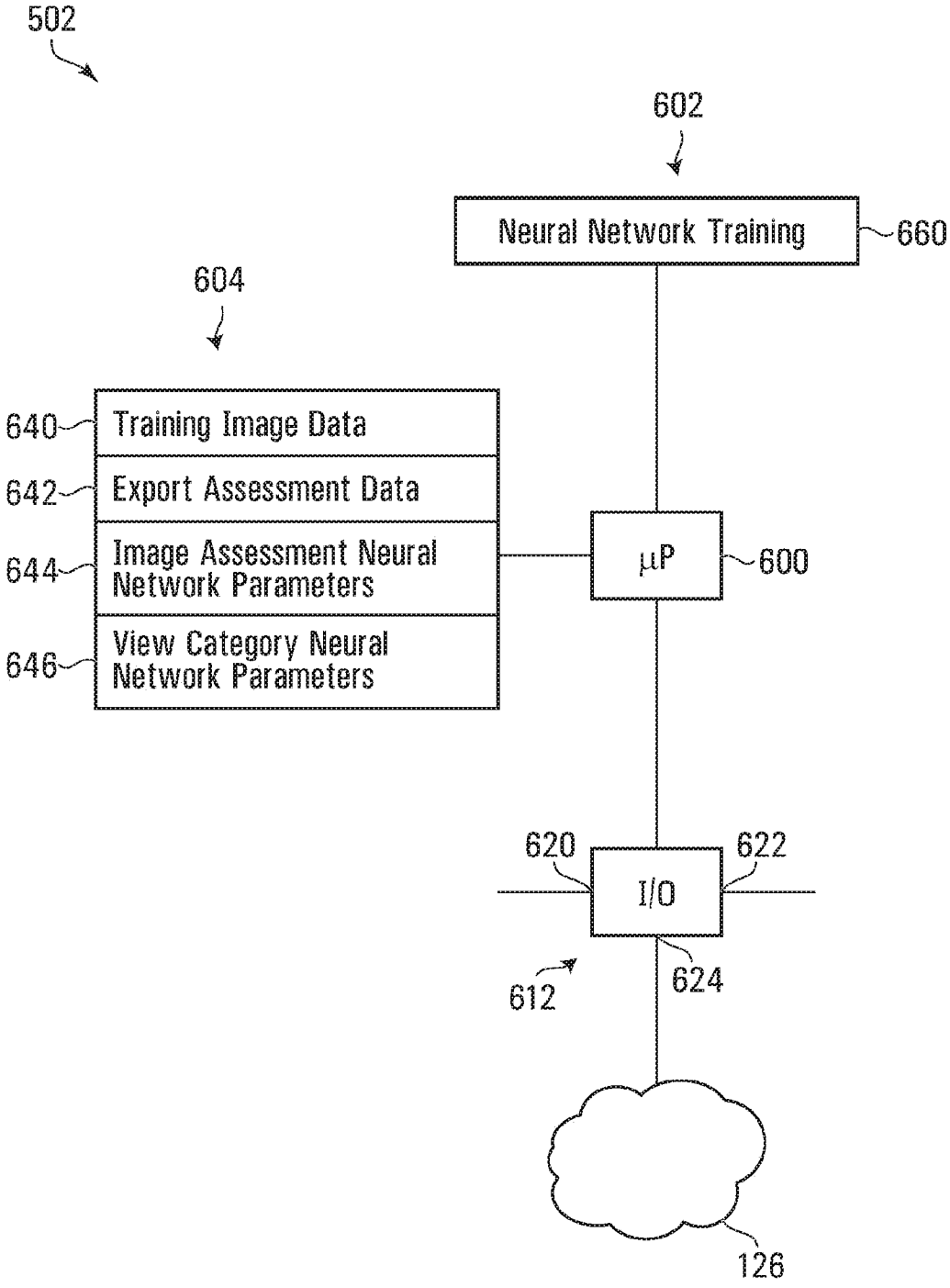

502
602
Neural Network Training
660
604
640
Training Image Data
642
Export Assessment Data
644
Image Assessment Neural Network Parameters
646
View Category Neural Network Parameters
μP
600
620
622
I/O
612
624
126

FIG. 15

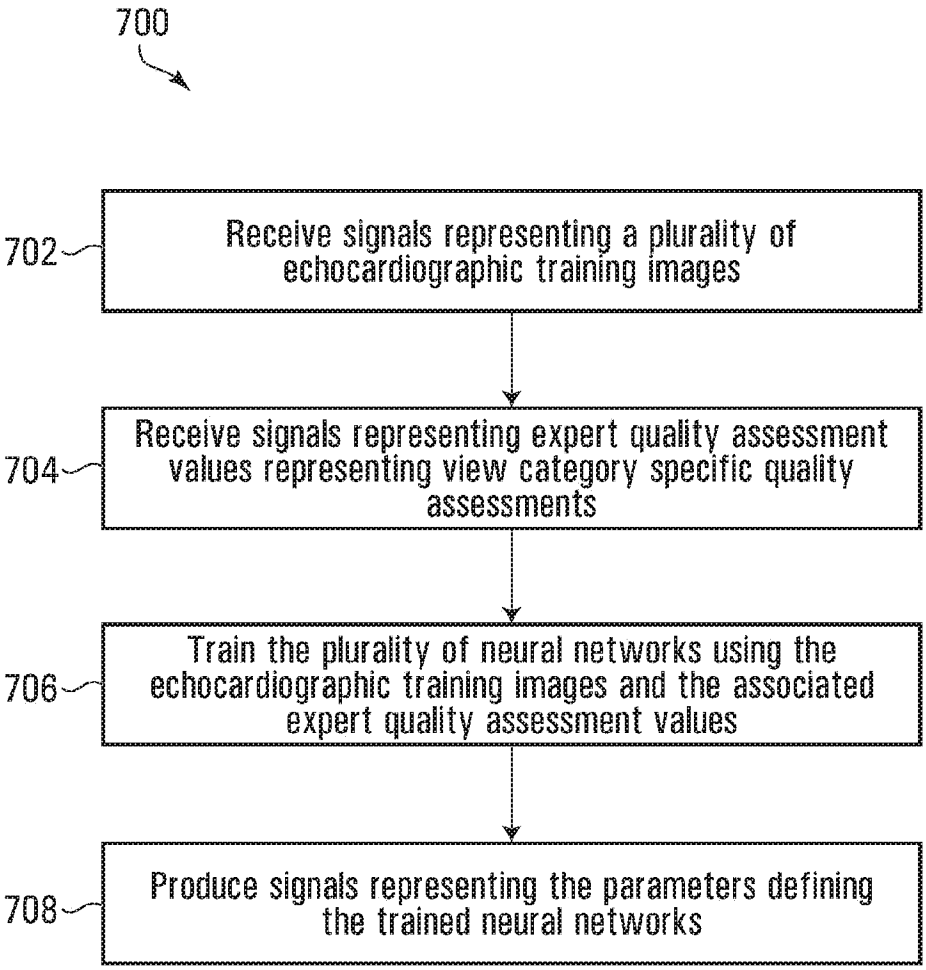

700
702
Receive signals representing a plurality of echocardiographic training images
704
Receive signals representing expert quality assessment values representing view category specific quality assessments
706
Train the plurality of neural networks using the echocardiographic training images and the associated expert quality assessment values
708
Produce signals representing the parameters defining the trained neural networks

FIG. 16

740

Training image file

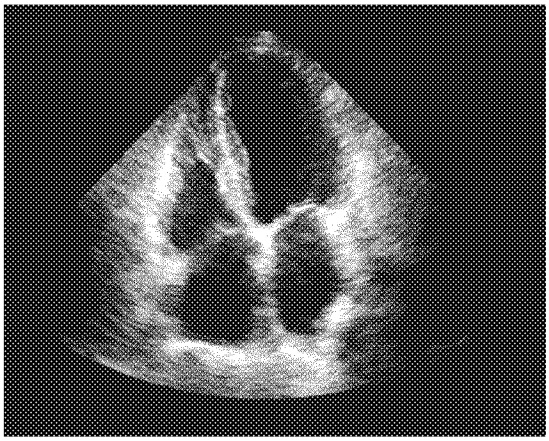
742	Image ID	20150820181200000
744	Image group ID	1
746	View category ID	AP4
748	Image data	

FIG. 17

780

Expert quality assessment record

782	Image group ID	1
784	Expert quality assessment	4

FIG. 18

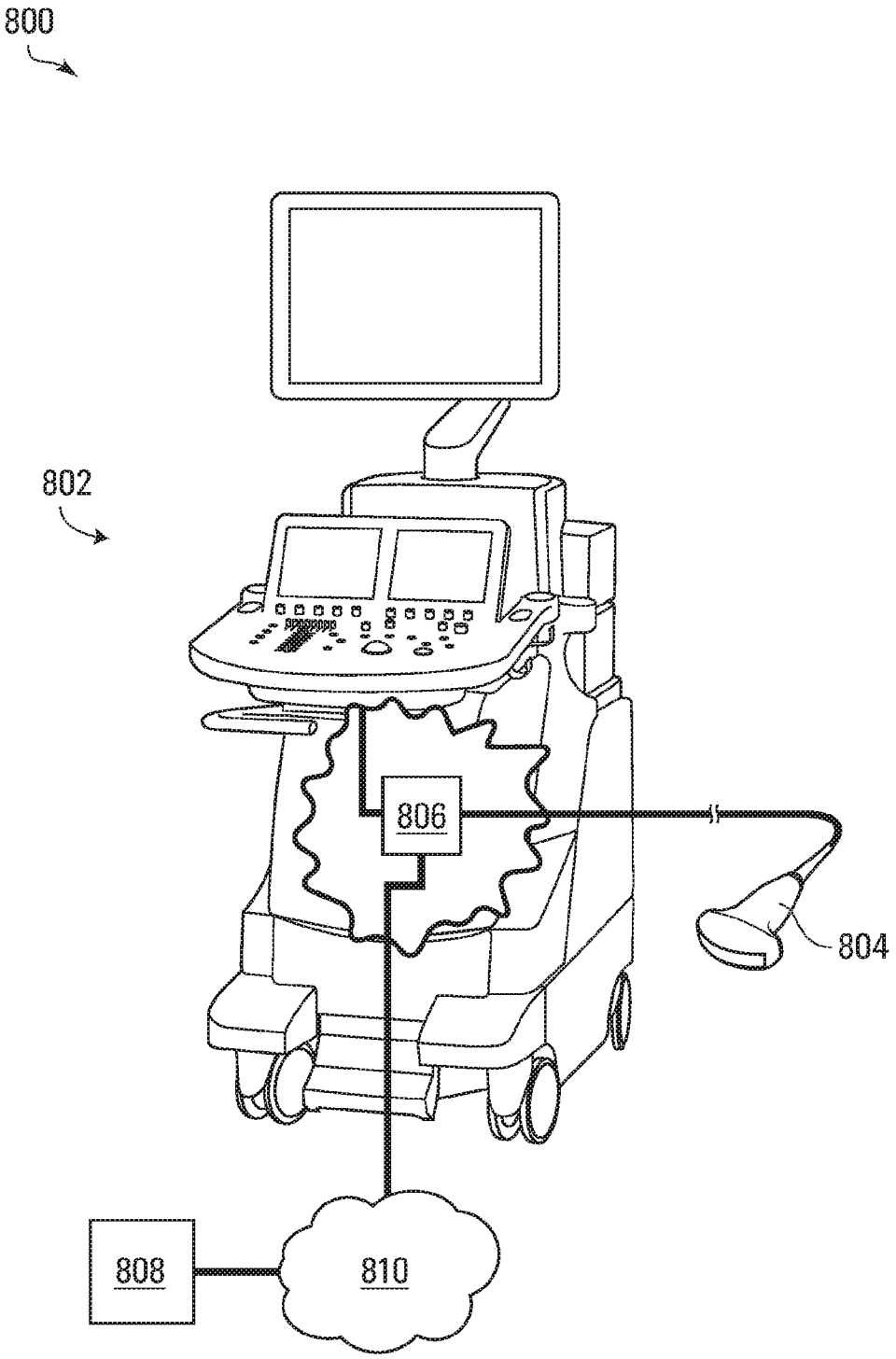


FIG. 19

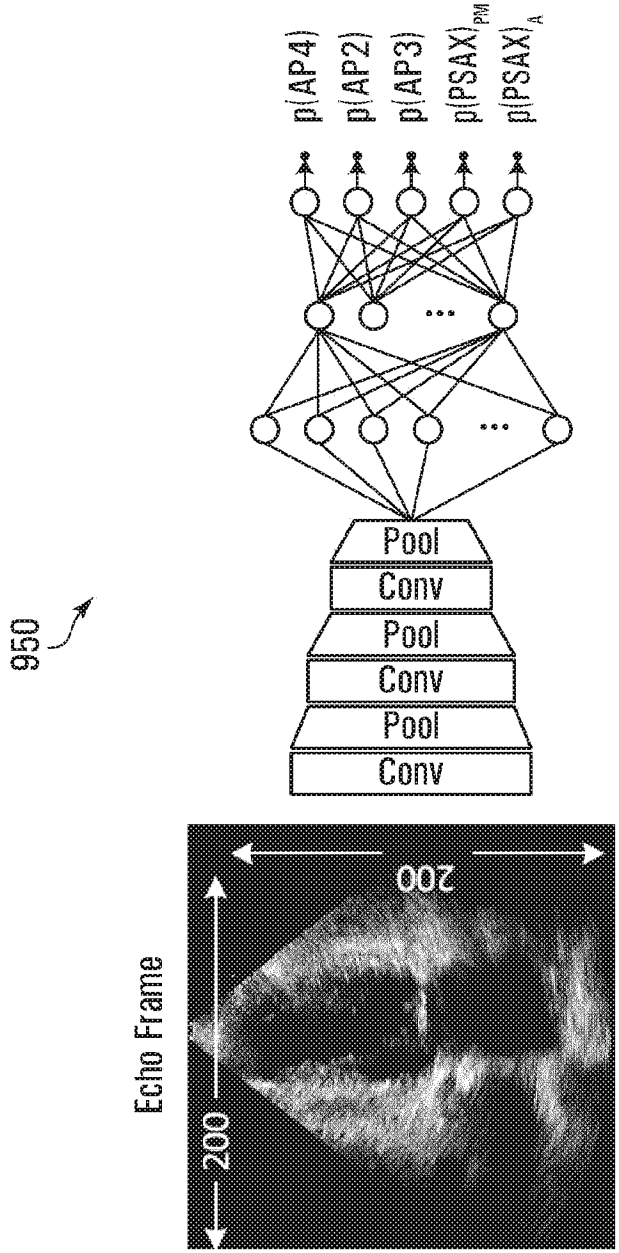

p(AP4)
p(AP2)
p(AP3)
p(PSAX)PM
p(PSAX)A
Pool
Conv
Pool
Conv
Pool
Conv
950
Echo Frame
200
200

FIG. 20

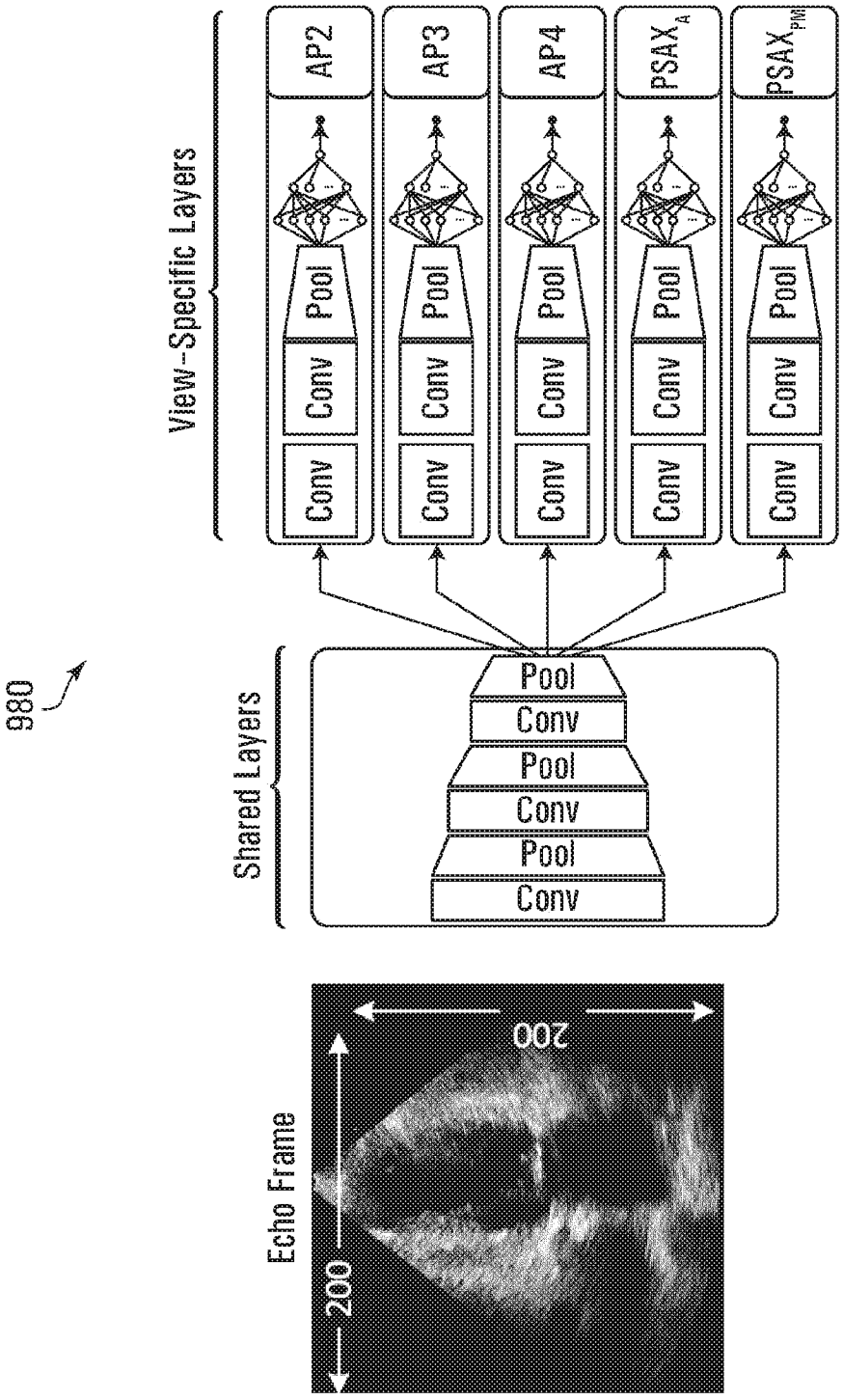

980
Shared Layers
Pool
Conv
Pool
Conv
Pool
Conv
View-Specific Layers
AP2
AP3
AP4
PSAX$_A$
PSAX$_{PM}$
Pool
Conv
Conv
Echo Frame
200
200

FIG. 21

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***A61B 8/00*** (2006.01), ***A61B 8/06*** (2006.01), ***A61B 8/14*** (2006.01), ***G06N 3/08*** (2006.01), ***G06T 7/00*** (2017.01)

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 (2006): A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Database: Canadian Patent Database (Intellect), Questel Orbit, Google Patents, IEEE Xplore

Keywords: echocardiography, images, assess, category, classify, neural network, training

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2009/0088640 (PARK et al.) 2 April 2009 (02-04-2009) * Paragraphs [0007]-[0009], [0019], [0020], [0023], [0024], [0027]-[0029], [0032], [0034]-[0036], [0038]-[0041], [0049]-[0052], [0056], [0059], [0062], [0069], [0073] and [0074] *	1-7, 13, 17-23, 29 and 33-35 --- 8-12, 14-16, 24-28 and 30-32
Y	US 2005/0020903 (KRISHNAN et al.) 27 January 2005 (27-01-2005) * Paragraphs [0039] and [0040] *	8-12, 14-16, 24-28 and 30-32
A	US 2009/0074280 (LU et al.) 19 March 2009 (19-03-2009)	1-35
A	US 2011/0082371 (CHONO) 7 April 2011 (07-04-2011)	1-35
A	US 5776063 (DITTRICH et al.) 7 July 1998 (07-07-1998)	1-35

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"&"	document member of the same patent family
"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		

Date of the actual completion of the international search 28 June 2017 (28-06-2017)	Date of mailing of the international search report 13 July 2017 (13-07-2017)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Alan Chan (819) 639-2473

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Guo, Y. et al, Automatic classification of Intracardiac Tumor and Thrombi in Echocardiography Based on Sparse Representation, IEEE Journal of Biomedical and Health Informatics, vol. 19, no. 2, March 2015.	1-35
A	Zhou, S.K. et al., Image-based multiclass boosting and echocardiographic view classification, Proceedings of the 2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'06), June 2006.	1-35
A	Carneiro, G. et al., Combining Multiple Dynamic Models and Deep Learning Architectures for Tracking the Left Ventricle Endocardium in Ultrasound Data, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, no. 11, November 2013.	1-35
A	Brotherton, T. et al., Classifying Tissue and Structure in Echocardiograms, IEEE Engineering in Medicine and Biology, November/December 1994.	1-35

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2009088640A1	02 April 2009 (02-04-2009)	US2009088640A1	02 April 2009 (02-04-2009)
		US8092388B2	10 January 2012 (10-01-2012)
		WO2009042074A1	02 April 2009 (02-04-2009)
US2005020903A1	27 January 2005 (27-01-2005)	US2005020903A1	27 January 2005 (27-01-2005)
		US7912528B2	22 March 2011 (22-03-2011)
		AU2004251359A1	06 January 2005 (06-01-2005)
		AU2004251359B2	22 January 2009 (22-01-2009)
		AU2004251360A1	06 January 2005 (06-01-2005)
		AU2004316027A1	01 September 2005 (01-09-2005)
		AU2004316027B2	30 July 2009 (30-07-2009)
		CA2529929A1	06 January 2005 (06-01-2005)
		CA2530595A1	06 January 2005 (06-01-2005)
		CA2555080A1	01 September 2005 (01-09-2005)
		CA2555080C	24 April 2012 (24-04-2012)
		CN1839391A	27 September 2006 (27-09-2006)
		CN1839392A	27 September 2006 (27-09-2006)
		CN100481096C	22 April 2009 (22-04-2009)
		CN1914617A	14 February 2007 (14-02-2007)
		EP1636731A2	22 March 2006 (22-03-2006)
		EP1636757A2	22 March 2006 (22-03-2006)
		EP1711908A2	18 October 2006 (18-10-2006)
		EP1711908B1	31 May 2017 (31-05-2017)
		JP2007524461A	30 August 2007 (30-08-2007)
		JP2007526016A	13 September 2007 (13-09-2007)
		JP2007527743A	04 October 2007 (04-10-2007)
		US2005049497A1	03 March 2005 (03-03-2005)
		US7640051B2	29 December 2009 (29-12-2009)
		US2005209519A1	22 September 2005 (22-09-2005)
		US7653227B2	26 January 2010 (26-01-2010)
		US2005059876A1	17 March 2005 (17-03-2005)
		US7693315B2	06 April 2010 (06-04-2010)
		US2010121178A1	13 May 2010 (13-05-2010)
		WO2005001740A2	06 January 2005 (06-01-2005)
		WO2005001740A3	09 June 2005 (09-06-2005)
		WO2005001769A2	06 January 2005 (06-01-2005)
		WO2005001769A3	22 December 2005 (22-12-2005)
		WO2005078631A1	25 August 2005 (25-08-2005)
		WO2005081168A2	01 September 2005 (01-09-2005)
		WO2005081168A3	01 December 2005 (01-12-2005)
US2009074280A1	19 March 2009 (19-03-2009)	US2009074280A1	19 March 2009 (19-03-2009)
		US8073215B2	06 December 2011 (06-12-2011)
		CN101390759A	25 March 2009 (25-03-2009)
		CN101390759B	06 March 2013 (06-03-2013)
		DE102008046861A1	14 May 2009 (14-05-2009)
		DE102008046861B4	01 June 2011 (01-06-2011)
		JP2009072593A	09 April 2009 (09-04-2009)
		KR20090029673A	23 March 2009 (23-03-2009)
		KR101556311B1	04 November 2015 (04-11-2015)
US2011082371A1	07 April 2011 (07-04-2011)	US2011082371A1	07 April 2011 (07-04-2011)
		CN102056654A	11 May 2011 (11-05-2011)
		CN102056547B	14 May 2014 (14-05-2014)
		EP2298176A1	23 March 2011 (23-03-2011)
		EP2298176A4	19 December 2012 (19-12-2012)
		JPWO2009148041A1	27 October 2011 (27-10-2011)
		JP5438002B2	12 March 2014 (12-03-2014)
		WO2009148041A1	10 December 2009 (10-12-2009)
US5776063A	07 July 1998 (07-07-1998)	US5776063A	07 July 1998 (07-07-1998)
		WO9814117A1	09 April 1998 (09-04-1998)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
C6 PATENT GROUP INCORPORATED, OPERATING AS THE "CARBON PATENT GROUP"
64 HOLLAND ST W, SUITE 1
P.O. BOX 173
BRADFORD, Ontario
Canada, L3Z 2A8

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	8 November 2019 (08-11-2019)
Applicant's or agent's file reference P1593PC00	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/CA2019/051192	28 August 2019 (28-08-2019)	31 August 2018 (31-08-2018)

International Patent Classification (IPC) or both national classification and IPC
IPC: ***G06T 7/00*** (2017.01) , ***A61B 8/13*** (2006.01) , ***G06N 3/08*** (2006.01) , ***G06T 1/40*** (2006.01)

Applicant
THE UNIVERSITY OF BRITISH COLUMBIA

1. This opinion contains indications relating to the following items:

- ☑ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☑ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☑ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/CA	Date of completion of this opinion	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	06 November 2019 (06-11-2019)	Enji Al-Saber (819) 639-1843

Box No I **Basis of this opinion**

1. With regard to the **language**, this opinion has been established on the basis of:

☑ the international application in the language in which it was filed.

☐ a translation of the international application into which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(b))

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

a. ☐ forming part of the international application as filed:

☐ in the form of an Annex C/ST.25 text file.

☐ on paper or in the form of an image file.

b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims 1 to 24	YES
	Claims None	NO
Inventive step (IS)	Claims None	YES
	Claims 1 to 24	NO
Industrial applicability (IA)	Claims 1 to 24	YES
	Claims None	NO

2. Citations and explanations:

Reference is made to the following documents:

D1: WO 2017/181288 Al (THE UNIVERSITY OF BRITISH COLUMBIA), 26 October 2017 (26.10.2017).
D2: US 2006/0147107 A1 (Microsoft Corporation), 06 July 2006 (06.07.2006).
D3: US 8,712,157 B2 (Xerox Corporation), 29 April 2014 (29.04.2014).
D4: Kim et al., "Deep Convolutional Neural Models for Picture-Quality Prediction", IEEE Signal Processing Magazine, November 2017.

The present application relates to facilitating ultrasonic image analysis and training neural networks to facilitate ultrasonic image analysis; wherein the analysis is performed by receiving signals representing a set of ultrasound images of the subject, deriving one or more extracted feature representations from the set of ultrasound images, determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images, determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

ARTICLE 33(2) PCT- NOVELTY

Documents D1 to D4 are considered to represent the closest prior art. Document D1 discloses facilitating echocardiographic image analysis using a system including a processor configured to receive signals representing an echocardiographic image, associate the image with a view category of a plurality of predetermined view categories and determine a quality assessment value to be associated with the echocardiographic image. D2 discloses learning-based assessment of the quality of an image, wherein an image quality assessment system trains an image classifier based on a training set of sample images that have quality ratings. D3 discloses predicting an image quality of an image by generating a first descriptor based on semantic content information for the image and generating a second descriptor based on aesthetic features extracted from the image, wherein a quality value is assigned to the image based on a categorizer trained to assign a quality value to an image based on the first and second descriptors. D4 discusses the use of deep convolutional neural models for picture-quality prediction.

However, none of the cited documents discloses facilitating ultrasonic image analysis and training neural networks to facilitate ultrasonic image analysis; wherein the analysis is performed by receiving signals representing a set of ultrasound images of the subject, deriving one or more extracted feature representations from the set of ultrasound images, determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images, determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images, as per claims 1 to 24 of the present application.

Therefore, claims 1 to 24 are considered novel and satisfy Article 33(2) PCT.

Continued on Supplemental Box, page 5 of 5

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claims

Claim 1 does not comply with PCT Article 6. Claim 1 recites "deriving one or more extracted feature representations from the set of ultrasound images". It is not clear what is meant by the expression "deriving one or more extracted feature representations". More particularly, it is not clear what derives the extracted feature representations or how they are derived. Claim 1 further recites "determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images". It is not clear what is meant by the expression "a quality assessment value". Furthermore, claim 1 recites "determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images". It is not clear what is meant by the expression "image property". The description states that the image property may be a view category (see also claim 2). It is not clear what specifically is meant by the expression "view category".

Claim 12 does not comply with PCT Article 6. Claim 12 recites "receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images". It is not clear how the quality assessment values are determined or where they are received from. Claim 12 further recites "receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images". It is not clear how the image properties are determined or where they are received from.

Observation

The description contains an incorporation by reference statement found at page 1, line 6.

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**

Continuation of: **Box V, page 3 of 5**

ARTICLE 33(3) PCT - INVENTIVE STEP

D1 is considered the most relevant prior art. Having regard to claim 1 of the present application, D1 discloses a computer-implemented method of facilitating image analysis (D1, abstract) of a subject, the method comprising receiving signals representing a set of images of the subject (D1, claim 1); deriving one or more extracted feature representations from the set of images and determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of images (D1, claims 1 to 8: determine a quality assessment value); determining, based on the derived one or more extracted feature representations, an image property associated with the set of images (D1, claims 1 and 5, associate the first image with a view category); and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images (D1, claims 1 to 8 disclose producing signals representing the quality assessment value. Producing the signals including the view category would not involve an inventive step on the part of the person skilled in the art).

The present application recites a computer-implemented method of facilitating ultrasonic image analysis, while D1 discloses facilitating echocardiographic image analysis. This difference does not amount to an inventive step. Therefore, claim 1 would have been obvious to a person skilled in the art having regard to D1 in light of the common general knowledge in the art. Claims 2 to 11 do not contain additional features which, in combination with the features of any claim to which they refer, patentably distinguish them over the subject matter of D1 in light of the common general knowledge in the art. The elements recited in these claims are either features that are already known from the prior art, or common implementation and design details which are well known to a person skilled in the art.

Claim 12 recites training neural networks to facilitate ultrasonic image analysis, the method comprising receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images; receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images; and training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network. In relation to claim 12 of the present application, D1 discloses a processor configured to train neural networks by receiving signals representing a plurality of training images, each of the plurality of training images associated with one of the plurality of predetermined image view categories; receiving signals representing respective quality assessment values representing view category specific quality assessments of the plurality of training images; and training the neural networks using the plurality of training images as inputs and the associated quality assessment values as desired outputs to determine the sets of neural network parameters defining the neural networks (D1, claim 9 and pages 32 to 42 of the description).

The present application recites a computer-implemented method of facilitating training neural networks for ultrasonic images, while D1 discloses facilitating training neural networks for echocardiographic images. This difference does not amount to an inventive step. Therefore, claim 12 would have been obvious to a person skilled in the art having regard to D1 in light of the common general knowledge in the art. Claims 13 to 20 do not contain additional features which, in combination with the features of any claim to which they refer, patentably distinguish them over the subject matter of D1 in light of the common general knowledge in the art. The elements recited in these claims are either features that are already known from the prior art, or common implementation and design details which are well known to a person skilled in the art.

Claims 21 to 24 recite systems and computer-readable media for implementing the methods of claims 1 to 20. Therefore, claim 21 to 24 are considered obvious physical embodiments of the subject matter of claims 1 to 20.

Therefore, claims 1 to 24 are considered to lack an inventive step and do not satisfy Article 33(3) PCT.

ARTICLE 33(4) PCT - INDUSTRIAL APPLICABILITY

The subject matter of claims 1 to 24 is considered to be industrially applicable, and thus fulfills the requirements of Article 33(4) PCT.

Electronic Acknowledgement Receipt

EFS ID:	37908875
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Customer Number:	20995
Filer:	Vladislav Z. Teplitskiy/Lisa Than
Filer Authorized By:	Vladislav Z. Teplitskiy
Attorney Docket Number:	CRBN001.002AUS
Receipt Date:	03-DEC-2019
Filing Date:	30-AUG-2019
Time Stamp:	12:23:39
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		IDS.pdf	172538 c0dc89bedcf973036f4ecd0a525aed8a4a597f2a	yes	3

	Multipart Description/PDF files in .zip description			
	Document Description		Start	End
	Transmittal Letter		1	1
	Information Disclosure Statement (IDS) Form (SB08)		2	3
Warnings:				
Information:				
2	Foreign Reference	WO2014097090A1.pdf	8905283 f64ac211e6e98ad9ca4c6728b8b75c465bdd7cf7	no	41
Warnings:				
Information:				
3	Foreign Reference	WO2017181288A1.pdf	19290822 a17c33c4b0a18f15f4eb86499803de0b8b10f42e	no	90
Warnings:				
Information:				
4	Non Patent Literature	2019_CES_Butterfly.pdf	583590 713f7911489b52de8840253cb5ff9a4b7bcfc85a	no	1
Warnings:				
Information:				
5	Non Patent Literature	Abdi_2017.PDF	10167058 9cf716faf91038c88b72ad31514806a672a3cfe4	no	10
Warnings:				
Information:				
6	Non Patent Literature	Abdi_Quality.pdf	1591458 c5502be503600c4d44397eb7cf1cd7a336c82aff	no	9
Warnings:				
Information:				
7	Non Patent Literature	Healthcare_Summit_2017.pdf	527593 a47b535b53e2e90373056ddfe2b0b8938bde665b	no	1
Warnings:				

Information:					
8	Non Patent Literature	Hochreiter_1997.PDF	396938 7a730b063db113fe44b1a4ec97c1eeff7a5c4669	no	32
Warnings:					
Information:					
9	Non Patent Literature	PTO_20191108_P1593PC00_WOSA.PDF	315619 4a09fe86461c5402468a7f6d87913f5796198cc2	no	5
Warnings:					
Information:					
10	Non Patent Literature	Loffe_2015.PDF	173548 c1baed41e4bc9401b1b2ec8ef55ba45543f7a1a3	no	11
Warnings:					
Information:					
11	Non Patent Literature	LU_AUTOMPR.pdf	536844 27c65779c068a2dd67b766dbd9c326885c81d5e1	no	4
Warnings:					
Information:					
12	Non Patent Literature	Nair_2010.PDF	668384 a538b05ebb01a40323997629e171c91aa28b8e2f	no	8
Warnings:					
Information:					
13	Non Patent Literature	PTO_20191108_P1593PC00_SSGY.PDF	105122 938e599ca18be291071b8a297ef9f9130381a8a8	no	2
Warnings:					
Information:					
14	Non Patent Literature	Sri-Kaushik_Pavani2012_Chapter_QualityMetricForParasternalLon.pdf	1279248 33de678eebc47745217818dd9e8803142a359145	no	8
Warnings:					
Information:					

15	Non Patent Literature	Huang.pdf	559790 7bbb51378ce14b50b961bf7b06b2dffe2505e1a6	no	9
Warnings:					
Information:					
16	Non Patent Literature	KIM.pdf	1879665 2606c46e6de2c7b9b31fa2ba7cff977fca504a76	no	12
Warnings:					
Information:					
			Total Files Size (in bytes):	47153500	

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

INFORMATION DISCLOSURE STATEMENT

First Inventor	:	Purang Abolmaesumi
App. No.	:	16/557261
Filed	:	August 30, 2019
For	:	ULTRASONIC IMAGE ANALYSIS
Examiner	:	Currently Unassigned
Art Unit	:	3793
Conf. No.	:	6889

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

References and Listing

Pursuant to 37 CFR 1.56, an Information Disclosure Statement listing references is provided herewith. Copies of any listed foreign and non-patent literature references are being submitted.

No Disclaimers

To the extent that anything in the Information Disclosure Statement or the listed references could be construed as a disclaimer of any subject matter supported by the present application, Applicant hereby rescinds and retracts such disclaimer.

Timing of Disclosure

This Information Disclosure Statement is being filed before the receipt of a First Office Action on the merits, and presumably no fee is required. If a First Office Action on the merits was mailed before the mailing date of this Statement, the Commissioner is authorized to charge the fee set forth in 37 CFR 1.17(p) to Deposit Account No. 11-1410.

Respectfully submitted,

KNOBBE, MARTENS, OLSON & BEAR, LLP

Dated: December 3, 2019

By: /Vladislav Z. Teplitskiy/
Vladislav Z. Teplitskiy
Registration No. 68,069
Registered Practitioner
Customer No. 20995
(949) 760-0404

31787148

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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	16557261
Filing Date	2019-08-30
First Named Inventor	Purang Abolmaesumi
Art Unit	2668
Examiner Name	BHATNAGAR, ANAND P
Attorney Docket Number	CRBN001.002AUS

U.S.PATENTS

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

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

U.S.PATENT APPLICATION PUBLICATIONS

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

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

FOREIGN PATENT DOCUMENTS

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

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16557261
	Filing Date	2019-08-30
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
	Examiner Name	BHATNAGAR, ANAND P
	Attorney Docket Number	CRBN001.002AUS

	1	International Search Report issued on November 8, 2019 for Application No. PCT/CA2019/051192, 3 pages.	☐
	2	Written Opinion of the International Searching Authority issued on November 8, 2019 for Application No. PCT/CA2019/051192, 5 pages.	☐

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

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	16557261
	Filing Date	2019-08-30
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
	Examiner Name	BHATNAGAR, ANAND P
	Attorney Docket Number	CRBN001.002AUS

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.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

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	/Vladislav Z. Teplitskiy/	Date (YYYY-MM-DD)	2020-01-07
Name/Print	Vladislav Z. Teplitskiy	Registration Number	68,069

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.**

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.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION
P1593PC00	see Form PCT/ISA/220 as well as, where applicable, item 5 below

International application No.	International filing date *(day/month/year)*	(Earliest)Priority date *(day/month/year)*
PCT/CA2019/051192	28 August 2019 (28-08-2019)	31 August 2018 (31-08-2018)

Applicant

THE UNIVERSITY OF BRITISH COLUMBIA

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☑ the international application in the language in which it was filed.

☐ a translation of the international application into which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☑ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☑ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 1

☑ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2019/051192

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***G06T 7/00*** (2017.01), ***A61B 8/13*** (2006.01), ***G06N 3/08*** (2006.01), ***G06T 1/40*** (2006.01)

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: ***G06T 7/00*** (2017.01), ***A61B 8/13*** (2006.01), ***G06N 3/08*** (2006.01), ***G06T 1/40*** (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Databases searched: QuestelOrbit, USPTO, Esp@cenet, PatentScope®, IEEE Xplore® Digital Library, Canadian Patent Database.

Keywords: image, analysis, feature, representation, quality assessment, property, ultrasound, view, category, neural, network, classification, training, convolutional, analyzer, processor, and related terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017/181288 A1 (THE UNIVERSITY OF BRITISH COLUMBIA), 26 October 2017 (26.10.2017). **Entire document**.	1 to 24
A	US 2006/0147107 A1 (Microsoft Corporation), 06 July 2006 (06.07.2006). **Entire document**.	1 to 24
A	US 8,712,157 B2 (Xerox Corporation), 29 April 2014 (29.04.2014). **Entire document**.	1 to 24
A	Kim et al., "Deep Convolutional Neural Models for Picture-Quality Prediction", IEEE Signal Processing Magazine, 13 November 2017 (13.11.2017). **Entire document**.	1 to 24

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

*	Special categories of cited documents:	"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
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
"D"	document cited by the applicant in the international application	"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
"E"	earlier application or patent but published on or after the international filing date	"&"	document member of the same patent family
"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		

Date of the actual completion of the international search 08 November 2019 (08-11-2019)	Date of mailing of the international search report 08 November 2019 (08-11-2019)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Enji Al-Saber (819) 639-1843

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
WO2017181288A1	26 October 2017 (26-10-2017)	WO2017181288A1	26 October 2017 (26-10-2017)
		CA3021697A1	26 October 2017 (26-10-2017)
		EP3445250A1	27 February 2019 (27-02-2019)
		US2019125298A1	02 May 2019 (02-05-2019)
US2006147107A1	06 July 2006 (06-07-2006)	US2006147107A1	06 July 2006 (06-07-2006)
		US7545985B2	09 June 2009 (09-06-2009)
US8712157B2	29 April 2014 (29-04-2014)	US2012269441A1	25 October 2012 (25-10-2012)
		US8712157B2	29 April 2014 (29-04-2014)
		FR2974433A1	26 October 2012 (26-10-2012)
		JP2012226744A	15 November 2012 (15-11-2012)
		JP5782404B2	24 September 2015 (24-09-2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
C6 PATENT GROUP INCORPORATED, OPERATING AS THE "CARBON PATENT GROUP"
64 HOLLAND ST W, SUITE 1
P.O. BOX 173
BRADFORD, Ontario
Canada, L3Z 2A8

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)* 8 November 2019 (08-11-2019)

Applicant's or agent's file reference
P1593PC00

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/CA2019/051192	28 August 2019 (28-08-2019)	31 August 2018 (31-08-2018)

International Patent Classification (IPC) or both national classification and IPC
IPC: ***G06T 7/00*** (2017.01), ***A61B 8/13*** (2006.01), ***G06N 3/08*** (2006.01), ***G06T 1/40*** (2006.01)

Applicant
THE UNIVERSITY OF BRITISH COLUMBIA

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [x] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/CA	Date of completion of this opinion	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	06 November 2019 (06-11-2019)	Enji Al-Saber (819) 639-1843

Box No I **Basis of this opinion**

1. With regard to the **language**, this opinion has been established on the basis of:

☑ the international application in the language in which it was filed.

☐ a translation of the international application into which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(b))

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

a. ☐ forming part of the international application as filed:

☐ in the form of an Annex C/ST.25 text file.

☐ on paper or in the form of an image file.

b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1 to 24	YES
	Claims	None	NO
Inventive step (IS)	Claims	None	YES
	Claims	1 to 24	NO
Industrial applicability (IA)	Claims	1 to 24	YES
	Claims	None	NO

2. Citations and explanations:

Reference is made to the following documents:

D1: WO 2017/181288 A1 (THE UNIVERSITY OF BRITISH COLUMBIA), 26 October 2017 (26.10.2017).
D2: US 2006/0147107 A1 (Microsoft Corporation), 06 July 2006 (06.07.2006).
D3: US 8,712,157 B2 (Xerox Corporation), 29 April 2014 (29.04.2014).
D4: Kim et al., "Deep Convolutional Neural Models for Picture-Quality Prediction", IEEE Signal Processing Magazine, November 2017.

The present application relates to facilitating ultrasonic image analysis and training neural networks to facilitate ultrasonic image analysis; wherein the analysis is performed by receiving signals representing a set of ultrasound images of the subject, deriving one or more extracted feature representations from the set of ultrasound images, determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images, determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

ARTICLE 33(2) PCT- NOVELTY

Documents D1 to D4 are considered to represent the closest prior art. Document D1 discloses facilitating echocardiographic image analysis using a system including a processor configured to receive signals representing an echocardiographic image, associate the image with a view category of a plurality of predetermined view categories and determine a quality assessment value to be associated with the echocardiographic image. D2 discloses learning-based assessment of the quality of an image, wherein an image quality assessment system trains an image classifier based on a training set of sample images that have quality ratings. D3 discloses predicting an image quality of an image by generating a first descriptor based on semantic content information for the image and generating a second descriptor based on aesthetic features extracted from the image, wherein a quality value is assigned to the image based on a categorizer trained to assign a quality value to an image based on the first and second descriptors. D4 discusses the use of deep convolutional neural models for picture-quality prediction.

However, none of the cited documents discloses facilitating ultrasonic image analysis and training neural networks to facilitate ultrasonic image analysis; wherein the analysis is performed by receiving signals representing a set of ultrasound images of the subject, deriving one or more extracted feature representations from the set of ultrasound images, determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images, determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images, and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images, as per claims 1 to 24 of the present application.

Therefore, claims 1 to 24 are considered novel and satisfy Article 33(2) PCT.

Continued on Supplemental Box, page 5 of 5

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claims

Claim 1 does not comply with PCT Article 6. Claim 1 recites "deriving one or more extracted feature representations from the set of ultrasound images". It is not clear what is meant by the expression "deriving one or more extracted feature representations". More particularly, it is not clear what derives the extracted feature representations or how they are derived. Claim 1 further recites "determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images". It is not clear what is meant by the expression "a quality assessment value". Furthermore, claim 1 recites "determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images". It is not clear what is meant by the expression "image property". The description states that the image property may be a view category (see also claim 2). It is not clear what specifically is meant by the expression "view category".

Claim 12 does not comply with PCT Article 6. Claim 12 recites "receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images". It is not clear how the quality assessment values are determined or where they are received from. Claim 12 further recites "receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images". It is not clear how the image properties are determined or where they are received from.

Observation

The description contains an incorporation by reference statement found at page 1, line 6.

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**

Continuation of: **Box V, page 3 of 5**

ARTICLE 33(3) PCT - INVENTIVE STEP

D1 is considered the most relevant prior art. Having regard to claim 1 of the present application, D1 discloses a computer-implemented method of facilitating image analysis (D1, abstract) of a subject, the method comprising receiving signals representing a set of images of the subject (D1, claim 1); deriving one or more extracted feature representations from the set of images and determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of images (D1, claims 1 to 8: determine a quality assessment value); determining, based on the derived one or more extracted feature representations, an image property associated with the set of images (D1, claims 1 and 5, associate the first image with a view category); and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images (D1, claims 1 to 8 disclose producing signals representing the quality assessment value. Producing the signals including the view category would not involve an inventive step on the part of the person skilled in the art).

The present application recites a computer-implemented method of facilitating ultrasonic image analysis, while D1 discloses facilitating echocardiographic image analysis. This difference does not amount to an inventive step. Therefore, claim 1 would have been obvious to a person skilled in the art having regard to D1 in light of the common general knowledge in the art. Claims 2 to 11 do not contain additional features which, in combination with the features of any claim to which they refer, patentably distinguish them over the subject matter of D1 in light of the common general knowledge in the art. The elements recited in these claims are either features that are already known from the prior art, or common implementation and design details which are well known to a person skilled in the art.

Claim 12 recites training neural networks to facilitate ultrasonic image analysis, the method comprising receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images; receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images; and training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network. In relation to claim 12 of the present application, D1 discloses a processor configured to train neural networks by receiving signals representing a plurality of training images, each of the plurality of training images associated with one of the plurality of predetermined image view categories; receiving signals representing respective quality assessment values representing view category specific quality assessments of the plurality of training images; and training the neural networks using the plurality of training images as inputs and the associated quality assessment values as desired outputs to determine the sets of neural network parameters defining the neural networks (D1, claim 9 and pages 32 to 42 of the description).

The present application recites a computer-implemented method of facilitating training neural networks for ultrasonic images, while D1 discloses facilitating training neural networks for echocardiographic images. This difference does not amount to an inventive step. Therefore, claim 12 would have been obvious to a person skilled in the art having regard to D1 in light of the common general knowledge in the art. Claims 13 to 20 do not contain additional features which, in combination with the features of any claim to which they refer, patentably distinguish them over the subject matter of D1 in light of the common general knowledge in the art. The elements recited in these claims are either features that are already known from the prior art, or common implementation and design details which are well known to a person skilled in the art.

Claims 21 to 24 recite systems and computer-readable media for implementing the methods of claims 1 to 20. Therefore, claim 21 to 24 are considered obvious physical embodiments of the subject matter of claims 1 to 20.

Therefore, claims 1 to 24 are considered to lack an inventive step and do not satisfy Article 33(3) PCT.

ARTICLE 33(4) PCT - INDUSTRIAL APPLICABILITY

The subject matter of claims 1 to 24 is considered to be industrially applicable, and thus fulfills the requirements of Article 33(4) PCT.

Electronic Acknowledgement Receipt

EFS ID:	38222498
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Customer Number:	20995
Filer:	Vladislav Z. Teplitskiy/Lisa Than
Filer Authorized By:	Vladislav Z. Teplitskiy
Attorney Docket Number:	CRBN001.002AUS
Receipt Date:	07-JAN-2020
Filing Date:	30-AUG-2019
Time Stamp:	12:02:55
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	IDS_.pdf	63859 7eb21104fa42fa094add3334b10eb9e5cf8ccfec	no	4

Warnings:

Caption Health Ex1004

Information:					
This is not an USPTO supplied IDS fillable form					
2	Non Patent Literature	ISR.pdf	364287 eda8170913cc41c8b8254ce223ea4b929f94c8b8	no	3
Warnings:					
Information:					
3	Non Patent Literature	WrittenOpinion.pdf	732369 795bca114fac48d05e840ebeb740bdd2842afe86	no	5
Warnings:					
Information:					
			Total Files Size (in bytes):	1160515	

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	6889

20995 7590 01/08/2020

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EXAMINER	
BHATNAGAR, ANAND P	

ART UNIT	PAPER NUMBER
2668	

NOTIFICATION DATE	DELIVERY MODE
01/08/2020	ELECTRONIC

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

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

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

efiling@knobbe.com
jayna.cartee@knobbe.com

Office Action Summary	Application No. 16/557,261	Applicant(s) Abolmaesumi et al.	
	Examiner ANAND P BHATNAGAR	Art Unit 2668	AIA (FITF) Status Yes

-- 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 MONTHS 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 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 08/30/2019.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

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

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

4)☐ 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*

5) ☑ Claim(s) 1-30 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-30 is/are rejected.

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

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

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

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

11)☑ The drawing(s) filed on 08/30/2019 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).

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).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** 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) ☑ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Claim Objections

2. Claim 21 is objected to because of the following informalities: A period is missing from the end of the claim/last limitation. Appropriate correction is required.

Claim Interpretation

3. The following is a quotation of 35 U.S.C. 112(f):

> (f) Element in Claim for a Combination. – An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

The following is a quotation of pre-AIA 35 U.S.C. 112, sixth paragraph:

> An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

4. The claims in this application are given their broadest reasonable interpretation using the plain meaning of the claim language in light of the specification as it would be understood by one of ordinary skill in the art. The broadest reasonable interpretation of a claim element (also commonly referred to as a claim limitation) is limited by the description in the specification when 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is invoked.

As explained in MPEP § 2181, subsection I, claim limitations that meet the following three-prong test will be interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph:

(A) the claim limitation uses the term "means" or "step" or a term used as a substitute for "means" that is a generic placeholder (also called a nonce term or a non-structural term having no specific structural meaning) for performing the claimed function;

(B) the term "means" or "step" or the generic placeholder is modified by functional language, typically, but not always linked by the transition word "for" (e.g., "means for") or another linking word or phrase, such as "configured to" or "so that"; and

(C) the term "means" or "step" or the generic placeholder is not modified by sufficient structure, material, or acts for performing the claimed function.

Use of the word "means" (or "step") in a claim with functional language creates a rebuttable presumption that the claim limitation is to be treated in accordance with 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. The presumption that the claim limitation is interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is rebutted when the claim limitation recites sufficient structure, material, or acts to entirely perform the recited function.

Absence of the word "means" (or "step") in a claim creates a rebuttable presumption that the claim limitation is not to be treated in accordance with 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. The presumption that the claim limitation is not interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112,

sixth paragraph, is rebutted when the claim limitation recites function without reciting sufficient structure, material or acts to entirely perform the recited function.

Claim limitations in this application that use the word "means" (or "step") are being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, except as otherwise indicated in an Office action. Conversely, claim limitations in this application that do not use the word "means" (or "step") are not being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, except as otherwise indicated in an Office action.

5. Claim limitations "means for receiving...," "means for deriving...," "means for determining...," and "means for producing..." have been interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, because it uses/they use a generic placeholder "means for" coupled with functional language without reciting sufficient structure to achieve the function. Furthermore, the generic placeholder is not preceded by a structural modifier.

Since the claim limitations invoke 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, claim 30 has been interpreted to cover the corresponding structure described in the specification that achieves the claimed function, and equivalents thereof.

If applicant wishes to provide further explanation or dispute the examiner's interpretation of the corresponding structure, applicant must identify the corresponding structure with reference to the specification by page and line number, and to the drawing, if any, by reference characters in response to this Office action.

If applicant does not intend to have the claim limitation(s) treated under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112 , sixth paragraph, applicant may amend the claim(s) so that it/they will clearly not invoke 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, or present a sufficient showing that the claim recites/recite sufficient structure, material, or acts for performing the claimed function to preclude application of 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph.

For more information, see MPEP § 2173 *et seq.* and *Supplementary Examination Guidelines for Determining Compliance With 35 U.S.C. 112 and for Treatment of Related Issues in Patent Applications*, 76 FR 7162, 7167 (Feb. 9, 2011).

Claim Rejections - 35 USC § 102

6. In the event the determination of the status of the application as subject to AIA 35 U.S.C. 102 and 103 (or as subject to pre-AIA 35 U.S.C. 102 and 103) is incorrect, any correction of the statutory basis for the rejection will not be considered a new ground of rejection if the prior art relied upon, and the rationale supporting the rejection, would be the same under either status.

7. 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 –

(a)(2) the claimed invention was described in a patent issued under section 151, or in an application for patent published or deemed published under section 122(b), in which the patent or application, as the case may be, names another inventor and was effectively filed before the effective filing date of the claimed invention.

Claims 1-30 are rejected under 35 U.S.C. 102(a)(2) as being anticipated by ABOLMAESUMI et al. (U.S. patent pub. 2019/0125298 A1 will be further referred to as Abol).

The applied reference has a common assignee and three inventors with the instant application. Based upon the earlier effectively filed date of the reference, it constitutes prior art under 35 U.S.C. 102(a)(2). This rejection under 35 U.S.C. 102(a)(2) might be overcome by: (1) a showing under 37 CFR 1.130(a) that the subject matter disclosed in the reference was obtained directly or indirectly from the inventor or a joint inventor of this application and is thus not prior art in accordance with 35 U.S.C. 102(b)(2)(A); (2) a showing under 37 CFR 1.130(b) of a prior public disclosure under 35 U.S.C. 102(b)(2)(B) if the same invention is not being claimed; or (3) a statement pursuant to 35 U.S.C. 102(b)(2)(C) establishing that, not later than the effective filing date of the claimed invention, the subject matter disclosed in the reference and the claimed invention were either owned by the same person or subject to an obligation of assignment to the same person or subject to a joint research agreement.

Regarding claim 1: Abol discloses a computer-implemented method of facilitating ultrasonic image analysis of a subject (abstract and fig. 1), the method comprising:

receiving signals representing a set of ultrasound images of the subject (fig. 3 and paragraph 0053);

deriving one or more extracted feature representations from the set of ultrasound images (figs 3 and 4 and paragraphs 0004-0010 and 0053-0061);

determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images (figs 3 and 4 and paragraphs 0004-0010 and 0053-0061, the quality is determined based on ultrasound image data);

determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images (figs 3 and 4 and paragraphs 0004-0010 and 0053-0061, the view category is determined and used for quality assessment. The view category is read as the image property.); and

producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images (fig. 3 and paragraphs 0053-0059, 0102, and 0103, the signals for the quality assessment are produced.).

Regarding claim 2: The method of claim 1 wherein the image property is a view category (figs 3 and 4 and paragraphs 0004-0010 and 0053-0061, the view category is determined and used for quality assessment. The view category is read as the image property.).

Regarding claim 3: The method of claim 2 wherein deriving the one or more extracted feature representations from the ultrasound images comprises, for each of the ultrasound images, deriving a first feature representation

associated with the ultrasound image (fig. 7 and paragraph 0007, a plurality of images are analyzed for quality.).

Regarding claim 4: The method of claim 3 wherein deriving the one or more extracted feature representations comprises, for each of the ultrasound images, inputting the ultrasound image into a commonly defined first feature extracting neural subnetwork to generate the first feature representation associated with the ultrasound image (figs. 5 and 6 and paragraphs 0066-0071).

Regarding claim 5: The method of claim 4 wherein deriving the one or more extracted feature representations comprises concurrently inputting each of a plurality of the ultrasound images into a respective implementation of the commonly defined first feature extracting neural network (figs. 5, 6 and 8-10 and paragraphs 0066-0071).

Regarding claim 6: The method of claim 4 wherein the commonly defined first feature extracting neural network includes a convolutional neural network (figs. 5, 6 and 8-10 and paragraphs 0066-0071).

Regarding claim 7: The method of claim 4 wherein deriving the one or more extracted feature representations comprises inputting the first feature representations into a second feature extracting neural network to generate respective second feature representations, each associated with one of the ultrasound images and wherein the one or more extracted feature representations include the second feature representations (figs. 5, 6 and 8-10 and paragraphs 0066-0071 and 0080-0089).

Regarding claim 8: The method of claim 7 wherein the second feature extracting neural network is a recurrent neural network (paragraph 0084).

Regarding claim 9: The method of claim 2 wherein determining the quality assessment value comprises inputting the one or more extracted feature representations into a quality assessment value specific neural network and wherein determining the image property comprises inputting the one or more extracted feature representations into an image property specific neural network (paragraphs 0038 and 0061-0067).

Regarding claim 10: The method of claim 9 wherein inputting the one or more extracted feature representations into the quality assessment value specific neural network comprises inputting each of the one or more extracted feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork and wherein inputting the one or more extracted feature representations into the image property determining neural network comprises inputting each of the one or more extracted feature representations into an implementation of a commonly defined image property specific neural network (figs. 5, 6 and 8-10 and paragraphs 0066-0071 and 0080-0089).

Regarding claim 11: The method of claim 2 wherein producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images comprises producing signals for causing a representation of the quality assessment value and a representation of

the image property to be displayed by at least one display in association with the set of ultrasound images (paragraphs 0103 and 0104).

Regarding claim 12: Abol discloses a computer-implemented method of training one or more neural networks to facilitate ultrasonic image analysis, the method comprising:

receiving signals representing a plurality of sets of ultrasound training images (fig. 16 and paragraphs 0127-0132. Also see claim 1.);

receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images (fig. 16 and paragraphs 0127-0132, Also see claims 1-3.);

receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images (fig. 16 and paragraphs 0127-0132, Also see claims 1-3. The view category is read as the image property.); and

training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network (fig. 16 and paragraphs 0127-0132.).

Regarding claim 13: The method of claim 12 wherein each of the image properties is a view category (fig. 16 and paragraphs 0127-0132, Also see claims 1-3. The view category is read as the image property.).

Regarding claim 14: The method of claim 13 wherein the neural network includes a feature extracting neural network, an image property specific neural network, and a quality assessment value specific neural network and wherein:

the feature extracting neural network is configured to take an input set of the plurality of sets of ultrasound training images as an input and to output one or more extracted feature representations (fig. 16 and paragraphs 0127-0132, Also see claims 1-3.);

the image property specific neural network is configured to take the one or more extracted feature representations as an input and to output a representation of an image property associated with the input set of ultrasound training images (fig. 16 and paragraphs 0127-0132, Also see claims 1-3 and 9.); and

the quality assessment specific neural network is configured to take the one or more extracted feature representations as an input and to output a quality assessment value associated with the input set of ultrasound training images (fig. 16 and paragraphs 0127-0132, Also see claims 1-3 and 9.).

Regarding claim 15: The method of claim 14 wherein the feature extracting neural network is configured to, for each of the ultrasound training images included in the input set of ultrasound training images, derive a first

feature representation associated with the ultrasound image(fig. 16 and paragraphs 0127-0132, Also see claims 1-3 and 9.).

Regarding claim 16: The method of claim 15 wherein the feature extracting neural network includes, for each of the ultrasound images included in the input set of ultrasound training images, a commonly defined first feature extracting neural network configured to take as an input the ultrasound training image and to output a respective one of the first feature representations (fig. 16 and paragraphs 0127-0132, Also see claims 1-3, 9, and 10.).

Regarding claim 17: The method of claim 16 wherein more than one implementation of the commonly defined first feature extracting neural networks are configured to concurrently generate the first feature representations (fig. 16 and paragraphs 0127-0132, Also see claims 1-3, 5, 9, and 10.).

Regarding claim 18: The method of claim 16 wherein the commonly defined first feature extracting neural network is a convolutional neural network (see claim 6).

Regarding claim 19: The method of claim 16 wherein the feature extracting neural network includes a second feature extracting neural network configured to take as an input the first feature representations and to output respective second feature representations, each associated with one of the ultrasound images included in the input set of ultrasound training images and wherein the one or more extracted feature representations include the second feature representations (See claim 7).

Regarding claim 20: The method of claim 19 wherein the second feature extracting neural network is a recurrent neural network (See claim 9).

Regarding claim 21: See claim 1.

Regarding claim 22: See claim 2.

Regarding claim 23: See claim 4.

Regarding claim 24: See claim 4.

Regarding claim 25: See claim 5.

Regarding claim 26: See claim 7.

Regarding claim 27: See claim 9.

Regarding claim 28: See claim 10.

Regarding claim 29: See claim 11.

Regarding claim 30: See claim 1.

Contact Information

8. Any inquiry concerning this communication or earlier communications from the examiner should be directed to ANAND P BHATNAGAR whose telephone number is (571)272-7416. The examiner can normally be reached on Monday-Friday 8am to 5pm.

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Vu Le can be reached on 571-272-7332. 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.

/ANAND P BHATNAGAR/
Primary Examiner, Art Unit 2668
January 4, 2020

Notice of References Cited	Application/Control No. 16/557,261	Applicant(s)/Patent Under Reexamination Abolmaesumi et al.	
	Examiner ANAND P BHATNAGAR	Art Unit 2668	Page 1 of 2

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20190125298-A1	05-2019	ABOLMAESUMI; Purang	G06N3/08	1/1
*	B	US-20180310920-A1	11-2018	Specht; Tanya	A61B8/5269	1/1
*	C	US-20190130554-A1	05-2019	Rothberg; Alex	G01S17/00	1/1
*	D	US-20050020903-A1	01-2005	Krishnan, Sriram	G16H50/20	600/407
*	E	US-20090088640-A1	04-2009	Park; Jin Hyeong	G06K9/6257	600/453
*	F	US-20190266716-A1	08-2019	Rothberg; Alex	G01S17/00	1/1
*	G	US-7672517-B2	03-2010	Buscema; Paolo Massimo	G06T5/20	382/162
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*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.

Notice of References Cited	Application/Control No. 16/557,261	Applicant(s)/Patent Under Reexamination Abolmaesumi et al.	
	Examiner ANAND P BHATNAGAR	Art Unit 2668	Page 2 of 2

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*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
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*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.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/557,261	Abolmaesumi et al.
	Examiner	Art Unit
	ANAND P BHATNAGAR	2668

CPC - Searched*		
Symbol	**Date**	**Examiner**
A61B8/5207, A61B8/0883, A61B8/463, A61B8/483, A61B8/5215, and A61B8/466 with text	01/04/2020	/AB/

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**
(A61B8/5207 OR A61B8/0883 OR A61B8/463 OR A61B8/483 OR A61B8/5215 OR A61B8/466).CPC.	01/04/2020	/AB/

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

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

Search Notes		
Search Notes	**Date**	**Examiner**
Inventor	01/04/2020	/AB/
EAST	01/04/2020	/AB/
CPC	01/04/2020	/AB/

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
Interference	see printout	01/04/2020	/AB/

/ANAND P BHATNAGAR/ Primary Examiner, Art Unit 2668	01/04/2020

PTO/SB/08 Equivalent

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	3793
(Multiple sheets used when necessary)	Examiner	Currently Unassigned
SHEET 1 OF 2	Attorney Docket No.	CRBN001.002AUS

U.S. PATENT DOCUMENTS

Examiner Initials	Cite No.	Document Number *Number - Kind Code (if known)* Example: 1,234,567 B1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear
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	2	7,680,308	03-16-2010	Dale	
	3	8,712,157	04-29-2014	Marchesotti et al.	
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	5	2006/0147107	07-06-2006	Zhang et al.	
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	9	2017/0360401	12-21-2017	Rothberg et al.	
	10	2017/0360402	12-21-2017	De Jonge et al.	
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Examiner Initials	Cite No.	Foreign Patent Document *Country Code-Number-Kind Code* Example: JP 1234567 A1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear	T[1]
	18	WO 2014/097090 A1	06-26-2014	Koninkl Philips NV [NL]		
	19	WO 2017/181288 A1	10-26-2017	Univ British Colombia [CA]		

Examiner Signature /ANAND P BHATNAGAR/	Date Considered 12/20/2019

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P.B/

PTO/SB/08 Equivalent

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	3793
(Multiple sheets used when necessary)	Examiner	Currently Unassigned
SHEET 2 OF 2	Attorney Docket No.	CRBN001.002AUS

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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, page(s), volume-issue number(s), publisher, city and/or country where published.	T[1]
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Examiner Signature /ANAND P BHATNAGAR/	Date Considered 12/20/2019

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[1] Place a check mark in this area when an English language Translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P.B/

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	22083	((University with British with Columbia)(Abolmaesumi near4 (Purang P."P.")(Rohling near4 (Robert R."R.")))(Tsang near4 (Teresa T."T.")))(Liao near4 (Zhibin Z."Z.")))(Abdi near4 (Amir A."A.")))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:08
S2	29093	(A61B/5207 OR A61B/0883 OR A61B/463 OR A61B/483 OR A61B/5215 OR A61B/466).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:09
S3	42	"7672491".pn.,"7680308".pn.,"8712157".pn.,"20050020903".pn.,"20060147107".pn.,"20090034808".pn.,"20090088640".pn.,"20150302638".pn.,"20170360401".pn.,"20170360402".pn.,"20170360403".pn.,"20170360411".pn.,"20170360412".pn.,"20180153505".pn.,"20190059851".pn.,"20190104949".pn.,"20190266716".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:13
S4	22083	((University with British with Columbia)(Abolmaesumi near4 (Purang P."P.")(Rohling near4 (Robert R."R.")))(Tsang near4 (Teresa T."T.")))(Liao near4 (Zhibin Z."Z.")))(Abdi near4 (Amir A."A.")))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:20
S5	452	S4 and ((ultrasound doppler echo echocardiog$6) near5 ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:20
S6	352	S5 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:26
S7	142	S6 and ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near5 (quali$4 inspect$4 noise$3 artifact$3 textur$4)) and quali$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:29
S8	23	S7 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) APE AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SCS IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 10:48
S9	29093	(A61B/5207 OR A61B/0883 OR A61B/463 OR A61B/483 OR A61B/5215 OR A61B/466).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:24
S10	17118	S9 and ((ultrasound doppler echo echocardiog$6) near5 ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:24
S11	9397	S10 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:25
S12	168	S11 and ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near5 (quali$4 inspect$4 noise$3 artifact$3 textur$4)) and (quali$4 near (assess$4 determinat$4 estimat$4 calculat$4))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:29
S13	68	S12 and ((propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) APE AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SCS IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:31
S14	22083	((University with British with Columbia)(Abolmaesumi near4 (Purang P."P.")(Rohling near4 (Robert R."R.")))(Tsang near4 (Teresa T."T.")))(Liao near4 (Zhibin Z."Z.")))(Abdi near4 (Amir A."A.")))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:32
S15	452	S14 and ((ultrasound doppler echo echocardiog$6) near5 ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:32

EAST Search History

S16	352	S15 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:32
S17	5142	S16 and ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near5 (qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:32
S18	23	S17 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) APC AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:32
S19	67	S13 not S18	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 11:32
S20	442	"7672491".pn.,"7680308".pn.,"8712157".pn.,"20050020903".pn.,"20060147107".pn.,"20090034808".pn.,"20090088640".pn.,"20150302638".pn.,"20170360401".pn.,"20170360402".pn.,"20170360403".pn.,"20170360411".pn.,"20170360412".pn.,"20180153505".pn.,"20190069851".pn.,"20190104949".pn.,"20190266716".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 12:10
S21	27	S20 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 12:10
S22	19	S21 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 12:11
S23	11814	(((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 13:45
S24	1437	S23 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) APC AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 13:48
S25	525	S24 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) same qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 13:57
S26	11814	(((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 14:01
S27	1437	S26 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) APC AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 14:01
S28	525	S27 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) same qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 14:01
S29	1112	S28 and ((neural artificial$4 machine$1) near4 (learn$4 intelligen$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 14:01
S30	389	S29 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with qualit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/20 14:07
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S32	4	"20171812285".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 11:16
S33	440	(US-20020186818-$ or US-20060099876-$ or US-20090034808-$ or US-20090088640-$ or US-20110077526-$ or US-20120142730-$ or US-20150302638-$ or US-20160302759-$ or US-20170360402-$ or US-20170360403-$ or US-20180103865-$ or US-20180116725-$ or US-20180153505-$ or US-20180310920-$ or US-20190059851-$ or US-20190125209-$ or US-20190130554-$ or US-20190142390-$ or US-20190261956-$ or US-20190266716-$).did. or ((US-10140734-$ or US-7672491-$ or US-7672517-$ or US-7680308-$ or US-7783094-$ or US-8465433-$ or US-8494829-$ or US-8512247-$ or US-8784320-$ or US-9204863-$ or US-9237892-$ or US-9307859-$ or US-9364188-$ or US-9384566-$ or US-9445789-$ or US-9451886-$ or US-9700294-$).did. or (WO-2017191289-$).did. or (US-20170360411-$ or WO-2014080319-$).did.	US-PGPUB; USPAT; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 11:36
S34	440	(US-20020186818-$ or US-20060099876-$ or US-20090034808-$ or US-20090088640-$ or US-20110077526-$ or US-20120142730-$ or US-20150302638-$ or US-20160302759-$ or US-20170360402-$ or US-20170360403-$ or US-20180103865-$ or US-20180116725-$ or US-20180153505-$ or US-20180310920-$ or US-	US-PGPUB;	OR	ON	2020/01/04

		20190059851.$ or US-20190125298.$ or US-20190130554.$ or US-20190142390.$ or US-20190261956.$ or US-20190266716.$).did. or (US-10140734.$ or US-7672491.$ or US-7672517.$ or US-7680308.$ or US-7783094.$ or US-8465433.$ or US-8494829.$ or US-8512247.$ or US-8784320.$ or US-9204863.$ or US-9237382.$ or US-9307959.$ or US-9364198.$ or US-9384566.$ or US-9445788.$ or US-9451886.$ or US-9700284.$).did. or (WO-2017181288.$).did. or (US-20170360411.$ or WO-2014080319.$).did.	USPAT; FPRS; DERWENT			13:37
S35	440	(US-20020186819.$ or US-20060089976.$ or US-20080034809.$ or US-20080088640.$ or US-20110077528.$ or US-20120142730.$ or US-20150302538.$ or US-20160302758.$ or US-20170360402.$ or US-20170360403.$ or US-20180103865.$ or US-20180116725.$ or US-20180133505.$ or US-20180310020.$ or US-20190059851.$ or US-20190125298.$ or US-20190130554.$ or US-20190142390.$ or US-20190261956.$ or US-20190266716.$).did. or (US-10140734.$ or US-7672491.$ or US-7672517.$ or US-7680308.$ or US-7783094.$ or US-8465433.$ or US-8494829.$ or US-8512247.$ or US-8784320.$ or US-9204863.$ or US-9237382.$ or US-9307959.$ or US-9364198.$ or US-9384566.$ or US-9445788.$ or US-9451886.$ or US-9700284.$).did. or (WO-2017181288.$).did. or (US-20170360411.$ or WO-2014080319.$).did.	US-PGPUB; USPAT; FPRS; DERWENT; IBM_TDB	OR	ON	2020/01/04 14:09
S36	223	S35 and quality and (ultrasound$3 doppler echo echocardiograph$3) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 14:09
S37	4	"20171812 88".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 17:29
S38	2	S37 and quality and (ultrasound$3 doppler echo echocardiograph$3) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 17:29

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S39	18816	quality and (ultrasound$3 doppler echo echocardiograph$3) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT	OR	ON	2020/01/04 17:33
S40	11258	(quality with (ultrasound$3 doppler echo echocardiograph$3)) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT	OR	ON	2020/01/04 17:34
S41	424	S40 and ((tomograph$4 scan$4 slice$1 imag$4 pictur$4) near4 (featur$4 characteristic$3 attribute$3)) and (propert$4 textur$4 view$3)	US-PGPUB; USPAT	OR	ON	2020/01/04 17:37
S42	172	S41 and (quality near4 (determinat$4 determin$3 detect$4 assess$5 analy$4))	US-PGPUB; USPAT	OR	ON	2020/01/04 17:38
S43	31	S40 and ((tomograph$4 scan$4 slice$1 imag$4 pictur$4) near4 view$3) and convolution$3 and recurrent$1	US-PGPUB; USPAT	OR	ON	2020/01/04 17:47
S44	20	S42 and ((tomograph$4 scan$4 slice$1 imag$4 pictur$4) near4 view$3) and convolution$3 and recurrent$1	US-PGPUB; USPAT	OR	ON	2020/01/04 17:47

1/4/2020 6:18:28 PM
C:\Users\abhatnagar\Documents\EAST\Workspaces\16557261.wsp

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BIB DATA SHEET

CONFIRMATION NO. 6889

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
16/557,261	08/30/2019	382	2668	CRBN001.002AUS

APPLICANTS

The University of British Columbia, Vancouver, CANADA;

INVENTORS

Purang Abolmaesumi, Vancouver, CANADA;
Robert Rohling, Vancouver, CANADA;
Teresa Tsang, North Vancouver, CANADA;
Zhibin Liao, Adelaide, AUSTRALIA;
Amir Abdi, Vancouver, CANADA;

**** CONTINUING DATA ***************************

This application is a CON of PCT/CA2019/051192 08/28/2019
and claims benefit of 62/725,913 08/31/2018

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** ** SMALL ENTITY **
09/11/2019

Foreign Priority claimed	❑ Yes ☑ No	❑ Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
35 USC 119(a-d) conditions met	❑ Yes ☑ No		CANADA	13	30	4
Verified and Acknowledged	/ANAND P BHATNAGAR/ Examiner's Signature	Initials				

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KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
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IRVINE, CA 92614
UNITED STATES

TITLE

ULTRASONIC IMAGE ANALYSIS

FILING FEE RECEIVED		
1595	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

BIB (Rev. 05/07).

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS

CONFIRMATION NO. 6889

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KNOBBE MARTENS OLSON & BEAR LLP
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PUBLICATION NOTICE

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Title:ULTRASONIC IMAGE ANALYSIS

Publication No.US-2020-0069292-A1
Publication Date:03/05/2020

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

First Inventor	:	Purang Abolmaesumi
App. No.	:	16/557261
Filed	:	August 30, 2019
For	:	ULTRASONIC IMAGE ANALYSIS
Examiner	:	Bhatnagar, Anand P.
Art Unit	:	2668
Conf. No.	:	6889

AMENDMENT AND RESPONSE TO OFFICE ACTION

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

Dear Commissioner:

In response to the Non-Final Office Action mailed January 8, 2020, Applicant respectfully submits the following comments and amendments for the above-identified application.

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

Summary of the Interview begins on page 8.

Remarks begin on page 9 of this paper.

AMENDMENTS TO THE CLAIMS

1. (Original) A computer-implemented method of facilitating ultrasonic image analysis of a subject, the method comprising:

receiving signals representing a set of ultrasound images of the subject;

deriving one or more extracted feature representations from the set of ultrasound images;

determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images;

determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and

producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

2. (Original) The method of claim 1 wherein the image property is a view category.

3. (Original) The method of claim 2 wherein deriving the one or more extracted feature representations from the ultrasound images comprises, for each of the ultrasound images, deriving a first feature representation associated with the ultrasound image.

4. (Original) The method of claim 3 wherein deriving the one or more extracted feature representations comprises, for each of the ultrasound images, inputting the ultrasound image into a commonly defined first feature extracting neural subnetwork to generate the first feature representation associated with the ultrasound image.

5. (Original) The method of claim 4 wherein deriving the one or more extracted feature representations comprises concurrently inputting each of a plurality of the ultrasound images into a respective implementation of the commonly defined first feature extracting neural network.

6. (Original) The method of claim 4 wherein the commonly defined first feature extracting neural network includes a convolutional neural network.

7. (Original) The method of claim 4 wherein deriving the one or more extracted feature representations comprises inputting the first feature representations into a second feature

extracting neural network to generate respective second feature representations, each associated with one of the ultrasound images and wherein the one or more extracted feature representations include the second feature representations.

8. (Original) The method of claim 7 wherein the second feature extracting neural network is a recurrent neural network.

9. (Original) The method of claim 2 wherein determining the quality assessment value comprises inputting the one or more extracted feature representations into a quality assessment value specific neural network and wherein determining the image property comprises inputting the one or more extracted feature representations into an image property specific neural network.

10. (Original) The method of claim 9 wherein inputting the one or more extracted feature representations into the quality assessment value specific neural network comprises inputting each of the one or more extracted feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork and wherein inputting the one or more extracted feature representations into the image property determining neural network comprises inputting each of the one or more extracted feature representations into an implementation of a commonly defined image property specific neural network.

11. (Original) The method of claim 2 wherein producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images comprises producing signals for causing a representation of the quality assessment value and a representation of the image property to be displayed by at least one display in association with the set of ultrasound images.

12. (Original) A computer-implemented method of training one or more neural networks to facilitate ultrasonic image analysis, the method comprising:

receiving signals representing a plurality of sets of ultrasound training images;

receiving signals representing quality assessment values, each of the quality assessment values associated with one of the sets of ultrasound training images and representing a quality assessment of the associated set of ultrasound training images;

receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images; and

training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network.

13. (Original) The method of claim 12 wherein each of the image properties is a view category.

14. (Original) The method of claim 13 wherein the neural network includes a feature extracting neural network, an image property specific neural network, and a quality assessment value specific neural network and wherein:

the feature extracting neural network is configured to take an input set of the plurality of sets of ultrasound training images as an input and to output one or more extracted feature representations;

the image property specific neural network is configured to take the one or more extracted feature representations as an input and to output a representation of an image property associated with the input set of ultrasound training images; and

the quality assessment specific neural network is configured to take the one or more extracted feature representations as an input and to output a quality assessment value associated with the input set of ultrasound training images.

15. (Original) The method of claim 14 wherein the feature extracting neural network is configured to, for each of the ultrasound training images included in the input set of ultrasound training images, derive a first feature representation associated with the ultrasound image.

16. (Original) The method of claim 15 wherein the feature extracting neural network includes, for each of the ultrasound images included in the input set of ultrasound training images, a commonly defined first feature extracting neural network configured to take as an input the ultrasound training image and to output a respective one of the first feature representations.

17. (Original) The method of claim 16 wherein more than one implementation of the commonly defined first feature extracting neural networks are configured to concurrently generate the first feature representations.

18. (Original) The method of claim 16 wherein the commonly defined first feature extracting neural network is a convolutional neural network.

19. (Original) The method of claim 16 wherein the feature extracting neural network includes a second feature extracting neural network configured to take as an input the first feature representations and to output respective second feature representations, each associated with one of the ultrasound images included in the input set of ultrasound training images and wherein the one or more extracted feature representations include the second feature representations.

20. (Original) The method of claim 19 wherein the second feature extracting neural network is a recurrent neural network.

21. (Currently Amended) A system for facilitating ultrasonic image analysis comprising at least one processor configured to:

receive signals representing a set of ultrasound images of the subject;

derive one or more extracted feature representations from the set of ultrasound images;

determine, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images;

determine, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and

produce signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

22. (Original) The system of claim 21 wherein the image property is a view category.

23. (Original) The system of claim 22 wherein the at least one processor is configured to, for each of the ultrasound images, input the ultrasound image into a commonly defined first feature extracting neural subnetwork to generate a first feature representation associated with the ultrasound image.

24. (Original) The system of claim 23 wherein the at least one processor is configured to, for each of the ultrasound images, input the ultrasound image into a commonly

defined first feature extracting neural subnetwork to generate the first feature representation associated with the ultrasound image.

25. (Original) The system of claim 24 wherein the at least one processor is configured to concurrently input each of a plurality of the ultrasound images into a respective implementation of the commonly defined first feature extracting neural network.

26. (Original) The system of claim 24 wherein the at least one processor is configured to input the first feature representations into a second feature extracting neural network to generate respective second feature representations, each associated with one of the ultrasound images and wherein the one or more extracted feature representations include the second feature representations.

27. (Original) The system of claim 22 wherein the at least one processor is configured to input the one or more extracted feature representations into a quality assessment value specific neural network and to input the one or more extracted feature representations into an image property specific neural network.

28. (Original) The system of claim 27 wherein the at least one processor is configured to input each of the one or more extracted feature representations into an implementation of a commonly defined quality assessment value specific neural subnetwork and to input each of the one or more extracted feature representations into an implementation of a commonly defined image property specific neural network.

29. (Original) The system of claim 22 wherein the at least one processor is configured to produce signals for causing a representation of the quality assessment value and a representation of the image property to be displayed by at least one display in association with the set of ultrasound images.

30. (Original) A system for facilitating ultrasonic image analysis, the system comprising:

means for receiving signals representing a set of ultrasound images of the subject;

means for deriving one or more extracted feature representations from the set of ultrasound images;

means for determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images;

means for determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and

means for producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images.

SUMMARY OF THE EXAMINER INTERVIEW

A telephone interview was conducted on January 27, 2020 and attended by Applicant's representative Keith Lim, and Examiner Anand P Bhatnagar. Applicant's representative and the Examiner discussed the Office Action dated January 8, 2020, and the art based rejection. It was agreed that a statement invoking the exception under 35 U.S.C. § 102(b)(2)(C) would overcome the rejection.

REMARKS

This paper is responsive to the non-final Office Action dated January 8, 2020 (the "Office Action"). By the foregoing amendments, Applicant has amended claim 21 to correct a typographical error. No new matter has been added. In view of the following remarks, Applicant respectfully submits that the application is in condition for allowance.

Objection to the Claim 21

The Office Action objected to claim 21 for minor informalities. Applicant amended claim 21, and respectfully requests withdrawal of the objection to claim 21.

Rejection under 35 U.S.C. § 102

Claims 1-30 stand rejected under 35 U.S.C. § 102(a)(2) as being unpatentable over U.S. Patent Publ. No. 2019/0125298 A1 ("Abolmaesumi"). Applicant respectfully submits that the Abolmaesumi reference does not qualify as prior art under 35 U.S.C. §102(a)(2) because it falls into the exception under 35 U.S.C. § 102(b)(2)(C). Specifically, Abolmaesumi and the present application were, not later than the effective filing date of the claimed invention in the present application, subject to an obligation of assignment to the University of British Columbia. Accordingly, Applicant requests withdrawal of the rejections.

Conclusion

For the foregoing reasons, Applicant respectfully submits that the application is in condition for allowance. The Examiner is invited to contact the undersigned by telephone to resolve any remaining issues.

No Disclaimers or Disavowals

Although the present communication may include alterations to the application or claims, or characterizations of claim scope or referenced art, Applicant is not conceding in this application that previously pending claims are not patentable. Rather, any alterations or characterizations are being made to facilitate expeditious prosecution of this application. Applicant reserves the right to pursue at a later date any previously pending or other broader or

narrower claims that capture any subject matter supported by the present disclosure, including subject matter found to be specifically disclaimed herein or by any prior prosecution. Accordingly, reviewers of this or any parent, child or related prosecution history shall not reasonably infer that Applicant has made any disclaimers or disavowals of any subject matter supported by the present application.

Please charge any additional fees, including any fees for additional extension of time, or credit overpayment to Deposit Account No. 11-1410.

Respectfully submitted,

KNOBBE, MARTENS, OLSON & BEAR, LLP

Dated: March 19, 2020

By:/Keith M Lim/_____
Keith M Lim
Registration No. 68,912
Registered Practitioner
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32087554

INFORMATION DISCLOSURE STATEMENT

First Inventor	:	Purang Abolmaesumi
App. No.	:	16/557261
Filed	:	August 30, 2019
For	:	ULTRASONIC IMAGE ANALYSIS
Examiner	:	Bhatnagar, Anand P.
Art Unit	:	2668
Conf. No.	:	6889

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

References and Listing

Pursuant to 37 CFR 1.56, an Information Disclosure Statement listing references is provided herewith. Copies of any listed foreign and non-patent literature references are being submitted.

No Disclaimers

To the extent that anything in the Information Disclosure Statement or the listed references could be construed as a disclaimer of any subject matter supported by the present application, Applicant hereby rescinds and retracts such disclaimer.

Timing of Disclosure

This Information Disclosure Statement is being filed after receipt of a First Office Action, but before the mailing date of a Final Action and before the mailing date of a Notice of Allowance.

This Statement is accompanied by the fees set forth in 37 CFR 1.17(p). The Commissioner is hereby authorized to charge any additional fees which may be required or to credit any overpayment to Account No. 11-1410.

Respectfully submitted,

KNOBBE, MARTENS, OLSON & BEAR, LLP

Dated: March 19, 2020

By: /Keith M Lim/_____
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
(Multiple sheets used when necessary)	Examiner	Bhatnagar, Anand P.
SHEET 1 OF 3	Attorney Docket No.	CRBN001.002AUS

U.S. PATENT DOCUMENTS					
Examiner Initials	Cite No.	Document Number *Number - Kind Code (if known)* Example: 1,234,567 B1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear
	1	5,776,063	07-07-1987	Dittrich et al.	
	2	7,912,528	03-22-2011	Krishnan, et al.	
	3	8,594,398	11-26-2013	Beymer, et al.	
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	7	8,917,917	12-23-2014	Bwymar, et al.	
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	10	20050251013	11-10-2005	Krishnan, et al	
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	14	20110082371	04-07-2011	Chono	
	15	20150086093	03-26-2015	Fonte, et al.	
	16	20170026298	01-26-2017	Huo	
	17	U.S. Patent Application No. 16/095,601, including its prosecution history, and the Office Actions therein.	10-22-2018	Abolmaesumi	

FOREIGN PATENT DOCUMENTS						
Examiner Initials	Cite No.	Foreign Patent Document *Country Code-Number-Kind Code* Example: JP 1234567 A1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear	**T**[1]
	18	WO 2014/155272	10-02-2014	KONINKLIJKE PHILIPS NV.		

Examiner Signature	Date Considered

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
(Multiple sheets used when necessary)	Examiner	Bhatnagar, Anand P.
SHEET 2 OF 3	Attorney Docket No.	CRBN001.002AUS

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[1]
	19	ALISON NOBLE, et al., "Ultrasound Image Segmentation: A Survey," published in IEEE Transactions on Medical maging from the Institute of Electrical and Electronics Engineers in August 2006. Volume 25, issue 8, pages 87-1010.	
	20	A.S. MILLER, et al., "Review of Neural Network Applications in Medical Imaging and Signal Processing," published in Medical & Biological Engineering & Computing in September 1992. Volume 30, pages 449-464.	
	21	CANADIAN INTELLECTUAL PROPERTY OFFICE, International Search Report and Written Opinion of the international Searching Authority in PCT/CA2017/050496, dated July 13, 2017, which is the international application to this U.S. application.	
	22	CURT G. DEGROFF, MD; et al., "Artificial Neural Network-Based Method of Screening Heart Murmurs in Children," published in Circulation by the American Heart Association on June 5, 2001. Volume 103, issue 22, pages 2711-2716.	
	23	DIPTI ITCHHAPORIA, MD; et al., "Artificial Neural Networks: Current Status in Cardiovascular Medicine," published in the Journal of the American College of Cardiology (JACC) in August 1996. Volume 28, issue 2, pages 515-521	
	24	HAO CHEN, et al., "Iterative Multi-domain Regularized Deep Learning for Anatomical Structure Detection and Segmentation from Ultrasound Images," submitted to Medical Image Computing and Computer Assisted Intervention, Dart 2 (MICCAI) in July 2016.	
	25	HOO-CHANG SHIN, et al., "Deep Convolutional Neural Networks for Computer-Aided Detection: CNN Architectures, Dataset Characteristics and Transfer Learning," submitted to hllps://www.arXiv.org on February 10, 2016.	
	26	J. JIANG, et al., "Medical Imaging Analysis with Artificial Neural Networks," published in Computerized Medical Imaging and Graphics in 2010. Volume 34, issue 8, pages 617-631.	
	27	NEELAM SINHA, et al., "Quality Assessment in Magnetic Resonance Images," published in Critical Reviews™ in Biomedical Engineering {CRMBE) in 2010. Volume 38, issue 2, pages 127-141.	
	28	NIMA TORBATI, et al., "An Efficient Neural Network Based Method for Medical Image Segmentation," published in computers in Biology and Medicine by Elsevier on January 1, 2014. Volume 44, pages 76-87.	
	29	NOHA EL-ZEHIRY, et al., "Learning the Manifold of Quality Ultrasound Acquisition," published in Medical Image computing and Computer Assisted Intervention, Part 1 (MCCAil) in September 2013.	
	30	November 8, 2019, Extended European Search Report from the EUROPEAN PATENT OFFICE in European Patent Application Serial No. 17785210.0, which is a foreign counterpart to this application.	
	31	R.H. CLAYTON, et al., "Recognition of Ventricular Fibrillation Using Neural Networks," published in Medical & Biological Engineering & Computing in March 1994. Volume 32, pages 217-220.	
	32	S. KEVIN ZHOU, et al., "Image-based Multiclass Boosting and Echocardiographic View Classification," in 2006 IEEE computer Society Conference on Computer Vision and Pattern Recognition {CVPR'06). Volume 2, pages 1559-1565	
	33	SHIJUN WANG, et al., "Machine Learning and Radiology," published in Medical Image Analysis by Elsevier in July J012. Volume 16, issue 5, pages 993-951.	
	34	SRI-KAUSHIK PAVANI, et al., "Quality Metric for Parasternal Long Axis B-Mode Echocardiograms," published in Medical Image Computing and Computer Assisted Intervention {MICCAI) in January 2012. Volume 15, part 2, pages 178-485.	

Examiner Signature	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.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
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	35	STEN ROAR SNARE, et al., "Real-Time Scan Assistant for Echocardiography," in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control in March 2012. Volume 59, issue 3, pages 583-589.	
	36	TIMOTHY J_ W. DAWES, FRCA, PhD; et al., "Machine Learning of Three-dimensional Right Ventricular Motion Enables Outcome Prediction in Pulmonary Hypertension: A Cardiac MR Imaging Study," published online in Radiology n January 2017.	
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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Foreign Reference	WO2014155272A1.pdf	2556235 e566a000841345c810623f1549a3664a839f578a	no	27
Warnings:					
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2	Non Patent Literature	NOBLE-Ultrasound_image_segmentation-a-survey.pdf	1906614 2cb10e31b9d33ecda15978bcd936e72a32a3ab32	no	24
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3	Non Patent Literature	Miller_Med_Biol_Eng_Comp_1992.pdf	5597999 edd294d3844c71873093ee00c73fd5e9f2df0fc5	no	16
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4	Non Patent Literature	PCT_CA2017_071317_Intl_Search_Report.pdf	514361 6fafabf4dfc7a95a66bf69c402f1e16b544e94fb	no	4
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5	Non Patent Literature	DeGroff_Circulation_2011.pdf	2426625 21dab943a40e9f724c0d379942e6d90a0f411822	no	6
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6	Non Patent Literature	ITCHHAPORIA_JACC_1996.pdf	1857165 e1b89bc4fe07ce00e34b174ba7e45ee18dc496a4	no	7
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8	Non Patent Literature	SHIN-Deep-Convolutional-Neural-Networks.pdf	5484751 c0305e8327fc2ffe4075ae803a9a3c2b89160ec0	no	14
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9	Non Patent Literature	Jiang_Med_Imag_Graph_2010.pdf	455999 e61092bf16d7705ffe2513cf4b7165bd7b4f0e94	no	15
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12	Non Patent Literature	El-Zehiry_MCCAIL_2013.pdf	1480233 e81ab3d4e2f54f263257335bb82a320320329294	no	9
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13	Non Patent Literature	Supplementary_Euro_Search_Report_11082019.pdf	71171 77b7381fe5799a73e187d5674d6edbe1804186b9	no	1
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14	Non Patent Literature	Clayton_Med_Bio_Eng_Comp_1994.pdf	1060645 4df95e5885ad2b28680da8cb3f97d14ae063723b	no	4
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15	Non Patent Literature	ZHOU-Image-based-Multiclass-Boosting-and-Echocardiographic-View-Classification.pdf	588618 d60ba8a466f0de95e748e0bce1c976342774ca48	no	7
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16	Non Patent Literature	Wang_Med_Image_Analy_2012.pdf	1159576 cd4c5649c46e1c4b76a243da6ccb9d6ff6214269	no	19
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17	Non Patent Literature	Pavani_MICCAI_2012.pdf	1218645 8a96e221731ff31d148265fe6a9be80b444e6851	no	8
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18	Non Patent Literature	SNARE-Real-time-scan-assistant-for-echocardiography.pdf	1800428 c19469ce2d9396c00e544e3769c665c0102a36cd	no	7
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19	Non Patent Literature	Dawes_Radiology_2017.pdf	1919276 8e0a83d7d9fc1692c5f0518cc15d624e5e9131e2	no	10
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22	Non Patent Literature	AMIR.PDF	2855619 58df2f9fe99c2e846751727d1c77cbae7792bce1	no	8
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23	Non Patent Literature	Abdi_SPIE_2017.PDF	2929579 807ea27d504a4813bf932638e386b23f5ff9c982	no	8
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24		Response.pdf	53878 696e97722a0a663329ab9f17281a98a8d9ec8783	yes	10

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(54) **Title**: REAL-TIME QUALITY CONTROL FOR ACQUISITION OF 3D ULTRASOUND IMAGES

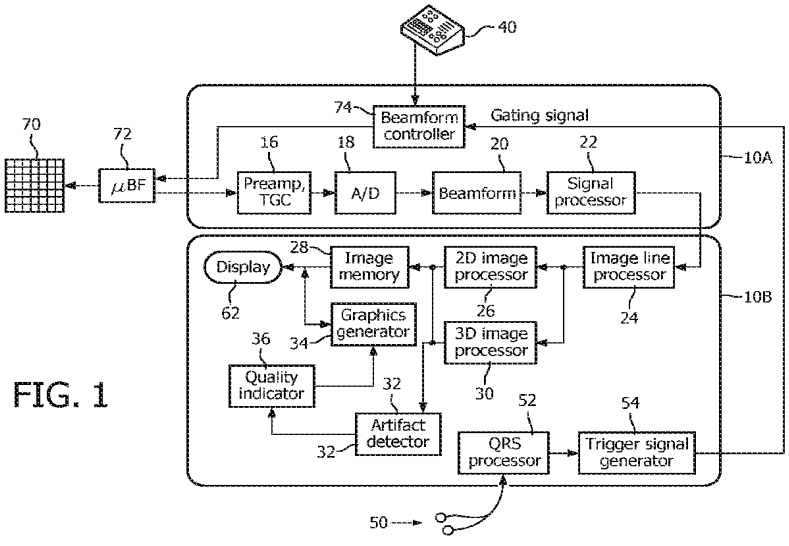


FIG. 1

(57) **Abstract**: An ultrasound system acquires 3D ultrasound images by acquisition of subvolume images of a 3D volumetric object, then spatially aligning adjacent subvolumes to form a wide view 3D image. If the subvolumes are acquired during the occurrence of motion or acoustic shadowing, the 3D image can be too contaminated by artifacts to be suitable for accurate quantified measurement. An artifact detector assesses a 3D image for the presence of such artifacts and controls a quality indicator which display an indication of the suitability of a 3D image for quantification during live imaging. This can alert a user to rescan the patient to reacquire an image of the anatomy which is artifact-free and better suited for accurate quantification.

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REAL-TIME QUALITY CONTROL FOR ACQUISITION OF 3D ULTRASOUND IMAGES

This invention relates to ultrasonic diagnostic imaging systems and, in particular, to ultrasound systems which provide an indication of the suitability of 3D ultrasound images for quantified measurements.

Ultrasonic imaging system are commonly used to assess the medical condition of a patient. Usually these exams entail not only the assessment of physiological characteristics of the organs of a patient but also the measurement of both structural and functional attributes of the body. One type of exam where measurements are always important is an obstetrical exam where the growth and health of a developing fetus is assessed. Structural assessment can identify the possible presence of developing birth defects and measurements are made of the sizes and shapes of developing bones of a fetus to determine fetal age and gestational progress. Measurements are also made of blood flow characteristics and cardiac outflow tract development. In order to be able to make precise measurements it is important to have very high quality ultrasound images. One impediment to acquiring the necessary high quality images is the fact that the fetus will move in the mother's womb, particularly in the later stages of a pregnancy when the developing baby is more active. When the fetus moves during imaging the image will become distorted and contaminated with motion artifacts. One artifact which can render measurements inaccurate if not impossible is image discontinuities caused by the fetus being in one position during the initial part

of a scan, then in a different position during the latter part of the scan. The appearance of an organ in the image is thus inaccurate since the organ was in different orientations during different parts of image acquisition. Moreover, obstetrical exams are often performed by scanning the patient and acquiring images, then analyzing the images and making measurements of the imaged anatomy after the patient has left the exam room. The clinician may thus learn only later that the acquired images are unsuitable for measurement, at a time when the patient is no longer present for re-scanning. Accordingly it is desirable to be able to overcome these difficulties in fetal imaging. In particular, it is desirable to be able to know at the time of scanning that images are flawed so that the patient can be re-scanned while still present in the exam room.

There is one fetal examination technique that exacerbates these problems ever further. That is the fetal cardiac imaging technique known as "spatial-temporal image correlation," or STIC. With STIC, a sweep is made through the fetal heart with ultrasound and many image frames are acquired over a sequence of heart cycles. When done by manually scanning with a 2D ultrasound probe, this image acquisition consists of physically moving the probe across the abdomen of the patient and can take ten seconds or longer. The same acquisition can be performed in somewhat less time with a mechanical 3D probe which mechanically sweeps the image plane of a one dimensional transducer array through the fetal heart region while acquiring planar images at incremental transducer positions. Both require that images be acquired at each spatial plane of the heart and at each phase of the heart cycle needed for the required temporal

resolution. As each plane is acquired both its spatial position and heart cycle phase is recorded, the latter usually being done by synthesis of the fetal heart rate as the fetal ECG cannot be acquired in the presence of the mother's much stronger ECG signal. See US Pat. 7,261,695 (Brekke et al.) which describes a technique for developing a synthetic heart cycle trigger signal. After the acquisition is complete, image frames of the desired anatomy, created by MPR reconstruction if necessary, are reordered both spatially and temporally into a loop of images of a single heart cycle according to their phase sequence in the fetal heart cycle. Due to the extensive amount of time needed to acquire all the images needed for a STIC heart loop reconstruction, the possibility of contamination by fetal motion artifacts is highly likely.

One approach to fetal heart imaging which significantly reduces image acquisition time is to use a fully electronic matrix array probe. A matrix array probe performs electronic beam steering of a one dimensional or two dimensional array transducer without the need to physically move the probe or transducer at all. This significantly shortens the image acquisition time. But to acquire a full heart image it is often necessary to acquire sectional views of portions of the heart individually, then assemble them into a full view as described in US Pat. 5, 993,390 (Savord et al.) If there is motion during the time needed to acquire all of the partial views, there can be discontinuity artifacts due to heart motion where the sections are joined together. It is thus desirable to be able to detect these image artifacts when performing both mechanical and fully electronic scanning, and to do so at the time of

scanning so that contaminated images can be identified and replaced with newly scanned, artifact-free images while the patient is still present.

In accordance with the principles of the present invention, a diagnostic ultrasound imaging system is described which detects artifacts in ultrasound images which can prevent precise anatomical measurements. The system alerts the operator to the presence of such artifacts so that the operator can take immediate action such as to re-scan the patient. Artifacts with a high likelihood of degrading anatomical measurements in an image include motion artifacts and shadowing artifacts. In examples illustrated below these artifacts are detected by image processing including lateral filtering and pixel block matching. The alerting device may be a needle gauge, colored bar indicator, numerical indicator, or a simple binary yes/no indicator.

In the drawings:

FIGURE 1 illustrates in block diagram form an ultrasonic diagnostic imaging system constructed in accordance with the principles of the present invention.

FIGURES 2a, 2b, and 2c illustrate the acquisition of a full heart image in three separately scanned segments.

FIGURE 3 illustrates the problem of image discontinuity due to motion which is addressed by an implementation of the present invention.

FIGURE 4 illustrates the problem of image shadowing which is addressed by an implementation of the present invention.

FIGURES 5a and 5b illustrate the operation of a lateral filter in accordance with the present invention to detect motion artifacts and shadowing

artifacts.

Referring first to FIGURE 1, an ultrasound system constructed in accordance with the principles of the present invention is shown in block diagram form. The illustrated ultrasound system operates through two major subsystems, a front end acquisition subsystem 10A and a display subsystem 10B. An ultrasound probe is coupled to the acquisition subsystem to transmit ultrasound waves and receive ultrasound echo signals. The probe may do this with a linear (one-dimensional) row of transducer elements, or may use a two-dimensional matrix array of transducer elements 70 and a micro-beamformer 72 located in the probe. The micro-beamformer contains circuitry which controls the signals applied to groups of elements of the array transducer 70 and does some processing of the echo signals received by elements of each group. Micro-beamforming in the probe advantageously reduces the number of conductors in the cable between the probe and the ultrasound system and is described in US Pat. 5,997,479 (Savord et al.) and in US Pat. 6,436,048 (Pesque), and provides electronic steering and focusing of beams on transmit and during beam reception for the production of highly resolved image data of volumetric regions of the body in real time and suitable for anatomical quantification and measurement.

The probe 70,72 is coupled to the acquisition subsystem 10A of the ultrasound system. The acquisition subsystem includes a beamform controller 74 which provides control signals to the microbeamformer 72, instructing the probe as to the timing, frequency, direction and focusing of transmit and receive beams. The beamformer controller can also control the timing of acquisition so as to be

synchronized to physiological activity of the body indicated by gating signals. The beamform controller also controls the beamforming of echo signals received by the acquisition subsystem by its control of analog-to-digital (A/D) converters 18 and a system beamformer 20. Partially beamformed echo signals received by the probe are amplified by preamplifier and TGC (time gain control) circuitry 16 in the acquisition subsystem, then digitized by the A/D converters 18. The digitized echo signals are formed into fully steered and focused beams by the main system beamformer 20. The echo signals are processed by a signal processor 22 which performs digital filtering, B mode and M mode detection, and Doppler processing, and can also perform other signal processing such as harmonic separation, speckle reduction, and other desired image signal processing. Image acquisition is directed by commands from a user control panel 40 operated by a system operator.

The echo signals produced by the acquisition subsystem 10A are coupled to the display subsystem 10B, which processes the echo signals for display in the desired image format on a display screen 62. The echo signals are processed by an image line processor 24, which is capable of sampling the echo signals, splicing segments of beams into complete line signals, and averaging line signals for signal-to-noise improvement or flow persistence. The image lines for a 2D (two dimensional) image are scan converted into the desired image format by a 2D image processor 26 which performs R-theta conversion as is known in the art. The 2D image processor can thus format rectilinear or sector image formats. The 2D images are stored in an image memory 28 with other 2D images from which they can be displayed on the

display 62. The images in memory are also overlaid with graphics to be displayed with the images, which are generated by a graphics generator 34. Individual images or image sequences can be stored in the image memory 28 for display of image loops or live sequences.

For real-time volumetric imaging the display subsystem 10B also includes a 3D (three dimensional) image processor 30 which receives image lines from the image line processor 24 for the rendering of real-time three dimensional images. The 3D images can be displayed as live (real time) 3D images on the display 62 or stored in the image memory 28 for later review and diagnosis. The 2D and 3D images are coupled to an artifact detector 32 which detects image artifacts in accordance with the present invention that could degrade anatomical measurements using the images. The artifact detector 32 is coupled to a quality indicator circuit 36 which produces a graphic or numeric indication of image quality on the display screen 62 by means of the graphic generator 34.

An ECG subsystem is provided for use when it is desirable to acquire images at particular phases of the heart cycle. ECG leads 50 can be adhesively attached to a patient and provide ECG signals for a QRS processor 52 which identifies the R-wave peak of each heartbeat. The timing of the R-wave is used to acquire images at particular phases of the heart cycle. Images of the heart can be acquired at specific phases of the heart cycle by coupling the R-wave timing as a trigger signal from a trigger signal generator 54 to the beamform controller 74 and the controls of the control panel 40 are used to select the desired heart phases at which heart phase-gated

images are to be acquired by the ultrasound system.

FIGURES 2a-2c illustrate the acquisition of a wide view image of the heart 100 using the sectional approach described in the above-mentioned US Pat. 5,993,390 (Savord et al.) During one heart cycle one section (subvolume) of the heart 100 is imaged repeatedly. In this example the heart images being acquired are 3D images acquired with a matrix array probe having a two dimensional array transducer 70. Since only a small section or subvolume of the heart is being imaged, the number of scanlines transmitted and received is relatively low, meaning that a sectional image can be acquired in a relatively short time and a significant number of phases of the heart can be imaged during one heartbeat. After a first group of sectional images has been acquired of the LA and a portion of the LV as shown in FIGURE 2a, an adjacent section of the heart is scanned as shown in FIGURE 2b. This section is scanned during a different heartbeat but at the same heart phases as the first section, causing the second group of sectional images to be temporally aligned to the same heart phases as the first group. Scanning is then completed in this example by scanning a third group of sectional images of a third adjoining section of the heart during another heartbeat as shown in FIGURE 2c. The images of the third group are acquired at the same heart phases as those of the other two groups. A sequence of full heart images can now be produced by forming each image of the sequence with adjacent sub-images of the three sectional images of a common heart phase. The sequence can be replayed as a loop, enabling the clinician to view a wide 3D image of the heart beating in real time due to the temporal alignment of the heart sections used to form

each wide view image.

But the temporal alignment of the sections of each wide view image does not assure that the sections are properly spatially aligned. If the patient is still during the image acquisition the image sections will be spatially aligned and the wide view images useful for quantified measurement, but if the patient moves during the image acquisition this will not be the case. This is particularly true during fetal imaging. While an adult patient can be asked to remain stationary and will do so during scanning, a fetus in the womb of the mother can move at any time. This can result in a 3D image with motion artifacts as shown in FIGURE 3. In this example the two dimensional matrix array transducer 70 is scanning consecutive planes each of which is normal to the plane of the drawing sheet. When a planar image is formed from consecutively acquired adjacent scanlines, acquisition of the scanlines is generally rapid enough that the effect of motion on the resultant image is minimal. When the array transducer scans the next (*e.g.*, adjacent) image plane, the time interval between acquisition of the two planes can be significant enough that motion artifact can manifest themselves more severely. This is especially true for a group of image planes of a section acquired during one heartbeat relative to a group of image planes acquired during another heartbeat. For purposes of this example a plane which is images by consecutively acquired scanlines will be referred to as an azimuth planes and the adjacent positioning of such azimuth planes over the 3D volume will be referred to as the elevation dimension. When the 3D ultrasound probe is a mechanical probe in which a one dimensional array is

oscillated back and forth to sweep the image plane of the array through the 3D volume, imaging is done by acquiring consecutive azimuth planes in the plane of the array as the array is oscillated in elevation. Thus, the drawing of FIGURE 3 is an elevation view of the heart formed from multiple adjacent azimuth images oriented normal to the page with groups of azimuth images being acquired of sections of the heart 100 during different heartbeats.

In this example the 3D image exhibits distortion due to motion artifacts. While the section of the heart between section boundary lines 42 and 44 is seen to be smooth and continuous, it is seen that the adjacent section between boundary lines 46 and 48 does not spatially align at lines 44, 46. The patient has moved between acquisition of these two volume segments as seen by the slightly lower offset of the section to the right of 44,46. This is also the case albeit to a lesser degree when the boundary 44 of the first section is matched with the middle of the section between boundary lines 56 and 58. The motion offset is seen again where the boundary 58 of the center section fall in the middle of the third section between boundaries 46 and 48. A disjuncture or break in the wall of the heart is seen at the top and bottom of the heart along boundary line 58 in FIGURE 3. Accordingly measurements taken of the heart such as chamber dimensions and volumes will be inaccurate due to the effect of motion on the 3D images.

Another problem which affects the accuracy of measurements in ultrasound images and particularly 3D images is the effect of shadowing. Shadowing is the problem of acoustic absorption or scattering caused by a near field object when trying to image anatomy

at a greater depth of field. FIGURE 4 illustrates the problem. In this drawing a two dimensional matrix array transducer 70 is scanning the heart volume. The path of acoustic energy between the array transducer and the heart 100 is seen to contain an object 60 which absorbs or scatters acoustic energy, such as a rib of the body. As a result, the anatomy of the heart below the rib 60 receives less transmitted energy and returning energy is also scattered or absorbed by the intervening object 60. The resultant image manifests a faint region due to the paucity of acoustic energy below the object as illustrated by the faint region 62 down the middle of the heart image 100. As a result, the boundary of the anatomy can appear blurred or indistinct where shadowing has occurred, rendering measurements inaccurate or impossible where shadowing has affected the image.

In accordance with the principles of the present invention the ultrasound system of FIGURE 1 includes an artifact detector 32 which detects artifacts in 3D ultrasound images which can affect the accuracy of quantified measurements such as dimensions, volumes and functional characteristics. The artifact detector 32 operates on real time images so that images which are deleteriously affected by artifacts can be identified immediately and the images reacquired while the patient is still present. The artifact detector provides an indication of artifact contamination to a quality indicator 36 which provides a numerical or graphical indication to the user of the degree of artifact contamination. The quality indication is provided to the user at the same time that the image is displayed so that the user can immediately examine the image and decide

whether it is suitable for quantification or a new image should be reacquired. FIGURES 3 and 4 show two exemplary quality indicators in association with ultrasound images. The quality indicator 82 of FIGURE 3 is a needle gauge type indicator where the position of the needle on the gauge indicates the degree of artifact contamination in the image and the suitability of the image for quantification. In this example the needle is seen to be positioned toward the left side of the gauge, indicating a poor image for quantification. When the image is a high quality artifact-free image the needle will be positioned at the upper end (right side) of the gauge. In FIGURE 4 the quality indicator 92 is a bar-type indicator with color shades ranging to red at the bottom of the bar and colors ranging toward green at the top. An arrow or carat on the side of the bar indicates the quality of the image for quantification. For a highly contaminated image the carat will be down toward the red end of the bar and for a high quality artifact-free image the carat will move to the upper green end of the bar.

In a preferred implementation the artifact detector 32 comprises a lateral filter which assesses an image in a lateral direction, as motion artifacts are most likely to be most severe in the lateral elevation dimension. The lateral filter compares laterally (*e.g.*, elevationally) distinct scanlines, image planes or volumes to look for discontinuities in an image which are characteristic of motion. The operation of a lateral filter of the present invention may be understood with reference to FIGURES 5a and 5b. FIGURE 5a depicts a series of grids of pixels 102 which are portions of elevationally adjacent image planes 201-209. Such image plane

portions illustrate the pixels of the outer surface 106 of the heart at the top of the image of FIGURE 3 which are located as indicated at 80 in the drawing. As the arrow 104 shows in the perspective view of the image planes in FIGURE 5b illustrates, the dark groups of pixels of the outer surface are in lateral alignment or at least partially overlap from plane 201 to plane 205 where the surface appears continuous in FIGURE 3. FIGURE 3 shows that the surface exhibits a discontinuity at boundary line 58 where a group of planes acquired during one heartbeat are displayed abutting a group of planes acquired during another heartbeat. This is due to the movement of the subject during the image acquisition. As a result, the dark group of pixels of the heart surface in image plane 207 is offset from alignment with the dark group of pixels of the heart surface in the adjacent image plane 205. In this case the adjacent section of the heart is located upward in its new position relative to the previous section image as indicated by the upward transition of the alignment arrow 104. The transition is seen at the top of the heart image in FIGURE 3 by the discontinuity in the surface at the top of the image at 80. Consequently the lateral filter of the artifact detector 32 will detect this motion artifact by the failure of the blocks of pixels in the laterally disposed image planes to align in a smoothly continuous way and will control the quality indicator 36 accordingly. The user will then know that the image of FIGURE 3 is adversely affected by an artifact which can affect quantified measures of the anatomy of the 3D image.

FIGURE 5b illustrates the operation of a lateral filter in an implementation of the present invention when assessing a image with shadowing artifacts such

as that shown in FIGURE 4. In this image of the heart it is seen that the surface at the top of the heart image appears sharply defined by a distinctly dark border where shadowing is not present, but becomes faintly defined and indistinct in the acoustic shadow as indicated at 90. This is reflected in the series of partial planes of pixel grids 102 shown in FIGURE 5b. Without the shadowing effect the pixels of the surface of the heart appear dark and distinct as shown by darkened pixels 112 in elevationally adjacent image planes 211 and 213. The arrow 204 indicates the lateral alignment of these pixels of the heart surface. But in image plane 215 it is seen that the laterally adjacent group of aligned pixels 114 are of low intensity, faint and indistinct and blurred over a larger group of pixels than in the previous image planes which are not affected by shadowing. The artifact detector 32 will thus know from this comparison of laterally aligned groups of pixels that the image is affected by a shadowing artifact starting with image plane 215.

This comparison of pixels in adjacent image planes may be performed in what is known as block matching. Block matching is often used to detect motion in images of the same anatomy which are temporally different, or in spatially different images of stationary images when aligning the images as in panoramic imaging. In the examples described above block matching can be used to identify alignment characteristics of images which are both spatially and temporally different. Since the images are spatially different as in the case of spatially adjacent image planes along the surface of anatomy, it would not be expected that groups or blocks of pixels would be perfectly aligned. That would only

occur if the anatomical boundary were in perfect alignment with the grid axes of the pixel planes. Since this alignment is unlikely it is expected that a block of pixels in one image plane will not be located in exactly the same pixel location in an adjacent plane, but that there will likely be a locational variation from plane to plane. But the variation can be expected to be relatively continuous from plane to plane, such as a partial overlap of corresponding pixel groups with an offset from plane to plane in the same direction. A sharp discontinuity in offset such as that occurring between the darkened block of pixels in plane 205 of FIGURE 5a and the darkened block of pixel in adjacent plane 207 is a mark of, not a sudden transition of the organ boundary, but a discontinuity due to a motional effect between image plane acquisition times.

WHAT IS CLAIMED IS:

1. A diagnostic ultrasound imaging system which indicates the presence of artifact contamination of ultrasound images which can affect the ability to perform accurate measurements using the images comprising:

a probe adapted to acquire ultrasound image data over time from a volume of an object;

an image processor, responsive to acquisition by the probe, which produces ultrasound images using the acquired ultrasound image data;

a display coupled to the image processor which displays the ultrasound images in real time;

an artifact detector, responsive to the image data of an ultrasound image which detects artifacts in the image which can affect the accuracy of quantified measurements on the image; and

a quality indicator, coupled to the artifact detector, and responsive to the detection of artifacts by the artifact detector for indicating the suitability of an ultrasound image for quantification.

2. The diagnostic ultrasound imaging system of Claim 1, wherein the image processor further comprises an ultrasound image processor which produces 3D ultrasound images,

wherein the display is coupled to the image processor to display 3D ultrasound images in real time, and

wherein the quality indicator indicates the suitability of a 3D ultrasound image for quantification.

3. The diagnostic ultrasound imaging system of Claim 1, wherein the quality indicator is further coupled to a display which displays a visible indication of the suitability of an ultrasound image for quantification concurrently with the display of the ultrasound image.

4. The diagnostic ultrasound imaging system of Claim 1, wherein the artifact detector further comprises a lateral filter.

5. The diagnostic ultrasound imaging system of Claim 4, wherein the probe is further adapted to acquire ultrasound image data successively from image planes which are adjacent to each other in an elevation dimension,

wherein the lateral filter is further adapted to perform filtering of elevationally adjacent image planes.

6. The diagnostic ultrasound imaging system of Claim 4, wherein the probe is further adapted to acquire ultrasound image data successively from image subvolumes which are spatially adjacent to each other in an elevation dimension,

wherein the image processor further comprises an ultrasound image processor which produces 3D ultrasound images, and

wherein the lateral filter is further adapted to perform filtering of elevationally adjacent image subvolumes.

7. The diagnostic ultrasound imaging system of Claim 1, wherein the image processor further comprises an ultrasound image processor which

produces 3D ultrasound images,

wherein the artifact detector is further responsive to the image data of a 3D ultrasound image to detect motion artifacts in the image.

8. The diagnostic ultrasound imaging system of Claim 7, wherein the artifact detector is further responsive to the image data of a 3D ultrasound image to detect discontinuities in the boundary of an image of an object.

9. The diagnostic ultrasound imaging system of Claim 8, wherein the artifact detector is further adapted to detect discontinuities in the boundary of an image of an object by lateral filtering.

10. The diagnostic ultrasound imaging system of Claim 1, wherein the artifact detector is further adapted to detect shadowing artifacts in an image.

11. The diagnostic ultrasound imaging system of Claim 10, wherein the artifact detector is further adapted to detect shadowing artifacts by spatially lateral filtering as a function of image intensity.

12. The diagnostic ultrasound imaging system of Claim 1, wherein the quality indicator is further coupled to the display for the display of a visible indication of the suitability of an ultrasound image,

wherein the visible indication further comprises a numeric indicator.

13. The diagnostic ultrasound imaging system of Claim 1, wherein the quality indicator is further coupled to the display for the display of a visible

indication of the suitability of an ultrasound image, wherein the visible indication further comprises a graphic indicator.

14. The diagnostic ultrasound imaging system of Claim 13, wherein the graphic indicator further comprises an indication bar.

15. The diagnostic ultrasound imaging system of Claim 1, wherein the quality indicator is further adapted to indicate the suitability of an ultrasound image for quantification as a function of the number or kind of image artifacts detected by the artifact detector.

1/4

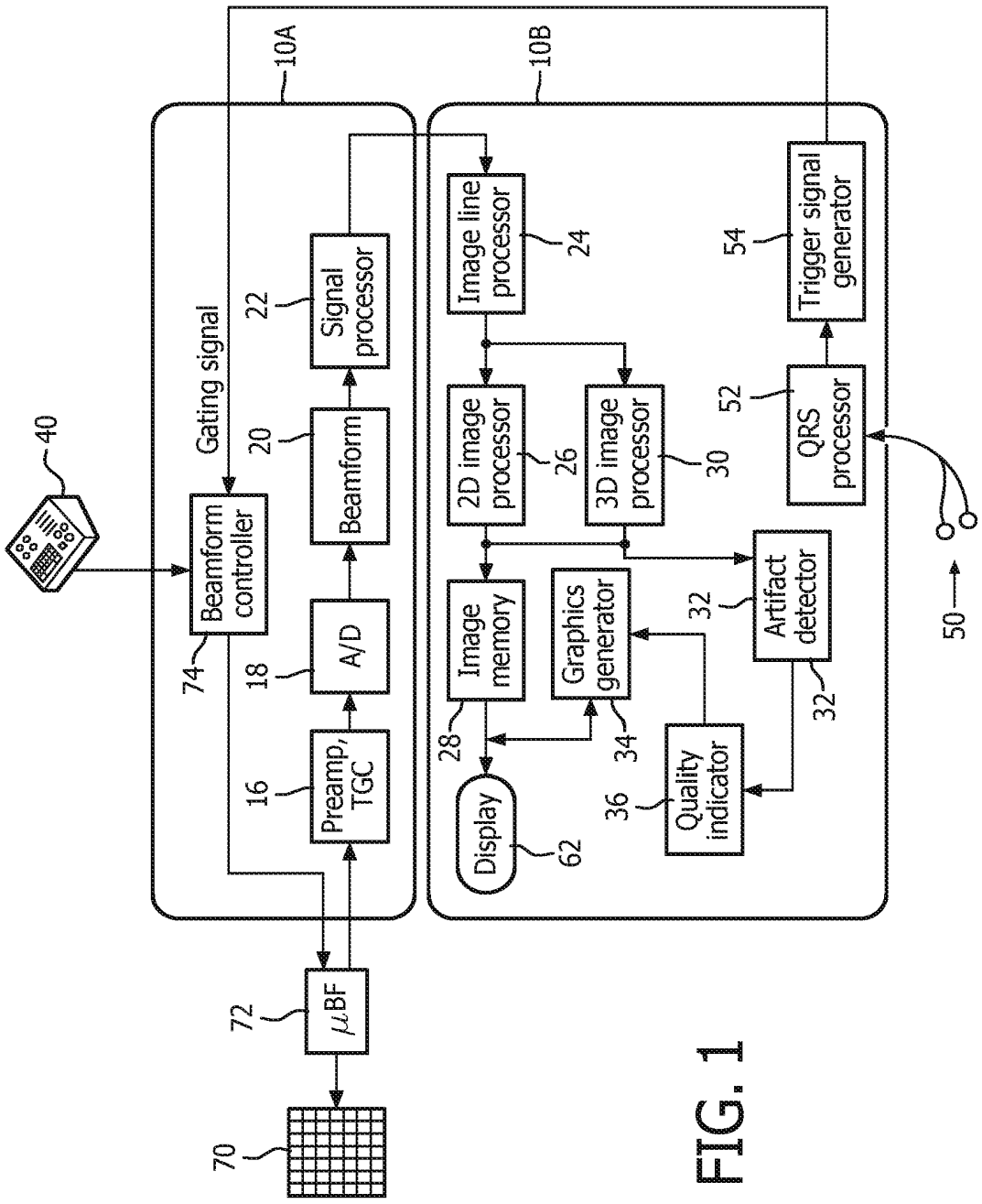

10A
10B
40
Gating signal
Beamform controller
74
A/D
18
Beamform
20
Signal processor
22
Preamp, TGC
16
μBF
72
70
Image line processor
24
2D image processor
26
3D image processor
30
Image memory
28
Graphics generator
34
Display
62
Quality indicator
36
Artifact detector
32
32
QRS processor
52
Trigger signal generator
54
50

FIG. 1

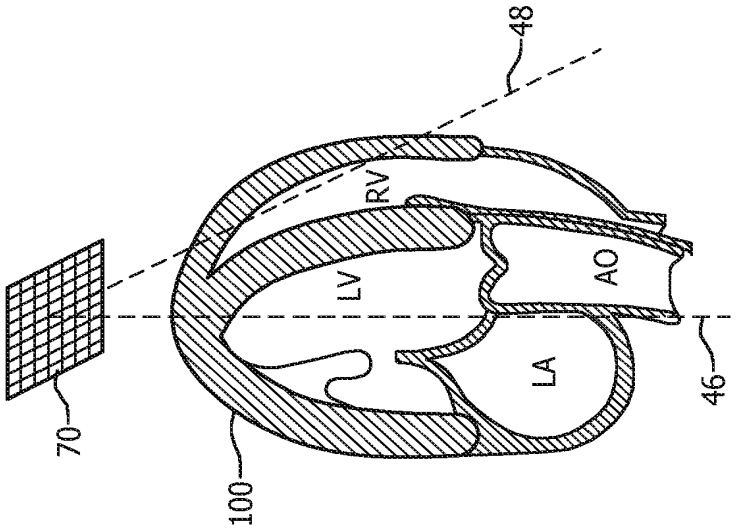


FIG. 2c

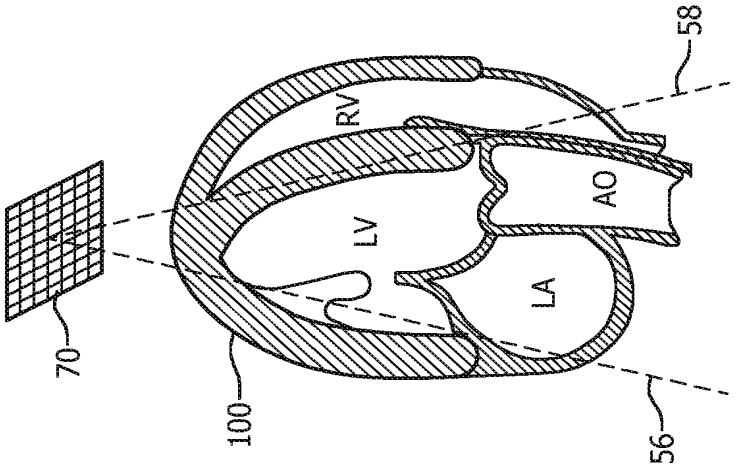


FIG. 2b

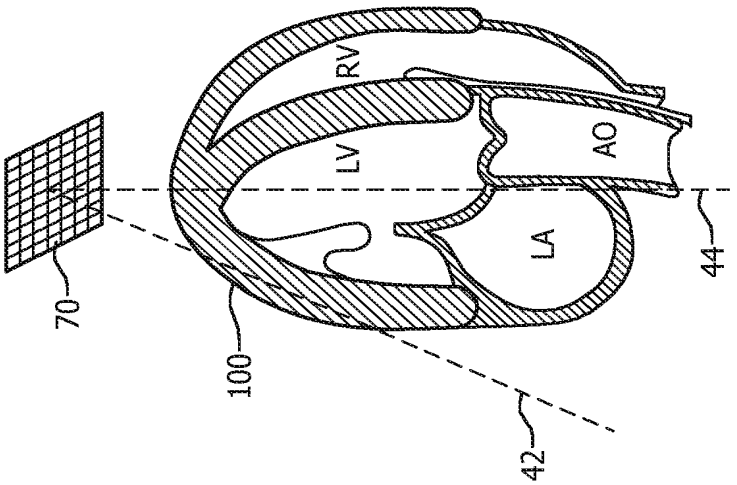


FIG. 2a

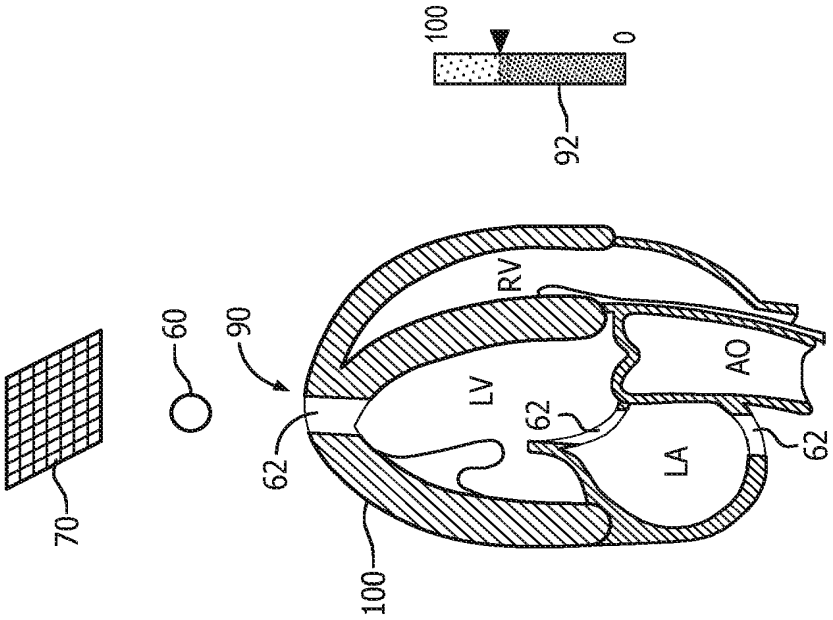

100
0
92
70
60
90
62
RV
LV
62
AO
LA
62
100

FIG. 4

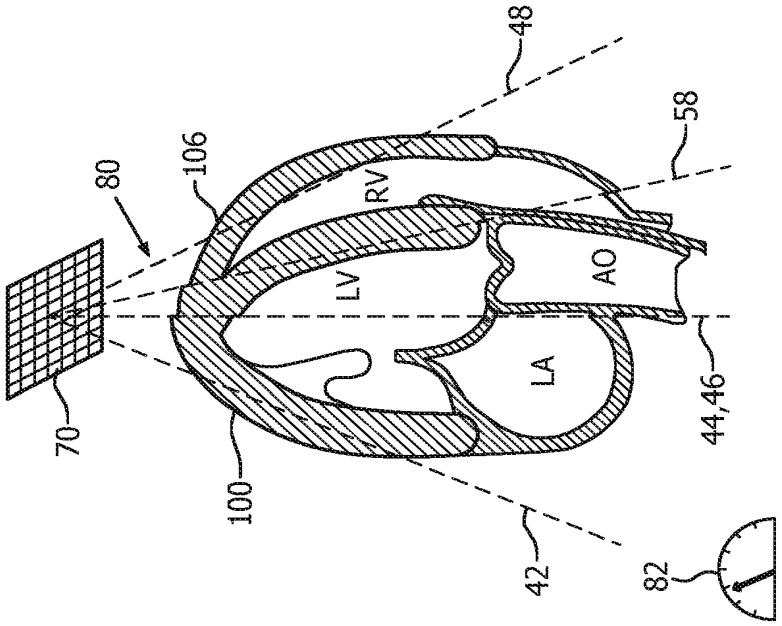

48
58
80
106
RV
LV
AO
LA
70
44,46
100
42
82

FIG. 3

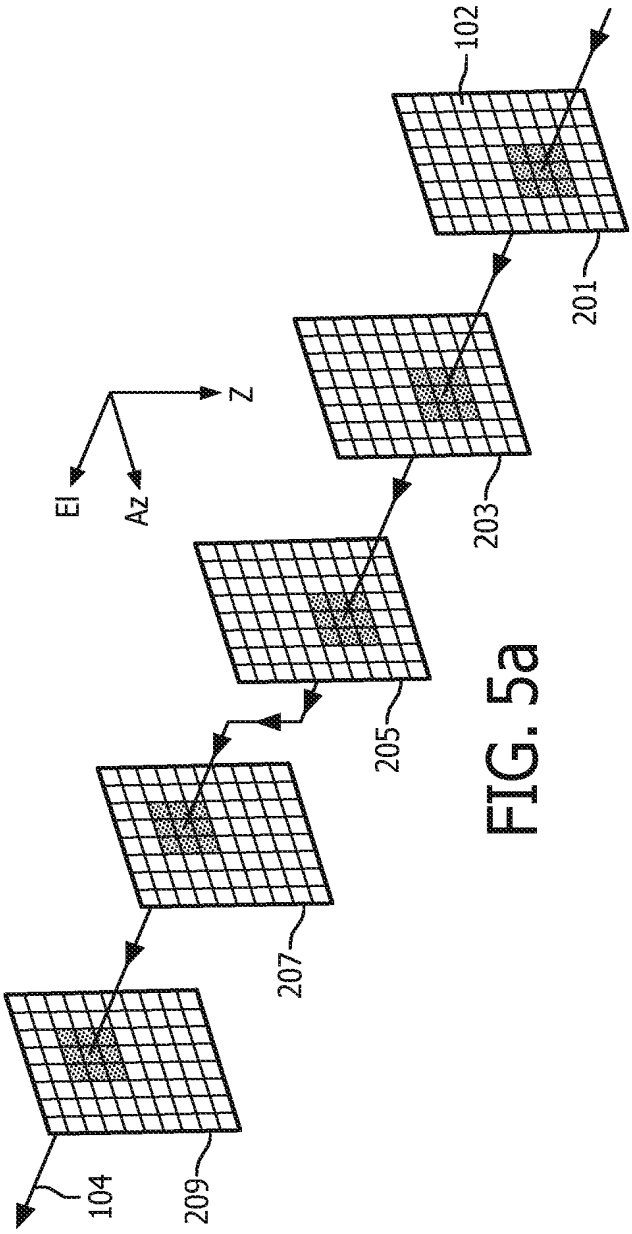

102
201
203
205
207
209
104
El
Az
Z

FIG. 5a

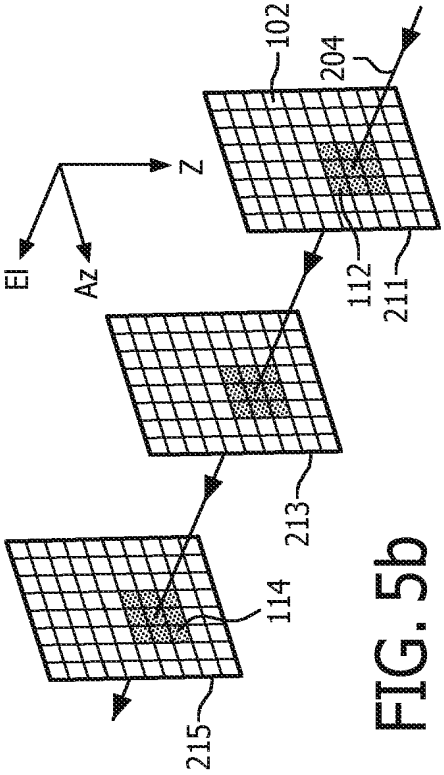

102
204
112
211
213
114
215
El
Az
Z

FIG. 5b

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/060091

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B8/08
ADD.

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)
A61B G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/059586 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; JONG JING-MING [US]) 30 June 2005 (2005-06-30) abstract page 4, line 3 - page 5, line 1; figure 1 page 6, line 2 - page 7, line 24; figures 2,3,4 page 8, line 22 - page 9, line 17; figure 5	1-9, 12-15
X	US 2012/123267 A1 (DOW ALASDAIR [US] ET AL) 17 May 2012 (2012-05-17) paragraphs [0004], [0005], [0019], [0020] - [0027]; claim 1; figures 1,5-8 & US 6 299 579 B1 (PETERSON ROY B [US] ET AL) 9 October 2001 (2001-10-09) figures 2,3a-3d, 5a-5b, 6	1-9

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"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
24 June 2014	02/07/2014

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, Fax: (+31-70) 340-3016	Daoukou, Eleni

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2011/218439 A1 (MASUI HIRONARI [JP] ET AL) 8 September 2011 (2011-09-08) paragraphs [0032], [0036], [0045] - [0046]; figures 2,12,13	1-9 12-15
X	US 2012/224759 A1 (MASUI HIRONARI [JP] ET AL) 6 September 2012 (2012-09-06) paragraphs [0045], [0047], [0056] - [0060], [0068], [0072] - [0074]; claims 1,2; figures 6,11,13,16	1,3-5, 12-15
X	US 2005/113695 A1 (MILLER STEVEN C [US] MILLER STEVEN CHARLES [US]) 26 May 2005 (2005-05-26) paragraphs [0018] - [0022], [0026]; figures 2-5	1-5,10, 11
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/060091

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below
P1496PC00		
International application No.	International filing date *(day/month/year)*	(Earliest)Priority date *(day/month/year)*
PCT/CA2017/050496	21 April 2017 (21-04-2017)	21 April 2016 (21-04-2016)

Applicant
THE UNIVERSITY OF BRITISH COLUMBIA

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☑ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☑ the international application in the language in which it was filed.

☐ a translation of the international application into which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☑ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☑ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 1

☑ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2017/050496

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***A61B 8/00*** (2006.01), ***A61B 8/06*** (2006.01), ***A61B 8/14*** (2006.01), ***G06N 3/08*** (2006.01), ***G06T 7/00*** (2017.01)

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 (2006): A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Database: Canadian Patent Database (Intellect), Questel Orbit, Google Patents, IEEE Xplore

Keywords: echocardiography, images, assess, category, classify, neural network, training

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2009/0088640 (PARK et al.) 2 April 2009 (02-04-2009) * Paragraphs [0007]-[0009], [0019], [0020], [0023], [0024], [0027]-[0029], [0032], [0034]-[0036], [0038]-[0041], [0049]-[0052], [0056], [0059], [0062], [0069], [0073] and [0074] *	1-7, 13, 17-23, 29 and 33-35 --- 8-12, 14-16, 24-28 and 30-32
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☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
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"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		

Date of the actual completion of the international search 28 June 2017 (28-06-2017)	Date of mailing of the international search report 13 July 2017 (13-07-2017)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Alan Chan (819) 639-2473

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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		AU2004251359B2	22 January 2009 (22-01-2009)
		AU2004251360A1	06 January 2005 (06-01-2005)
		AU2004316027A1	01 September 2005 (01-09-2005)
		AU2004316027B2	30 July 2009 (30-07-2009)
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		CA2530595A1	06 January 2005 (06-01-2005)
		CA2555080A1	01 September 2005 (01-09-2005)
		CA2555080C	24 April 2012 (24-04-2012)
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PTO/SB/06 (09-11)
Approved for use through 1/31/2014. 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 16/557,261	Filing Date 08/30/2019	☐ To be Mailed

ENTITY: ☐ LARGE ☑ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $50 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $230 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 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	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	03/19/2020	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 30	Minus	** 30	= 0		x $50 =	0
	Independent (37 CFR 1.16(h))	* 4	Minus	*** 4	= 0		x $230 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/CRYSTAL QUEEN/
*** 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.	

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.

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

20995 7590 06/25/2020

KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614

EXAMINER
BHATNAGAR, ANAND P

ART UNIT	PAPER NUMBER
2668	

DATE MAILED: 06/25/2020

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	6889

TITLE OF INVENTION: ULTRASONIC IMAGE ANALYSIS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	09/25/2020

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

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

HOW TO REPLY TO THIS NOTICE:

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

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

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

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

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed 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: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

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

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

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

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

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

20995 7590 06/25/2020

KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
IRVINE, CA 92614

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

Certificate of Mailing or Transmission

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

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	6889

TITLE OF INVENTION: ULTRASONIC IMAGE ANALYSIS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	09/25/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
BHATNAGAR, ANAND P	2668	382-128000

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 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,

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

1 _____

2 _____

3 _____

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

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

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

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

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

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

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

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

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

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

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

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

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

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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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	6889

20995 7590 06/25/2020

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FOURTEENTH FLOOR
IRVINE, CA 92614

EXAMINER	
BHATNAGAR, ANAND P	

ART UNIT	PAPER NUMBER
2668	

DATE MAILED: 06/25/2020

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

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

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

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

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

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

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

Privacy Act Statement

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

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

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

Notice of Allowability	Application No. 16/557,261	Applicant(s) Abolmaesumi et al.	
	Examiner ANAND P BHATNAGAR	Art Unit 2668	AIA (FITF) Status Yes

-- 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 3/19/2020.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

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

3. ☑ The allowed claim(s) is/are 1-30 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

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

   Certified copies:

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

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

   * Certified copies not received: _____ .

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

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

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

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

Attachment(s)

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

/ANAND P BHATNAGAR/ Primary Examiner, Art Unit 2668	6/18/2020

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

2. Applicant's amendment/response filed on 3/19/2020 has been entered and made of record.

3. Applicant has amended claim 21. Applicant has not added or canceled any claims. Currently, claims 1-30 are pending. Examiner refers to the action below.

4. Applicant has amended claim 21, therefore, the objection to this claim is now withdrawn.

Response to Arguments

5. Applicant's arguments, see remarks, filed 3/19/2020, have been fully considered and are persuasive. The 35USC 102(a)(2) has been withdrawn.

Claim Interpretation

6. The following is a quotation of 35 U.S.C. 112(f):

> (f) Element in Claim for a Combination. – An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

The following is a quotation of pre-AIA 35 U.S.C. 112, sixth paragraph:

> An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

7. The claims in this application are given their broadest reasonable interpretation using the plain meaning of the claim language in light of the specification as it would be understood by one of ordinary skill in the art. The broadest reasonable interpretation of a claim element (also commonly referred to as a claim limitation) is limited by the description in the specification when 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is invoked.

As explained in MPEP § 2181, subsection I, claim limitations that meet the following three-prong test will be interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph:

(A) the claim limitation uses the term "means" or "step" or a term used as a substitute for "means" that is a generic placeholder (also called a nonce term or a non-structural term having no specific structural meaning) for performing the claimed function;

(B) the term "means" or "step" or the generic placeholder is modified by functional language, typically, but not always linked by the transition word "for" (e.g., "means for") or another linking word or phrase, such as "configured to" or "so that"; and

(C) the term "means" or "step" or the generic placeholder is not modified by sufficient structure, material, or acts for performing the claimed function.

Use of the word "means" (or "step") in a claim with functional language creates a rebuttable presumption that the claim limitation is to be treated in accordance with 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. The presumption that the claim limitation is interpreted under 35 U.S.C. 112(f) or pre-

AIA 35 U.S.C. 112, sixth paragraph, is rebutted when the claim limitation recites sufficient structure, material, or acts to entirely perform the recited function.

Absence of the word "means" (or "step") in a claim creates a rebuttable presumption that the claim limitation is not to be treated in accordance with 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. The presumption that the claim limitation is not interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is rebutted when the claim limitation recites function without reciting sufficient structure, material or acts to entirely perform the recited function.

Claim limitations in this application that use the word "means" (or "step") are being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, except as otherwise indicated in an Office action. Conversely, claim limitations in this application that do not use the word "means" (or "step") are not being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, except as otherwise indicated in an Office action.

8. Claim limitations "means for receiving...," "means for deriving...," "means for determining...," and "means for producing..." have been interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, because it uses/they use a generic placeholder "means for" coupled with functional language without reciting sufficient structure to achieve the function. Furthermore, the generic placeholder is not preceded by a structural modifier.

Since the claim limitations invoke 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, claim 30 has been interpreted to cover the

corresponding structure described in the specification that achieves the claimed function, and equivalents thereof.

If applicant wishes to provide further explanation or dispute the examiner's interpretation of the corresponding structure, applicant must identify the corresponding structure with reference to the specification by page and line number, and to the drawing, if any, by reference characters in response to this Office action.

If applicant does not intend to have the claim limitation(s) treated under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112 , sixth paragraph, applicant may amend the claim(s) so that it/they will clearly not invoke 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, or present a sufficient showing that the claim recites/recite sufficient structure, material, or acts for performing the claimed function to preclude application of 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph.

For more information, see MPEP § 2173 *et seq.* and *Supplementary Examination Guidelines for Determining Compliance With 35 U.S.C. 112 and for Treatment of Related Issues in Patent Applications*, 76 FR 7162, 7167 (Feb. 9, 2011).

Allowable Subject Matter

9. Claims 1-30 are allowed.

10. The following is an examiner's statement of reasons for allowance: The closest prior art of Rothberg et al. (U.S. patent pub. 2019/0130554 A1) discloses during ultrasound imaging the quality of the set of images obtained is obtained

and to updated the set of images and calculate a new quality measurement on the updated set of mages. Rothberg et al. nor any other prior art of record teaches, regarding claim 1, the features of “determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images,” these, in combination with the other claim limitations. Regarding claim 12, none of the prior art of record teaches the features of "receiving signals representing image properties, each of the image properties associated with one of the sets of ultrasound training images; and training a neural network, the training comprising, for each set of the plurality of sets of ultrasound training images, using the set of ultrasound training images as an input to the neural network and using the quality assessment values and the image properties associated with the set of ultrasound training images as desired outputs of the neural network," these, in combination with the other claim limitations. Regarding claim 21, none of the prior art of record teaches the features of "determine, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images; determine, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and produce signals representing the quality assessment value and the image property for causing the quality assessment value and the image property

to be associated with the set of ultrasound images," these, in combination with the other claim limitations. Regarding claim 30, none of the prior art of record teaches the features of "means for determining, based on the derived one or more extracted feature representations, a quality assessment value representing a quality assessment of the set of ultrasound images; means for determining, based on the derived one or more extracted feature representations, an image property associated with the set of ultrasound images; and means for producing signals representing the quality assessment value and the image property for causing the quality assessment value and the image property to be associated with the set of ultrasound images," these, in combination with the other claim limitations.

Regarding claims 2-11, 13-20, and 22-29 these claims are allowed since they are directly or indirectly dependent from allowed independent claims 1, 12, and 21, respectively.

11. 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.”

Contact Information

12. Any inquiry concerning this communication or earlier communications from the examiner should be directed to ANAND BHATNAGAR whose telephone

number is (571)272-7416. The examiner can normally be reached on M-F 7:30am-4:00pm.

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Vu Le can be reached on 571-272-4650. 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.

/ANAND P BHATNAGAR/
Primary Examiner, Art Unit 2668 June 18, 2020

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/557,261	Abolmaesumi et al.
	Examiner	**Art Unit**
	ANAND P BHATNAGAR	2668

CPC						
Symbol					**Type**	**Version**
A61B	/	8	/	5207	F	2013-01-01
A61B	/	8	/	0883	I	2013-01-01
A61B	/	8	/	463	I	2013-01-01
A61B	/	8	/	5215	I	2013-01-01
A61B	/	8	/	483	I	2013-01-01
A61B	/	8	/	466	A	2013-01-01

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

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/ANAND P BHATNAGAR/ Primary Examiner, Art Unit 2668	18 June 2020	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	3

U.S. Patent and Trademark Office — Part of Paper No.: 20200618

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/557,261	Abolmaesumi et al.
	Examiner	**Art Unit**
	ANAND P BHATNAGAR	2668

INTERNATIONAL CLASSIFICATION				
CLAIMED				
A61B	/	8	/	08

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

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

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 30	
/ANAND P BHATNAGAR/ Primary Examiner, Art Unit 2668 (Primary Examiner) 18 June 2020 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 3

U.S. Patent and Trademark Office Part of Paper No.: 20200618

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/557,261	Abolmaesumi et al.
	Examiner	**Art Unit**
	ANAND P BHATNAGAR	2668

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

CLAIMS

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

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	30	
/ANAND P BHATNAGAR/ Primary Examiner, Art Unit 2668	18 June 2020	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	3

U.S. Patent and Trademark Office — Part of Paper No.: 20200618

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/557,261	Abolmaesumi et al.
	Examiner	Art Unit
	ANAND P BHATNAGAR	2668

CPC - Searched*		
Symbol	Date	Examiner
A61B8/5207, A61B8/0883, A61B8/463, A61B8/483, A61B8/5215, and A61B8/466 with text	01/04/2020	/AB/

CPC Combination Sets - Searched*		
Symbol	Date	Examiner
(A61B8/5207 OR A61B8/0883 OR A61B8/463 OR A61B8/483 OR A61B8/5215 OR A61B8/466).CPC.	01/04/2020	/AB/

US Classification - Searched*			
Class	Subclass	Date	Examiner

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

Search Notes		
Search Notes	Date	Examiner
Inventor	01/04/2020	/AB/
EAST	01/04/2020	/AB/
CPC	01/04/2020	/AB/
updated	06/18/2020	/AB/

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
Interference	see printout	01/04/2020	/AB/

/ANAND P BHATNAGAR/ Primary Examiner, Art Unit 2668	06/18/2020


determine ultrasound image quality using (feature representation or ten
Sign in
5
ALL
IMAGES
VIDEOS
MAPS
NEWS
SHOPPING
8,220 Results
Any time

Ultrasound Image Quality - ACEP Now
https://www.acepnow.com/article/ultrasound-image-quality
Apr 01, 2011 · Identify issues and structures that degrade **ultrasound image quality**. Difficulty in obtaining adequate sonographic **images** is a challenge for many emergency physicians and can be a major hindrance to incorporating **ultrasound** into clinical practice.

[Sponsored] Ultrasound Image Quality Troubleshooting Tips ...
https://1technation.com/sponsored-ultrasound-image
Sep 30, 2019 · They can also affect our customer's ability to complete a diagnostic exam. To **determine** the cause of an **image** artifact issue, we look at three main factors: the environment, the transducer and the **ultrasound** system. The environment in which the **ultrasound** system resides can largely affect the **image quality**.

Improving image quality of diagnostic ultrasound by using ...
https://www.sciencedirect.com/science/article/pii/S0041624X1100120X
Highlights We develop a model to have higher resolution and/or deeper penetration in diagnostic **ultrasound**. The higher exposure levels than currently allowed by the FDA may be possible while staying within the safety limit. To obtain higher **quality** of **ultrasound image**, the user needs to adjust the acoustic power and frequency of the system. The **image quality** can be related to exposure time in ...

Cited by: 2 Author: Irfan Karagoz, M. Kemal Kardal
Publish Year: 2012

PEOPLE ALSO ASK

What is an ultrasound image?

What is reason for image quality?

What is the definition of contrast in an image?

Feedback

Despeckling of 3D ultrasound image using tensor low rank ...
https://www.sciencedirect.com/science/article/pii/S1746809419301752
In this paper, a new method for despeckling of 3D **ultrasound images** based on **tensor** low rank approximation technique is presented. The main motive of this paper is to establish a new denoising method which can incorporate the redundancy present in 3D **ultrasound image** in all directions unlike the existing techniques.

Cited by: 1 Author: Sameera V, Mohd Sagheer, Sudhish N ...
Publish Year: 2019

Precision imaging—its impact on image quality and ...
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4730958
Good **image quality** is reported to reduce operator dependence and to improve diagnostic confidence. 2,3 There have been many major improvements in **ultrasound image quality** since its initial clinical use in the 1970s, as a result of advancements in electronic and computational capabilities, as well as significant developments in transducer design ...

Author: Aditya Saitha, Louisa Lau, Patrick Bre... Publish Year: 2015

Ultrasound Imaging Guide - Providian Medical
https://www.providianmedical.com/ultrasound-imaging-guide
A Quick and Easy Guide For... What is A "Good" Ultrasound... Basic Optim

With 20+ years of training and technical support for our customers, we have created this ultrasound image optimization guide to provide you with a plain-English manual to understanding your ultrasound machine and how to get the best images. Keep in mind that manufacturer presets are often not "optimal" for your needs, and learning how to adjust your ultrasound machine's parameters will help you get the best image, become more efficient, and achieve better clinical results Navigation Menu Intr...

See more on providianmedical.com

Optimizing an Ultrasound Image - NYSORA
https://www.nysora.com/.../equipment/optimizing-ultrasound-image
Optimizing an **ultrasound image** is an essential skill during **ultrasound**-guided nerve blockade. Anatomically, a peripheral nerve is always located in the vicinity of an artery between fascial layers. The echotexture of normal nerve shows a hyperechoic, hypoechoic, or honeycomb pattern.There are several scanning steps to obtain adequate nerve imaging, including the selection of sonographic modes ...

USRA - Scanning Technique - Machine Setting

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www.usra.ca/regional-anesthesia/ultrasound-guided... ▾

Optimizing **Image Quality** Visualization of nerves with **ultrasound** depends on the operator's ability to properly: 1. locate the nerve (see Nerve Localization) 2. handle the transducer (see Transducer Movement) 3. maximize the **ultrasound** machine capability: - transducer frequency - proper adjustment of depth - focus - gain - use of compound imaging

[PDF] Image Formation in Diagnostic Ultrasound - NTNU

folk.ntnu.no/htorp/Undervisning/MEDT8007/litteratur/imageFormation.N.Wright.pdf

Image Formation in Diagnostic **Ultrasound** J. Nelson Wright Consultant, Medical Imaging and Signal Processing ... An **image** is a visual **representation** of a real object ... This is a global **property**. **Image** Formation in Diagnostic **Ultrasound**

Image Characteristics and Quality - SPRAWLS

sprawls.org/ppmi2/IMGCHAR ▾

The values selected will **determine** the **quality** of the **image** and the visibility of specific body **features**. Components Associated with the Medical Imaging Process The ability of an observer to detect signs of a pathologic process depends on a combination of three major factors: (1) **image quality**, (2) **viewing** conditions, and (3) observer ..

1 2 3 4 5 >

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	22,083	((University with British with Columbia)(Abolmaesumi near4 (Purang P "P."))(Rohling near4 (Robert R "R."))(Tsang near4 (Teresa T "T."))(Liao near4 (Zhibin Z "Z."))(Abdi near4 (Amir A "A.")))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2010:08
S2	29,093	(A61B8/5207 OR A61B8/0883 OR A61B8/463 OR A61B8/483 OR A61B8/5215 OR A61B8/466).CPC.	US-PGPUB; USPAT;	OR	ON	2019/12/2010:09

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S3	42	"7672491".pn.",7680308".pn.",8712157".pn.",20050020903".pn.",20060147107".pn.",20090034808".pn.",20090088640".pn.",20150302638".pn.",20170360401".pn.",20170360402".pn.",20170360403".pn.",20170360411".pn.",20170360412".pn.",20180153505".pn.",20190059851".pn.",20190104949".pn.",20190266716".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2010:13

S4	22,083	((University with British with Columbia)(Abolmaesumi near4 (Purang P "P."))(Rohling near4 (Robert R "R."))(Tsang near4 (Teresa T "T."))(Liao near4 (Zhibin Z "Z."))(Abdi near4 (Amir A "A.")))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2010:20	
S5	452	S4 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN	OR	ON	2019/12/2010:20	

			T; IBM_TDB			
S6	352	S5 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2010:26
S7	142	S6 and ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near5 (qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2019/12/2010:29

			JPO; DERWENT; IBM_TDB			
S8	23	S7 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) AP2 AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2010:48
S9	29,093	(A61B8/5207 OR A61B8/0883 OR A61B8/463 OR A61B8/483 OR A61B8/5215 OR A61B8/466).CPC.	US-PGPUB; USPAT; USOCR	OR	ON	2019/12/2011:24

			; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S10	17,118	S9 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2011:24
S11	9,397	S10 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4))	US-PGPUB;	OR	ON	2019/12/20

			US PAT; US OCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			11:25
S12	168	S11 and ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near5 (qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and (qualit$4 near (assess$4 determinat$4 estimat$4 calculat$4))	US-PGPUB; US PAT; US OCR; FPRS; EPO; JPO; DERWENT; IBM_T	OR	ON	2019/12/2011:29

			DB			
S13	28	S12 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) AP2 AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2011:31
S14	22,083	((University with British with Columbia)(Abolmaesumi near4 (Purang P "P."))(Rohling near4 (Robert R "R."))(Tsang near4 (Teresa T "T."))(Liao near4 (Zhibin Z "Z."))(Abdi near4 (Amir A "A.")))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DER	OR	ON	2019/12/2011:32

			WENT; IBM_TDB			
S15	452	S14 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2011:32
S16	352	S15 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2019/12/2011:32

			EPO; JPO; DERWENT; IBM_TDB			
S17	142	S16 and ((imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near5 (qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2011:32
S18	23	S17 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) AP2 AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT; US	OR	ON	2019/12/2011:32

			OCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S19	27	S13 not S18	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2011:32
S20	42	"7672491".pn.",7680308".pn.",8712157".pn.",20050020903".pn.",20060147107".pn.",20090034808".pn.",20090088640".pn.",20150302638".pn.",20170360401".pn."	US-PG	OR	ON	2019/1

		,20170360402".pn.",20170360403".pn.",20170360411".pn.",20170360412".pn.",20180153505".pn.",20190059851".pn.",20190104949".pn.",20190266716".pn.	PUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			2/2012:10
S21	27	S20 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM	OR	ON	2019/12/2012:10

			_TDB			
S22	19	S21 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1) with (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2012:11
S23	11,814	(((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DE	OR	ON	2019/12/2013:45

			RWENT;IBM_TDB			
S24	1,437	S23 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) AP2 AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB;USPAT;USOCR;FPRS;EPO;JPO;DERWENT;IBM_TDB	OR	ON	2019/12/2013:48
S25	525	S24 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) same qualit$4	US-PGPUB;USPAT;USOCR;FPRS	OR	ON	2019/12/2013:57

			; EPO; JPO; DERWENT; IBM_TDB			
S26	11,814	(((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2014:01
S27	1,437	S26 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) AP2 AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB; USPAT;	OR	ON	2019/12/2014:01

			US OCR; FPRS; EPO; JPO; DERWENT; IBM_TDB				
S28	525	S27 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) same qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2014:01	

S29	112	S28 and ((neural artificial$4 machine$1) near4 (learn$4 intelligen$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2014:01
S30	89	S29 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)) with qualit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN	OR	ON	2019/12/2014:07

			T; IBM_TDB				
S31	10	"2017181288".pn.",20090088640".pn.",20050020903".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2019/12/2218:36	
S32	4	"2017181288".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2020/01/0411:16	

			JPO; DERWENT; IBM_TDB			
S33	40	(US-20020186818-$ or US-20060098876-$ or US-20090034808-$ or US-20090088640-$ or US-20110077526-$ or US-20120142730-$ or US-20150302638-$ or US-20160302759-$ or US-20170360402-$ or US-20170360403-$ or US-20180103865-$ or US-20180116725-$ or US-20180153505-$ or US-20180310920-$ or US-20190059851-$ or US-20190125298-$ or US-20190130554-$ or US-20190142390-$ or US-20190261956-$ or US-20190266716-$).did. or (US-10140734-$ or US-7672491-$ or US-7672517-$ or US-7680308-$ or US-7783094-$ or US-8465433-$ or US-8494829-$ or US-8512247-$ or US-8784320-$ or US-9204863-$ or US-9237882-$ or US-9307959-$ or US-9364198-$ or US-9384566-$ or US-9445788-$ or US-9451886-$ or US-9700284-$).did. or (WO-2017181288-$).did. or (US-20170360411-$ or WO-2014080319-$).did.	US-PGPUB; USPAT; FPRS; DERWENT	OR	ON	2020/01/04 11:36
S34	40	(US-20020186818-$ or US-20060098876-$ or US-20090034808-$ or US-20090088640-$ or US-20110077526-$ or US-20120142730-$ or US-20150302638-$ or US-20160302759-$ or US-20170360402-$ or US-20170360403-$ or US-20180103865-$ or US-20180116725-$ or US-20180153505-$ or US-20180310920-$ or US-20190059851-$ or US-20190125298-$ or US-20190130554-$ or US-20190142390-$ or US-20190261956-$ or US-20190266716-$).did. or (US-10140734-$ or US-7672491-$ or US-7672517-$ or US-7680308-$ or US-7783094-$ or US-8465433-$ or US-8494829-$ or US-8512247-$ or US-8784320-$ or US-9204863-$ or US-9237882-$ or US-9307959-$ or US-9364198-$ or US-9384566-$ or US-9445788-$ or US-9451886-$ or US-9700284-$).did. or (WO-2017181288-$).did. or (US-20170360411-$ or WO-2014080319-$).did.	US-PGPUB; USPAT; FPRS; DERWENT	OR	ON	2020/01/04 13:37
S35	40	(US-20020186818-$ or US-20060098876-$ or US-20090034808-$ or US-20090088640-$ or US-20110077526-$ or US-20120142730-$ or US-20150302638-$ or US-20160302759-$ or US-20170360402-$ or US-20170360403-$ or US-20180103865-$ or US-20180116725-$ or US-20180153505-$ or US-20180310920-$ or US-20190059851-$ or US-20190125298-$ or US-20190130554-$ or US-20190142390-$ or US-20190261956-$ or US-20190266716-$).did. or (US-10140734-$ or US-7672491-$ or US-7672517-$ or US-7680308-$ or US-7783094-$	US-PGPUB; USPA	OR	ON	2020/01/04 14

		or US-8465433-$ or US-8494829-$ or US-8512247-$ or US-8784320-$ or US-9204863-$ or US-9237882-$ or US-9307959-$ or US-9364198-$ or US-9384566-$ or US-9445788-$ or US-9451886-$ or US-9700284-$).did. or (WO-2017181288-$).did. or (US-20170360411-$ or WO-2014080319-$).did.	T; FPRS; DERWENT			:09
S36	23	S35 and quality and (ultrasound$3 doppler echo echocardiograph$3) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 14:09
S37	4	"2017181288".pn.	US-PGPUB; USPAT; USOCR; FPRS	OR	ON	2020/01/04 17:20

			; EPO; JPO; DERWENT; IBM_TDB			
S38	2	S37 and quality and (ultrasound$3 doppler echo echocardiograph$3) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 17:20
S45	2	"20190125298".pn.	US-PGPUB; USPAT;	OR	ON	2020/01/04 19:03

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S46	1	S45 and convolution$4 and recurrent$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/0419:03

S47	0	S45 and (property with neural)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 19:09
S48	0	S45 and (property same neural)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWEN	OR	ON	2020/01/04 19:10

			T; IBM_TDB			
S49	1	S45 and ((property view) with neural)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/01/04 19:10
S50	2	S45 and (display$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2020/01/04 19:15

			JPO; DERWENT; IBM_TDB			
S511	31,104	(A61B8/5207 OR A61B8/0883 OR A61B8/463 OR A61B8/483 OR A61B8/5215 OR A61B8/466).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/06/0411:38
S512	31,172	(A61B8/5207 OR A61B8/0883 OR A61B8/463 OR A61B8/483 OR A61B8/5215 OR A61B8/466).CPC.	US-PGPUB; USPAT; USOCR	OR	ON	2020/06/1814:56

			; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S53	18,426	S52 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/06/18 15:08
S54	10,1	S53 and ((extract$4 obtain$4 deriv$4 segment$4 detect$4 determin$5 determinat$4) with (featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1 tensor$2) with (imag$4 representation$1 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 length$1 dimension$3))	US-PGPUB;	OR	ON	2020/06/18

	45		US PAT; US OCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			15:10
S55	329	S54 and (((featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1 tensor$2) near3 (imag$4 representation$1 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 length$1 dimension$3)) same ((imag$4 near4 propert$4)(view with categor$4)))	US-PGPUB; US PAT; US OCR; FPRS; EPO; JPO; DERWENT; IBM_T	OR	ON	2020/06/18 15:14

			DB			
S56	186	S55 and ((ultrasound doppler echo echocardiog$6 imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4) near4 qualit$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/06/18 15:18
S57	12, 469	(((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DER	OR	ON	2020/06/18 15:19

			WENT;IBM_TDB			
S58	1,572	S57 and (propert$4 region$1 ROI anatom$4) and (((view$3 render$4 display$4 present$4 show$4) near4 (categor$4 group$3)) AP2 AP3 AP4 AP5 PLAX RVIF PSAXM PSAXA PSAXPM PSAXAP SC4 SC5 IVC SUPRA)	US-PGPUB;USPAT;USOCR;FPRS;EPO;JPO;DERWENT;IBM_TDB	OR	ON	2020/06/18 15:19
S59	562	S58 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) same qualit$4	US-PGPUB;USPAT;USOCR;FPRS;	OR	ON	2020/06/18 15:19

			EPO; JPO; DERWENT; IBM_TDB			
S60	131	S59 and ((neural artificial$4 machine$1) near4 (learn$4 intelligen$4 network$3))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/06/18 15:19
S61	105	S60 and ((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4)) with qualit$4)	US-PGPUB; USPAT; US	OR	ON	2020/06/18 15:19

			OCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S62	184	S56 not S61	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/06/18 15:19
S63	183	S62 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4	US-PG	OR	ON	2020/0

		dimension$4))) with quality with (assess$5 judging judgement judge analysis analyze detect$4 determinat$4 obtain$4))	PUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			6/18 15:28
S64	46	"5776063".pn.",7912528".pn.",8594398".pn.",8744152".pn.",8750375".pn.",8891881".pn.",8917917".pn.",9652846".pn.",20050020903".pn.",20050251013".pn.",20090074280".pn.",20090088640".pn.",20100168578".pn.",20110082371".pn.",20150086093".pn.",20170026298".pn.",20140155272".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM	OR	ON	2020/06/18 17:11

			_TDB			
S65	10	S64 and (((ultrasound doppler echo echocardiog$6) near5 (imag$4 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 3D volume$1 (three near4 dimension$4))) with (evaluat$4 qualit$4 inspect$4 noise$3 artifact$3 textur$4)) and qualit$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2020/06/18 17:12
S66	1	S65 and (((featur$4 characteristic$4 bright$4 artifact$1 data$1 value$1 number$1 noise$4 dirt$4 intensit$4 attribut$4 luminanc$4 illuminanc$4 color$1 saturation$4 edge$1 line$1 tensor$2) near3 (imag$4 representation$1 scan$4 slice$1 tomograph$4 pictur$4 data photo$4 photograph$4 length$1 dimension$3)) same ((imag$4 near4 propert$4)(view with categor$4)))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DE	OR	ON	2020/06/18 17:13

						RWENT;IBM_TDB		

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S39	18,816	quality and (ultrasound$3 doppler echo echocardiograph$3) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT	OR	ON	2020/01/04 17:33
S40	1,258	(quality with (ultrasound$3 doppler echo echocardiograph$3)) and ((neural machine artificial) near4 (intelligenc$4 learn$4 network$3))	US-PGPUB; USPAT	OR	ON	2020/01/04 17:34
S41	424	S40 and ((tomograph$4 scan$4 slice$1 imag$4 pictur$4) near4 (featur$4 characteristic$3 attribute$3)) and (propert$4 textur$4 view$3)	US-PGPUB; USPAT	OR	ON	2020/01/04 17:37
S42	172	S41 and (quality near4 (determinat$4 determin$3 detect$4 assess$5 analy$4))	US-PGPUB; USPAT	OR	ON	2020/01/04 17:38
S43	31	S40 and ((tomograph$4 scan$4 slice$1 imag$4 pictur$4) near4 view$3) and convolution$3 and recurrent$1	US-PGPUB; USPAT	OR	ON	2020/01/04 17:47
S44	20	S42 and ((tomograph$4 scan$4 slice$1 imag$4 pictur$4) near4 view$3) and convolution$3 and recurrent$1	US-PGPUB; USPAT	OR	ON	2020/01/04 17:47

6/18/2020 5:17:24 PM
C:\Users\abhatnagar\Documents\EAST\Workspaces\16557261.wsp

PTO/SB/08 Equivalent

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
(Multiple sheets used when necessary)	Examiner	Bhatnagar, Anand P.
SHEET 1 OF 3	Attorney Docket No.	CRBN001.002AUS

U.S. PATENT DOCUMENTS					
Examiner Initials	Cite No.	Document Number *Number - Kind Code (if known)* Example: 1,234,567 B1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear
	1	5,776,063	07-07-1987	Dittrich et al.	
	2	7,912,528	03-22-2011	Krishnan, et al.	
	3	8,594,398	11-26-2013	Beymer, et al.	
	4	8,744,152	06-03-2014	Beymer, et al.	
	5	8,750,375	06-10-2014	Beymer, et al.	
	6	8,891,881	11-18-2014	Gupta, et al.	
	7	8,917,917	12-23-2014	Bwymar, et al.	
	8	9,652,846	05-16-2017	Codella, et al.	
	9	20050020903	01-27-2005	Krishnan, et al.	
	10	20050251013	11-10-2005	Krishnan, et al	
	11	20090074280	03-19-2009	Lu, et al.	
	12	20090088640	04-02-2009	Park, et al.	
	13	20100168578	07-01-2010	Garson JR, et al.	
	14	20110082371	04-07-2011	Chono	
	15	20150086093	03-26-2015	Fonte, et al.	
	16	20170026298	01-26-2017	Huo	
	17	U.S. Patent Application No. 16/095,601, including its prosecution history, and the Office Actions therein.	10-22-2018	Abolmaesumi	

FOREIGN PATENT DOCUMENTS						
Examiner Initials	Cite No.	Foreign Patent Document *Country Code-Number-Kind Code* Example: JP 1234567 A1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear	T[1]
	18	WO 2014/155272	10-02-2014	KONINKLIJKE PHILIPS NV.		

Examiner Signature /ANAND P BHATNAGAR/	Date Considered 06/18/2020

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	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
(Multiple sheets used when necessary)	Examiner	Bhatnagar, Anand P.
SHEET 2 OF 3	Attorney Docket No.	CRBN001.002AUS

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[1]
	19	ALISON NOBLE, et al., "Ultrasound Image Segmentation: A Survey," published in IEEE Transactions on Medical maging from the Institute of Electrical and Electronics Engineers in August 2006. Volume 25, issue 8, pages 87-1010.	
	20	A.S. MILLER, et al., "Review of Neural Network Applications in Medical Imaging and Signal Processing," published in Medical & Biological Engineering & Computing in September 1992. Volume 30, pages 449-464.	
	21	CANADIAN INTELLECTUAL PROPERTY OFFICE, International Search Report and Written Opinion of the international Searching Authority in PCT/CA2017/050496, dated July 13, 2017, which is the international application to this U.S. application.	
	22	CURT G. DEGROFF, MD; et al., "Artificial Neural Network-Based Method of Screening Heart Murmurs in Children," published in Circulation by the American Heart Association on June 5, 2001. Volume 103, issue 22, pages 2711-2716.	
	23	DIPTI ITCHHAPORIA, MD; et al., "Artificial Neural Networks: Current Status in Cardiovascular Medicine," published in the Journal of the American College of Cardiology (JACC) in August 1996. Volume 28, issue 2, pages 515-521	
	24	HAO CHEN, et al., "Iterative Multi-domain Regularized Deep Learning for Anatomical Structure Detection and Segmentation from Ultrasound Images," submitted to Medical Image Computing and Computer Assisted Intervention, Dart 2 (MICCAI) in July 2016.	
	25	HOO-CHANG SHIN, et al., "Deep Convolutional Neural Networks for Computer-Aided Detection: CNN Architectures, Dataset Characteristics and Transfer Learning," submitted to hllps://www.arXiv.org on February 10, 2016.	
	26	J. JIANG, et al., "Medical Imaging Analysis with Artificial Neural Networks," published in Computerized Medical Imaging and Graphics in 2010. Volume 34, issue 8, pages 617-631.	
	27	NEELAM SINHA, et al., "Quality Assessment in Magnetic Resonance Images," published in Critical Reviews™ in Biomedical Engineering {CRMBE) in 2010. Volume 38, issue 2, pages 127-141.	
	28	NIMA TORBATI, et al., "An Efficient Neural Network Based Method for Medical Image Segmentation," published in computers in Biology and Medicine by Elsevier on January 1, 2014. Volume 44, pages 76-87.	
	29	NOHA EL-ZEHIRY, et al., "Learning the Manifold of Quality Ultrasound Acquisition," published in Medical Image computing and Computer Assisted Intervention, Part 1 (MCCAil) in September 2013.	
	30	November 8, 2019, Extended European Search Report from the EUROPEAN PATENT OFFICE in European Patent Application Serial No. 17785210.0, which is a foreign counterpart to this application.	
	31	R.H. CLAYTON, et al., "Recognition of Ventricular Fibrillation Using Neural Networks," published in Medical & Biological Engineering & Computing in March 1994. Volume 32, pages 217-220.	
	32	S. KEVIN ZHOU, et al., "Image-based Multiclass Boosting and Echocardiographic View Classification," in 2006 IEEE computer Society Conference on Computer Vision and Pattern Recognition {CVPR'06). Volume 2, pages 1559-1565	
	33	SHIJUN WANG, et al., "Machine Learning and Radiology," published in Medical Image Analysis by Elsevier in July J012. Volume 16, issue 5, pages 993-951.	
	34	SRI-KAUSHIK PAVANI, et al., "Quality Metric for Parasternal Long Axis B-Mode Echocardiograms," published in Medical Image Computing and Computer Assisted Intervention {MICCAI) in January 2012. Volume 15, part 2, pages 178-485.	

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	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
(Multiple sheets used when necessary)	Examiner	Bhatnagar, Anand P.
SHEET 3 OF 3	Attorney Docket No.	CRBN001.002AUS

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[1]
	35	STEN ROAR SNARE, et al., "Real-Time Scan Assistant for Echocardiography," in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control in March 2012. Volume 59, issue 3, pages 583-589.	
	36	TIMOTHY J_ W. DAWES, FRCA, PhD; et al., "Machine Learning of Three-dimensional Right Ventricular Motion Enables Outcome Prediction in Pulmonary Hypertension: A Cardiac MR Imaging Study," published online in Radiology n January 2017.	
	37	XIAOGUANG LU, et al., "AutoMPR: Automatic Detection of Standard Planes in 3D Echocardiography," published in J008 5th IEEE International Symposium on Biomedical Imaging: From Nano to Macro in June 2008. Pages 1279-1282	
	38	XIAOMING LIU, et al., "Learning-based Scan Plane Identification from Fetal Head Ultrasound Images," published in Medical Imaging 2012: Ultrasonic Imaging, Tomography, and Therapy; 83200A in February 2012. Proceedings SPIE Volume 8320.	
	39	AMIR, et al., "Automatic quality assessment of apical four-chamber echocardiograms using deep convolutional neural networks," Proc. of SPIE Vol. 10133, downloaded March 9, 2020, 8 pages	
	40	ABDI, et al., "Automatic quality assessment of apical four-chamber echocardiograms using deep convolutional neural networks," Medical Imaging 2017: Image Processing, edited by Martin A. Styner, Elsa D. Angelini, Proc. of SPIE, Vol. 10133, 101330S, February 2017, 8 pages.	

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Medical ultrasound - Wikipedia
https://en.wikipedia.org/wiki/Ultrasound_scan

Medical **ultrasound** (also known as diagnostic sonography or ultrasonography) is a diagnostic imaging technique, or therapeutic application of **ultrasound**.It is used to create an **image** of internal body structures such as tendons, muscles, joints, blood vessels, and internal organs.Its aim is often to find a source of a disease or to exclude pathology.The practice of examining pregnant women **using** ...

ICD-9-CM: 88.7 MeSH: D014463
OPS-301 code: 3-03...3-05 ICD-10-PCS: B74

[PDF] Signal Processing Overview of Ultrasound Systems for ...
www.ti.com/lit/wp/sprab12/sprab12.pdf

an **ultrasound** system, which is composed of **image** enhancement, noise reduction, and display functionalities. Section 7 describes the **Doppler** mode of operation, which provides a visual display of

File Size: 458KB Page Count: 27

Resolution in ultrasound imaging | BJA Education | Oxford ...
https://academic.oup.com/bjaed/article/11/5/186/283004

Spatial Resolution | Temporal Resolution | Contrast Resolution | Cc

To understand how an image on the screen of an ultrasound system is produced, it is necessary to examine the features of a transducer and the ultrasound beams that it creates and receives. A transducer consists of many piezoelectric elements that convert electrical energy into sound energy and vice versa.5 Ultrasound, in the form of a pulsed beam, propagates from the surface of the transducer into soft tissue. Sound waves are absorbed in part by tissue but are also reflected back to the trans...

See more on academic.oup.com

Cited by: 59 Author: Alexander Ng, Justaan Swanevelder
Publish Year: 2011 Published: Aug 20, 2011

Despeckling of 3D ultrasound image using tensor low rank ...
https://www.sciencedirect.com/science/article/abs/pii/S1746809419301752

In this paper, a new method for despeckling of 3D **ultrasound** images based on **tensor** low rank approximation technique is presented. The main motive of this paper is to establish a new denoising method which can incorporate the redundancy present in 3D **ultrasound image** in all directions unlike the existing techniques.

Cited by: 1 Author: Sameera V, Mohd Sagheer, Sudhish N.
Publish Year: 2019

Ultrasound transducer image quality - Doppler and Color ...
https://www.youtube.com/watch?v=6MYljKcaRBU

Aug 25, 2017 · **Ultrasound** transducer **image quality - Doppler** and Color For more information, please visit https://www.mysonomaimaging.com/ultrasound https://www.soundergoo...

Ultrasound Image Formation from Doppler Transducer ...
https://link.springer.com/chapter/10.1007/978-3-319-56062-5_45

Doppler is an **ultrasound** probe that price is quite affordable. RF signal from the **Doppler** transducer is processed in several stages. These stages are bandpass filtering, envelope **detection** and logarithmic compression. From the experiments, this system can form a B-mode **image** and the **image** harmonic of the RF signal obtained from the **Doppler** ...

(PDF) Deep Learning in Medical Ultrasound Analysis: A Review
https://www.researchgate.net/publication/330729493...

A 'read' is counted each time someone views a publication summary (such as the title, abstract, and list of authors), clicks on a figure, or views or downloads the full-text.

[PDF] Image Formation in Diagnostic Ultrasound
folk.ntnu.no/htorp/Undervisning/MEDT8007/litteratur/imageFormation.N.Wright.pdf

Image Formation in Diagnostic **Ultrasound** J. Nelson Wright Consultant, Medical Imaging and Signal Processing ... Shift-Variance in Diagnostic **Ultrasound** 69 Pre-Detection **Image** Processing 70 ... **Image** Field Imaging System (f, t) An **image** is a visual **representation** of a real object. An **image** is generally of reduced dimensionality and characterizes ...

[PDF] Routine Ultrasound Equipment Tests for Quality Assurance
https://aapm.org/meetings/amos2/pdf/49-14380-45410-769.pdf

Routine **Ultrasound** Equipment Tests for **Quality** Assurance James A. Zagzebski, Ph.DJames A. Zagzebski, Ph.D. ... ** Issues related to **image** performance, such as spatial resolution, are not spatial resolution, are not included (except included (except ... ** Goodsitt et al, "RealGoodsitt et al, "Real-time B time B-mode **ultrasound** ...

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A Gallery of High-Resolution, Ultrasound, Color Doppler ...

https://www.ultrasound-images.com

3) Each sonographic **image** is labeled, leaving little to the imagination. 4) A short description is added to each **image** on the web site. Included are clinical details of the patient and major **ultrasound** findings of each case. 5) Best of all- the whole gallery of **ultrasound** images is open to view.

1 2 3 4 5 >

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

PTO/SB/08a (02-18)
Approved for use through 11/30/2020. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16557261
Filing Date	2019-08-30
First Named Inventor	Purang Abolmaesumi
Art Unit	2668
Examiner Name	BHATNAGAR, ANAND P
Attorney Docket Number	CRBN001.002AUS

U.S.PATENTS

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

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U.S.PATENT APPLICATION PUBLICATIONS

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

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

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NON-PATENT LITERATURE DOCUMENTS

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

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P.B/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	16557261
	Filing Date	2019-08-30
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
	Examiner Name	BHATNAGAR, ANAND P
	Attorney Docket Number	CRBN001.002AUS

	1	International Search Report issued on November 8, 2019 for Application No. PCT/CA2019/051192, 3 pages.	☐
	2	Written Opinion of the International Searching Authority issued on November 8, 2019 for Application No. PCT/CA2019/051192, 5 pages.	☐

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

EXAMINER SIGNATURE

Examiner Signature	/ANAND P BHATNAGAR/	Date Considered	06/18/2020

*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. /A.P.B/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	16557261
Filing Date	2019-08-30
First Named Inventor	Purang Abolmaesumi
Art Unit	2668
Examiner Name	BHATNAGAR, ANAND P
Attorney Docket Number	CRBN001.002AUS

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.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

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	/Vladislav Z. Teplitskiy/	Date (YYYY-MM-DD)	2020-01-07
Name/Print	Vladislav Z. Teplitskiy	Registration Number	68,069

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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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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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY.DOCKET NO./TITLE	REQUEST ID
16/557,261	08/30/2019	The University of British Columbia	CRBN001.002AUS	116494

Acknowledgement of Loss of Entitlement to Entity Status Discount

The entity status change request below filed through Private PAIR on 07/15/2020 has been accepted.

CERTIFICATIONS:

Change of Entity Status:

X Applicant changing to regular undiscounted fee status.

NOTE: Checking this box will be taken to be notification of loss of entitlement to small or micro entity status, as applicable.

This portion must be completed by the signatory or signatories making the entity status change in accordance with 37 CFR 1.4(d)(4).

Signature:	/Vladislav Z. Teplitskiy/
Name:	Vladislav Z. Teplitskiy
Registration Number:	68069

PART B - FEE(S) TRANSMITTAL

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

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

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

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

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

20995 7590 06/25/2020

KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
FOURTEENTH FLOOR
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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.

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

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	6889

TITLE OF INVENTION: ULTRASONIC IMAGE ANALYSIS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	~~SMALL~~ REGULAR	~~$500~~ $1000	$0.00	$0.00	$500	09/25/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
BHATNAGAR, ANAND P	2668	382-128000

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 03-09 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 Knobbe, Martens, Olson & Bear, LLP
2
3

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

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

(A) NAME OF ASSIGNEE: The University of British Columbia

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Vancouver, Canada

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

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

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

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

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

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☒ Applicant changing to regular undiscounted fee status.

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

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

Authorized Signature /Vladislav Z. Teplitskiy/ Date 07/15/2020

Typed or printed name Vladislav Z. Teplitskiy Registration No. 68,069

COMMENTS ON EXAMINER'S STATEMENT OF REASONS FOR ALLOWANCE

Inventor	:	Purang Abolmaesumi
App. No	:	16/557261
Filed	:	August 30, 2019
For	:	ULTRASONIC IMAGE ANALYSIS
Examiner	:	Bhatnagar, Anand P.
Art Unit	:	2668
Conf. No.	:	6889

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

Dear Commissioner:

Applicant thanks the Examiner for the indication of allowable subject matter in the Statement of Reasons for Allowance ("Statement") mailed June 25, 2020.

Applicant takes no position regarding any reasons for allowance presented by the Examiner (in the Notice of Allowance and/or elsewhere in the application's file history) other than the positions Applicant may have previously taken during prosecution. Therefore, any reasons for allowance presented by the Examiner should not be attributed to Applicant as an indication of the basis for Applicant's belief that the claims are patentable. Furthermore, Applicant respectfully submits that there may also be additional reasons for patentability of the claimed subject matter not explicitly stated in this record and Applicant does not waive its rights to such arguments by not further addressing such reasons herein.

Applicant also respectfully reserves the right to traverse the characterizations of what any particular reference shows or discloses, of what any combination of references shows or discloses, or the appropriateness of combining references. Applicant does not acquiesce to the characterizations of what any of the references discussed in the Statement disclose or suggest. Further, by making certain amendments to the claims, Applicant is not conceding that previously pending claims are not patentable. Rather, the amendments are being made to facilitate expeditious prosecution of this application. Applicant reserves the right to pursue at a later date

any previously pending or other broader or narrower claims that capture any subject matter supported by the application's disclosure. Accordingly, reviewers of this or any child or related prosecution history shall not reasonably infer that the Applicant has made any disclaimers or disavowals of any subject matter.

Applicant respectfully traverses the Statement to the extent it suggests that patentability rests on a particular limitation, or combination of particular limitations, of a particular claim or claims. It is each claim, taken as a whole and independent from other claims, that determines patentability. Moreover, Applicant respectfully traverses the Statement to the extent it paraphrases or summarizes limitations of the claims or implies that any of the claims requires something other than the combination of recited limitations. Applicant does not acquiesce to the Statement's characterization or interpretation of the claim language, including interpretation under 35 U.S.C. § 112(f).

Applicant respectfully objects to the Statement to the extent it may imply that patentability of the dependent claims rests solely on patentability of the independent claims. Applicant respectfully submits that each claim is patentable because of the particular combination of recited limitations.

Respectfully submitted,

KNOBBE, MARTENS, OLSON & BEAR, LLP

Dated: July 15, 2020

By:/Vladislav Z. Teplitskiy/
Vladislav Z. Teplitskiy
Registration No. 68,069
Registered Practitioner
(949) 760-0404

33134966

Electronic Patent Application Fee Transmittal

Application Number:	16557261
Filing Date:	30-Aug-2019
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Filer:	Vladislav Z. Teplitskiy/Lisa Than
Attorney Docket Number:	CRBN001.002AUS

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**1000**

Electronic Acknowledgement Receipt

EFS ID:	40007920
Application Number:	16557261
International Application Number:	
Confirmation Number:	6889
Title of Invention:	ULTRASONIC IMAGE ANALYSIS
First Named Inventor/Applicant Name:	Purang Abolmaesumi
Customer Number:	20995
Filer:	Vladislav Z. Teplitskiy/Evelyn Salcido
Filer Authorized By:	Vladislav Z. Teplitskiy
Attorney Docket Number:	CRBN001.002AUS
Receipt Date:	15-JUL-2020
Filing Date:	30-AUG-2019
Time Stamp:	15:49:58
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	E20207EF52402243
Deposit Account	111410
Authorized User	Evelyn Salcido

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	IssueFee.pdf	194875 2c45bb1a332b49d94bd6bd3f2d78376e431d2c29	no	1
Warnings:					
Information:					
2	Post Allowance Communication - Incoming	Post_AllowanceCommunication.pdf	22439 6722c0432b459a08dde26905512f131ec591edc4	no	2
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30409 f8edd148755cfaef015d92b2429be58f82c85d26	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	247723		

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

PTO/SB/08 Equivalent

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application No.	16/557261
	Filing Date	August 30, 2019
	First Named Inventor	Purang Abolmaesumi
	Art Unit	2668
(Multiple sheets used when necessary)	Examiner	Bhatnagar, Anand P.
SHEET 1 OF 3	Attorney Docket No.	CRBN001.002AUS

U.S. PATENT DOCUMENTS

Examiner Initials	Cite No.	Document Number *Number - Kind Code (if known)* Example: 1,234,567 B1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear
	1	5,776,063	~~07-07-1987~~	Dittrich et al.	07/1998
	2	7,912,528	03-22-2011	Krishnan, et al.	
	3	8,594,398	11-26-2013	Beymer, et al.	
	4	8,744,152	06-03-2014	Beymer, et al.	
	5	8,750,375	06-10-2014	Beymer, et al.	
	6	8,891,881	11-18-2014	Gupta, et al.	
	7	8,917,917	12-23-2014	Bwymar, et al.	
	8	9,652,846	05-16-2017	Codella, et al.	
	9	20050020903	01-27-2005	Krishnan, et al.	
	10	20050251013	11-10-2005	Krishnan, et al	
	11	20090074280	03-19-2009	Lu, et al.	
	12	20090088640	04-02-2009	Park, et al.	
	13	20100168578	07-01-2010	Garson JR, et al.	
	14	20110082371	04-07-2011	Chono	
	15	20150086093	03-26-2015	Fonte, et al.	
	16	20170026298	01-26-2017	Huo	
	17	U.S. Patent Application No. 16/095,601, including its prosecution history, and the Office Actions therein.	10-22-2018	Abolmaesumi	

Change(s) applied to document, /M.E.G./ 7/17/2020

FOREIGN PATENT DOCUMENTS

Examiner Initials	Cite No.	Foreign Patent Document *Country Code-Number-Kind Code* Example: JP 1234567 A1	Publication Date MM-DD-YYYY	Name	Pages, Columns, Lines Where Relevant Passages or Relevant Figures Appear	T[1]
	18	WO 2014/155272	10-02-2014	KONINKLIJKE PHILIPS NV.		

Examiner Signature /ANAND P BHATNAGAR/	Date Considered 06/18/2020

*__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.

[1] Place a check mark in this area when an English language Translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /A.P.B/

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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/557,261	08/25/2020	10751029	CRBN001.002AUS	6889

20995 7590 08/05/2020

KNOBBE MARTENS OLSON & BEAR LLP
2040 MAIN STREET
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ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

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

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

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

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

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

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

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ACKNOWLEDGEMENT OF CHANGE TO SMALL ENTITY STATUS

APPLICATION #	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET #	REQUEST ID
16/557,261	08/30/2019	Purang Abolmaesumi	CRBN001.002AUS	169429

The entity status change request below filed through Patent Center on 02/21/2024 has been accepted.

Certifications

APPLICANT ASSERTING SMALL ENTITY STATUS. See 37CFR 1.27.

Signature

I certify, in accordance with 37 CFR 1.4(d)(4), that I am one of the signatories making the entity status change.

Signature	Name	Registration #
/Vladislav Teplitskiy/	Vladislav Teplitskiy	68069