PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Nikolaos Pagoulatos et al.
For	:	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING

Docket No.	:	290139.403P1
Date	:	March 25, 2016

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

FEE DEFICIENCY AUTHORIZATION FORM

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Applicant(s) hereby authorize(s) the Director to charge any deficiencies or credit any overpayment in fees due by way of the enclosed papers only to Deposit Account No. 19-1090.

Respectfully submitted,

SEED Intellectual Property Law Group PLLC

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4799812_1

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING
First Named Inventor/Applicant Name:	Nikolaos Pagoulatos
Filer:	Justin E. Coe/Tyler Livas
Attorney Docket Number:	290139.403P1

Filed as Small Entity

Filing Fees for Provisional

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Provisional Application Filing Fee	2005	1	130	130
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**130**

Electronic Acknowledgement Receipt	
EFS ID:	25311325
Application Number:	62313601
International Application Number:	
Confirmation Number:	6103
Title of Invention:	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING
First Named Inventor/Applicant Name:	Nikolaos Pagoulatos
Customer Number:	500
Filer:	Justin E. Coe/Tyler Livas
Filer Authorized By:	Justin E. Coe
Attorney Docket Number:	290139.403P1
Receipt Date:	25-MAR-2016
Filing Date:	
Time Stamp:	18:51:04
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
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RAM confirmation Number	3901
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	290139_403P1_ADS.pdf	1823077 8b1b51a7c1bf3d84138faec196f708d9cb3b0a69	no	8
Warnings:					
Information:					
2		290139_403P1_APP.pdf	217448 6c8d228a26653ceea3d69c6dac197e098367e955	yes	29

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	19
Claims	20	23
Abstract	24	24
Drawings-only black and white line drawings	25	29

Warnings:					
Information:					
3	Miscellaneous Incoming Letter	290139_403P1_FDA.pdf	44899 546db5d4f338375a5fb580813fd0159ba255be93	no	1
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	29933 c34a8910634857ad6e3980d1b7d5595b26248ea6	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	2115357		

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

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

New International Application Filed with the USPTO as a Receiving Office
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PTO/AIA/14 (11-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

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
	Nikolaos		Pagoulatos	

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

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City	Bothell	State/Province	WA
Postal Code	98011	Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Ramachandra		Pailoor	

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

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Mailing Address of Inventor:

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Address 2	19125 North Creek Parkway #104

City	Bothell	State/Province	WA
Postal Code	98011	Country	US

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).

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

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

Customer Number	00500		
Email Address	justinc.docketing@seedip.com	Add Email	Remove Email

Application Information:

Title of the Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING		
Attorney Docket Number	290139.403P1	**Small Entity Status Claimed**	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	**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.

Please Select One:	● Customer Number	US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	00500		

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

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			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

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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).

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

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

☐ 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	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

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☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1 Remove

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.

Clear

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:

If the Applicant is an Organization check here. ☒

Organization Name	EchoNous, Inc.		
Mailing Address Information For Applicant:			
Address 1	19125 North Creek Parkway #104		
Address 2			
City	Bothell	**State/Province**	WA
Country	US	Postal Code	98011
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button. Add

Assignee Information including Non-Applicant Assignee Information:

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

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If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

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Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Justin Coe/			Date (YYYY-MM-DD)	2016-03-25
First Name	Justin	Last Name	Coe	Registration Number	67382

Additional Signature may be generated within this form by selecting the Add button. Add

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	290139.403P1
	Application Number	
Title of Invention	ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING	

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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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

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.

ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to U.S. Provisional Patent Application No. 62/302,109, filed March 1, 2016, and U.S. Provisional Patent Application No. 62/305,980 filed March 9, 2016, the entirety of which applications is hereby incorporated by reference to the maximum extent allowable by law.

BACKGROUND

Technical Field

This disclosure generally relates to ultrasound imaging systems and methods and, more particularly, to artificial intelligence based networks for ultrasound imaging and evaluation of ultrasound images.

Description of the Related Art

Ultrasound imaging is typically performed in a clinical setting by trained ultrasound experts. For diagnostic ultrasound imaging, particular views of an organ or other tissue or body feature (such as fluids, bones, joints or the like) are clinically significant. Such views may be prescribed by clinical standards as views that should be captured by the ultrasound technician, depending on the target organ, diagnostic purpose or the like. Ultrasound technicians generally require specialized and extensive training to properly operate ultrasound imaging equipment, and to recognize when an acquired image or view of an organ or other tissue or body feature of a patient adequately represents a clinically desirable view. Ultrasound images captured by an ultrasound technician may also be reviewed by a physician to determine whether the captured images sufficiently represent the clinically desirable or standard views.

While conventional ultrasound imaging systems may be suitable for most patients in a hospital or similar clinical setting, such systems require significant training to operate and to adequately

capture clinically desirable views. This adds to the overall cost of such ultrasound imaging and further limits the availability of ultrasound imaging to patients, as only well-trained professionals can properly operate conventional ultrasound imaging devices.

BRIEF SUMMARY

The present disclosure provides ultrasound data information systems and methods that facilitate ultrasound image recognition for the purposes of ultrasound image acquisition and interpretation. In particular, the ultrasound data information systems and methods are operable to determine whether, in the context of image acquisition, ultrasound images acquired by an ultrasound imaging device correspond to known, clinically desirable views of one or more organs or tissues or body features in a patient, or in the context of image interpretation, whether ultrasound images acquired by an ultrasound imaging device indicate certain pathologies or normal function. Artificial intelligence approaches are employed in a central artificial intelligence (AI) ultrasound image recognition training network, which is trained to recognize and/or make determinations regarding ultrasound images of a patient. The AI training network and/or the knowledge developed by the AI training network may be provided to, and implemented by, a number of ultrasound imaging devices that may be located anywhere. Utilizing the ultrasound image knowledge developed by the AI training network, the ultrasound imaging devices may thus acquire images of a patient and determine, for example, whether the acquired images represent one or more of the clinically desirable views. Ultrasound images acquired by the ultrasound imaging devices may then be transmitted back to the AI training network, as training input information, thereby further training the AI training network and developing further and/or refined ultrasound image knowledge.

The ultrasound imaging devices may receive periodic updates (*e.g.*, monthly, weekly, daily, or more frequently, etc.) from the AI training network, thus receiving the most recently developed ultrasound image knowledge stored in the AI training network with each update.

In at least one embodiment, an ultrasound data information system is provided that includes an ultrasound image recognition training network, stored at least partially on a computer device having one or more processors. The ultrasound image recognition training network is configured

to receive ultrasound training images and develop ultrasound image knowledge based on the received ultrasound training images. The ultrasound data information system further includes an ultrasound imaging device configured to acquire ultrasound images of a patient, and an ultrasound image recognition module within the ultrasound imaging device. The ultrasound image recognition module is configured to receive the ultrasound image knowledge, receive the acquired ultrasound images from the ultrasound imaging device, and determine, based on the ultrasound image knowledge, whether the received ultrasound images represent a clinically desirable view of an organ or a certain pathology.

In another embodiment, the present disclosure provides a method that includes receiving, by an ultrasound image recognition training network, ultrasound training images. The method further includes generating, by the ultrasound image recognition training network, ultrasound image knowledge based on the received ultrasound training images, and transmitting the ultrasound image knowledge to an ultrasound imaging device that is separate from and located remotely from the ultrasound image recognition training network. The ultrasound imaging device may thus acquire ultrasound images of a patient, and determine, based on the ultrasound image knowledge, whether the acquired ultrasound images represent a clinically desirable view of an organ.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 illustrates a block diagram of an ultrasound data information system in accordance with one or more embodiments of the disclosure;

Figure 2 is a block diagram illustrating an ultrasound imaging device in accordance with one or more embodiments of the disclosure;

Figure 3 is a block diagram illustrating training of an artificial intelligence ultrasound image recognition training network in accordance with one or more embodiments of the disclosure;

Figure 4 is a block diagram illustrating a neural network, which may be implemented by the artificial intelligence training network and/or an ultrasound image recognition module in the ultrasound imaging device, in accordance with one or more embodiments of the disclosure; and

Figure 5 is a flowchart illustrating an ultrasound image recognition method in accordance with one or more embodiments of the disclosure.

DETAILED DESCRIPTION

The present disclosure provides several embodiments of artificial intelligence network systems and methods for ultrasound imaging. The systems and methods provided herein may be particularly useful for ultrasound imaging performed by ultrasound technicians at all skill levels and/or for ultrasound imaging utilizing a handheld or mobile ultrasound imaging device which may be deployed in a non-traditional clinical setting. Utilizing artificial intelligence approaches, the systems and methods provided herein are capable of determining whether (i) acquired ultrasound images accurately or substantially accurately depict or represent, or do not accurately or substantially accurately depict or represent, a desired view of a structure and/or anatomy including, for example, a patient's organ or other tissue, feature or region of interest in a patient, and (ii) whether acquired images representing clinically desired views of anatomy indicate normal function or a particular pathology. For example, based on acquired ultrasound images determined to substantially accurately depict or represent a particular view of a heart, the artificial intelligence approaches may further indicate a particular problem with the mitral valves in the heart.

An artificial intelligence ultrasound image recognition training network ("AI training network") may be a cloud-based or distributed computing network, and may be accessible to a large number of ultrasound imaging devices. The AI training network may be trained using a large number of ultrasound images representing known or clinically determined views, and within these views ultrasound images may represent normal or pathological function. Through a training process, the parameters of the AI training network are optimized for recognition of a variety of views of structures, such as organs, tissue or any other region of interest in a patient and for a variety of normal and pathological conditions. The AI training network and/or the network parameters (*e.g.*, any knowledge learned by the AI training network via the training process) may be downloaded and implemented by the ultrasound imaging devices in order to recognize, interpret and/or make determinations with respect to acquired ultrasound images. Accordingly, the ultrasound imaging devices need not be

individually trained (which is a computationally intensive process). Ultrasound images acquired by the ultrasound imaging devices may be transmitted back to the AI training network, as training input to further train the AI training network.

Figure 1 illustrates a block diagram of an ultrasound data information system 100 in accordance with embodiments of the present disclosure. As shown in Figure 1, the ultrasound data information system 100 includes a number of ultrasound imaging devices 110, a communications network 102, a cloud-based artificial intelligence (AI) ultrasound image recognition training network 120 (referred to hereinafter as "AI training network 120") and an ultrasound image knowledge database 122. The ultrasound data information system 100 may further include one or more user computer devices 130.

The AI training network 120 is a cloud-based or distributed computing artificial intelligence network that is trained to recognize ultrasound images. In particular, the AI training network 120 may be trained to determine whether received ultrasound images represent a clinically desirable view of an organ or other aspect, region or feature of a patient, or whether the clinically desirable views indicate normal function or a particular pathology. The AI training network 120 may be implemented by any computationally intelligent system that employs artificial intelligence, drawing from training inputs to learn or otherwise generate knowledge (*e.g.*, as stored in the image knowledge database 122), which is utilized to determine whether received ultrasound images represent a clinically desirable view or whether the clinically desirable views indicate normal function or a particular pathology.

"Artificial intelligence" is used herein to broadly describe any computationally intelligent systems and methods that can learn knowledge (*e.g.*, based on training data), and use such learned knowledge to adapt its approaches for solving one or more problems. Artificially intelligent machines may employ, for example, neural network, deep learning, convolutional neural network, and Bayesian program learning techniques to solve problems such as image recognition. Further, artificial intelligence may include any one or combination of the following computational techniques: constraint program, fuzzy logic, classification, conventional artificial intelligence, symbolic manipulation, fuzzy set theory, evolutionary computation, cybernetics, data mining, approximate reasoning, derivative-free

optimization, decision trees, and/or soft computing. Employing one or more computationally intelligent techniques, the AI training network 120 may learn to adapt to an unknown and/or changing environment for better performance.

Through an artificial intelligence training process (described in further detail with respect to Figure 3), the AI training network 120 learns knowledge, which is stored in the image knowledge database 122. The knowledge stored in image knowledge database 122 may include a variety of information facilitating ultrasound image analysis, with respect to received ultrasound images, by the AI training network 120 and/or by an ultrasound image recognition module 121 within the ultrasound imaging devices 110, as will be described in further detail herein. In particular, for example, the image knowledge database 122 may contain information relating to various image views of various organs, and normal and pathological states of various organs. For example, the image knowledge database 122 may include information associated with clinically standard or desirable views of a heart. The clinically standard views of a heart may include, for example, suprasternal, subcostal, short- and long-axis parasternal, 2-chamber apical, 3-chamber apical, 4-chamber apical and 5-chamber apical views. Additionally, the information associated with clinically standard views may be information associated with a three-dimensional view, a two-dimensional cross section view and/or a set of two-dimensional cross section views. Similarly, the image knowledge database 122 may include information associated with normal function of organs, such as a heart, and various pathological conditions of an organ, including for example, cardiac muscle contractility and valve function. The image knowledge database 122 may be stored in any computer-readable storage medium accessible by the AI training network 120.

The AI training network 120 may include, or otherwise be executed by, one or more computer processors configured to perform the various functions and operations described herein. For example, the AI training network 120 may be executed by one or more general purpose computers or data processors selectively activated or configured by a stored computer program, or may be a specially constructed computing platform for carrying out the features and operations described herein. In particular, the AI training network 120 may be a cloud-based or distributed computing artificial intelligence network having a high level of computational capability such that it can receive and process

a very large number (*e.g.*, tens of thousands, or more) of training images to generate ultrasound image knowledge. In one or more embodiments, the AI training network 120 may be included within and/or executed in an ultrasound imaging device 110.

The ultrasound imaging devices 110 may be any ultrasound devices operable to acquire ultrasound images of a patient, and may be, for example, handheld ultrasound imaging devices. With reference to Figure 2, an ultrasound imaging device 110 may include a display 112, memory 114, one or more processors 116 and an ultrasound image recognition module 121. The ultrasound imaging device 110 may further include an acquired ultrasound image database 215 and/or a local ultrasound image knowledge database 212. The ultrasound imaging device 110 is operatively coupled to an ultrasound probe 118.

The memory 114 may be or include any computer-readable storage medium, including, for example, read-only memory (ROM), random access memory (RAM), flash memory, hard disk drive, optical storage device, magnetic storage device, electrically erasable programmable read-only memory (EEPROM), organic storage media, or the like.

The processor 116 may be any computer processor operable to execute instructions (*e.g.*, stored in memory 114) to perform the functions of the ultrasound imaging device 110 as described herein.

The ultrasound probe 118 is driven by the ultrasound imaging device 110 to transmit signals toward a target region in a patient, and to receive echo signals returning from the target region in response to the transmitted signals. In operation, a user of the ultrasound device 110 may hold the probe 118 against a patient's body at a position and angle to acquire a desired ultrasound image. The signals received by the probe (*i.e.*, the echo signals) are communicated to the ultrasound imaging device 110 and may form, or be processed to form, an ultrasound image of the target region of the patient. Further, the ultrasound images may be provided to the display 112, which may display the ultrasound images and/or any other relevant information to the user.

The ultrasound image recognition module 121 may incorporate, for example, a portion or all of the pre-trained cloud-based AI training network 120, including the image knowledge acquired

and stored in the image knowledge database 122. That is, the ultrasound imaging devices 110 may download, via a communications network 102, the AI training network 120 and/or the ultrasound image knowledge stored in the ultrasound image knowledge database 122 (which may be stored, for example, in the local ultrasound image knowledge database 212). Accordingly, the image knowledge learned by the AI training network 120 may be applied by the ultrasound image recognition module 121 to process and make determinations regarding the ultrasound images acquired by the ultrasound imaging device 110. Communications network 102 may utilize one or more protocols to communicate via one or more physical networks, including local area networks, wireless networks, dedicated lines, intranets, the Internet, and the like.

The ultrasound images thus acquired by the ultrasound imaging device 110 may be provided to, and processed by, the ultrasound image recognition module 121. The ultrasound image recognition module 121 receives the ultrasound images acquired by the ultrasound imaging device 110, and determines whether one or more of the received ultrasound images represent a clinically desirable view of an organ or other aspect, region or feature of the patient or whether the clinically desirable views indicate normal function or a particular pathology. The ultrasound image recognition module 121 may be implemented by any computationally intelligent system that employs artificial intelligence, drawing from learned knowledge such as contained in a local ultrasound image knowledge database 212, to determine whether received ultrasound images represent a clinically desirable view or whether the clinically desirable views indicate normal function or a particular pathology.

Figure 3 is a block diagram illustrating training of the cloud-based AI training network 120, in accordance with one or more embodiments. The AI training network 120 may initially be trained using training images 210. Training images 210 may include any ultrasound image information. For example, the training images 210 may include a variety of ultrasound image information associated with known views of an organ, such as the heart. As a further example, the training images 210 may be clinically desirable images of, *e.g.*, suprasternal views of a heart. In such a case, the training images 210 may be ultrasound images which have been pre-determined (*e.g.*, by a physician) as adequately showing a clinically desirable suprasternal view of a heart. Each such training image 210 may have slightly different characteristics (*e.g.*, higher quality images, lower quality images, blurry images, images taken

at slightly different angles, and so on), yet each such training image 210 may nonetheless be pre-determined as adequately representing a clinically desirable view of a heart. Similarly, a wide variety of images with various characteristics representing normal function and/or certain pathologies may be included in the training images 210.

Moreover, the training images 210 may include not only image information associated with clinically standard or desirable views, but may further include image information associated with non-clinically desirable views. Accordingly, the AI training network 120 may receive, for example, a view of a heart which is not representative of any particular clinically desirable view (*e.g.*, suprasternal, subcostal, short- and long-axis parasternal, 2-chamber apical, 3-chamber apical, 4-chamber apical and 5-chamber apical views). In such a case, the AI training network 120 may nonetheless recognize the image as being a view of a heart, and may further recognize the image as being an image somewhere between, for example, a 2-chamber apical view and a 3-chamber apical view. A clinically standard 3-chamber apical view is generally obtainable, for example, by rotating an ultrasound imaging probe about 60° counterclockwise with respect to the 2-chamber apical view. Ultrasound images obtained with the probe at an angle of rotation somewhere between, for example, 5° and 55° counterclockwise with respect to the 2-chamber apical view may be determined as not representing a clinically desirable view of a heart. However, the AI training network 120 may be trained with training images 210 showing a variety of known, but non-clinically desirable, views of a heart (such as views somewhere between the 2-chamber apical and the 3-chamber apical views), and thus may develop knowledge facilitating recognition of such views (*e.g.*, the AI training network 120 may recognize a view as representing a 35° counterclockwise rotation of the probe 118 with respect to the 2-chamber apical view). In accordance with a preferred embodiment, feedback is provided to the user regarding recognition (or lack thereof) and identification or interpretation (or lack thereof) of the image captured, in accordance with U.S. Patent Application No. 62/305,980, the entirety of which is herein incorporated by reference.

Other training input 220 may further be provided to the AI training network 120 for training. The other training input 220 may include, for example, manually-entered input to adjust or otherwise manage the image recognition model developed in the AI training network 120 through the training process.

Using training images 210, the AI training network 120 may implement an iterative training process. Training may be based on a wide variety of learning rules or training algorithms. For example, the learning rules may include one or more of the following: back-propagation, real-time recurrent learning, pattern-by-pattern learning, supervised learning, interpolation, weighted sum, reinforced learning, temporal difference learning, unsupervised learning, and/or recording learning.

The back-propagation learning algorithm is a common method of training artificial neural networks (and may be employed, for example, with the artificial neural network 300 shown in Figure 4). Back-propagation generally includes two phases: propagation and weight update. In the propagation phase, a training pattern's input is forward propagated through the neural network in order to generate the propagation's output activations. Then, the propagation's output activations are backward propagated through the neural network using the training pattern target in order to generate deltas (*i.e.*, the difference between the input and output values) of all output and hidden neurons. In the weight update phase, for each weight-synapse, the following steps are generally performed: 1. multiply its output delta and input activation to get the gradient of the weight; and 2. subtract a ratio (percentage) of the gradient from the weight. The propagation and weight update phases are repeated as desired until performance of the network is satisfactory.

As a result of the training, the AI training network 120 may learn to modify its behavior in response to the training images 210, and obtain or generate ultrasound image knowledge 230. The ultrasound image knowledge 230 may represent any information upon which an artificial intelligence network (*e.g.*, the AI training network 120 and/or the ultrasound image recognition module 121) may determine to be an appropriate response to new data or situations. In particular, the ultrasound image knowledge 230 represents relationships between ultrasound images and one or more views of an organ and normal versus pathological conditions of an organ (*e.g.*, one or more functions that describe one or more views of an organ based on ultrasound image parameters, coefficients, weighting information, parameters associated with the example neural network shown in Figure 4 or any such variable). The ultrasound image knowledge 230 may be stored in the ultrasound image knowledge database 122.

Once the AI training network 120 is sufficiently trained based on the initial training images 210, the ultrasound imaging devices 110 may download (*e.g.*, as indicated by reference numeral

103) the trained AI training network 120 and/or the image knowledge developed by the AI training network 120 and stored in the ultrasound image knowledge database 122, via the communications network 102. That is, the ultrasound image recognition module 121 in the ultrasound imaging devices 110 may include one or more portions of or be a copy of the already trained AI training network 120, and the local ultrasound image knowledge database 212 within the ultrasound imaging devices 110 may be provided with some or all of the ultrasound image knowledge stored in the ultrasound image knowledge database 122.

The ultrasound imaging devices 110 are thus equipped to acquire unknown ultrasound images during normal operational use, and to determine (*e.g.*, by the ultrasound image recognition module 121) whether the acquired ultrasound images represent a clinically desirable view of a patient or whether the clinically desirable views indicate normal function or a particular pathology.

Images acquired by the ultrasound imaging devices 110 during normal operational use (*e.g.*, acquired diagnostic images 217 of a patient) may be stored in the acquired ultrasound image database 215, and further may be provided to the AI training network 120 (shown in Figure 1, for example, at reference numeral 101) as additional training inputs, thereby further training the AI training network 120. Such acquired ultrasound images 217 may be images directly acquired by the ultrasound imaging devices 110 and/or may be images that have been verified, modified and/or otherwise clinically determined for use as training data for further training the AI training network 120. For example, the acquired ultrasound images 217 may include images obtained by an ultrasound imaging device 110, and which were not correctly determined by the local ultrasound image recognition module 121. For example, the ultrasound image recognition module 121 may determine that a particular image does not represent a clinically desirable view (*e.g.*, a suprasternal view of heart); however, that same image may in fact represent the clinically desirable view. For example, a physician or other such expert may, upon independent review of the ultrasound image, determine that the image does in fact show a clinically sufficient suprasternal view of heart, but the ultrasound image recognition module 121 did not make same determination, thus reflecting that the ultrasound image recognition module 121 may be further optimized to determine or recognize the image correctly. In such a case, the acquired ultrasound image may be modified, labeled or otherwise associated with training data indicating that the acquired image

represents a clinically desirable view (*e.g.*, a suprasternal view of a heart), and may thus be provided as an acquired ultrasound image 217 for further training the AI training network 120, which in turn is used to update the ultrasound image recognition module 121.

Ultrasound images obtained by the ultrasound imaging devices 110 may be stored in the acquired ultrasound image database 215 and/or may be modified to include training information (*e.g.*, indicating any known characteristics about the image, such as that the image represents or does not represent a particular clinically desirable view, normal function or known pathology) and then stored in the acquired ultrasound image database 215. Accordingly, acquired ultrasound images 217, having training information indicating one or more known characteristics about the acquired ultrasound images 217, may be provided to the AI training network 120 for further training and for further development and/or refinement of ultrasound image knowledge 230.

The acquired ultrasound images 217 used for further training the AI training network 120 may be received directly from the ultrasound imaging devices 110 (*e.g.*, by uploading images stored in the acquired image database 215, via communications network 102, to the AI training network 120) and/or from one or more user computer devices 130. For example, a physician may download ultrasound images from the ultrasound imaging devices 110 to a user computer device 130, and further may modify, label, or otherwise append training data to the ultrasound images indicating one or more known characteristics associated with the ultrasound images. The user computer device 130 may thus be utilized to transmit the acquired ultrasound images 217 (which may include, for example, the training data indicating one or more known characteristics) to the AI training network 120 for further training. User computer device 130 may also, or alternatively, be used to receive updated knowledge from the AI training network 120, which it may communicate to any associated ultrasound imaging device 110.

The acquired ultrasound images 217 are thus training images used to further train the AI training network 120. That is, the initial set of training images 210 are used to initially train the AI training network 120, and the acquired ultrasound images 217 are provided to further train the AI training network 120 after one or more ultrasound imaging devices 110 have been deployed and have acquired ultrasound images which may provide training value. The training images 210, as well as the

acquired ultrasound images 217, include the same type of information, *i.e.*, ultrasound image information and associated training labels.

The training images 210 and/or the acquired ultrasound images 217 for training the AI training network 120 may include a sequence of images (*e.g.*, a video clip having a sequence of successively-acquired image frames). For example, a clip may include a sequence of images indicating a dynamic phenomenon such as heart motion/contractility. Such a clip may be provided to the AI training network 120 as initial training images 210 and/or as acquired ultrasound images 217 for further training the AI training network 120.

Based on the training images 210, the AI training network 120 may learn to modify its behavior, and may apply knowledge contained in the image knowledge database 122 to alter the manner in which it makes determinations with respect to new inputs, such as, for example, acquired ultrasound image information 217 received from the ultrasound imaging devices 110. The acquired ultrasound images 217 may be provided to the AI training network 120 via the communications network 102, and thus may be used as additional training input to further train the AI training network 120, and to generate further developed image knowledge 230, which may be stored in the image knowledge database 122.

Figure 4 is a block diagram illustrating one example of an artificial neural network 300, which may be implemented by the AI training network 120 and/or the ultrasound image recognition module 121, in accordance with one or more embodiments. Artificial neural networks (ANNs) are artificial intelligence models that are used to estimate or approximate functions that can depend on a large number of inputs, and which are generally unknown. Such neural networks generally include a system of interconnected "neurons" which exchange information between each other. The connections have numeric weights that can be tuned based on experience, and thus neural networks are adaptive to inputs and are capable of learning.

The artificial neural network 300 shown in Figure 4 includes three layers: an input layer 310 including input neurons i_1 through i_3, a hidden layer 320 including hidden layer neurons h_1 through h_4, and an output layer 330 including output neurons f_1 and f_2. While the neural network 300 of Figure 4

is shown having three layers, it should be readily appreciated that additional layers may be included in the neural network 300 as desired to achieve optimal training and performance of the AI training network 120 and/or the ultrasound image recognition module 121. Similarly, the neurons in each layer are shown for exemplary purposes, and it should be readily understood that each layer may include more, even significantly more, neurons than shown in Figure 3.

The neural network 300 may be trained (*e.g.*, in an embodiment where the AI training network 120 is a neural network 300) by providing training images 210 and/or acquired ultrasound images 217 to the input layer 310. As described with respect to Figure 3, the training images (as well as the acquired ultrasound images 217, provided as training input to the AI training network 120) may include ultrasound image information having a wide variety of known characteristics, including, for example, various organ views, normal function, various pathologies, various image qualities or characteristics, various imaging angles, and so on. Through training, the neural network 300 may generate and/or modify the hidden layer 320, which represents weighted connections mapping the training images 210 and/or acquired ultrasound images 217 provided at the input layer 310 to known output information at the output layer 330 (*e.g.*, classification of an image as a subcostal view of a heart, a suprasternal view, etc.). Relationships between neurons of the input layer 310, hidden layer 320 and output layer 330, formed through the training process and which may include weight connection relationships, are generally referred to herein as "ultrasound image knowledge," and may be stored, for example, in the ultrasound image knowledge database 122.

Once the neural network 300 has been sufficiently trained, the neural network 300 may be provided to the ultrasound imaging devices 110, and implemented, for example, by ultrasound image recognition module 121. As such, the neural network 300 may receive non-training ultrasound images at the input layer 310 (*i.e.*, ultrasound images taken of a patient utilizing the ultrasound imaging device 110). Utilizing ultrasound image knowledge stored in the ultrasound image knowledge database 122 (which may be provided to and stored in the local ultrasound image knowledge database 212, and which may include, for example, weighted connection information between neurons of the neural network 300), the neural network 300 may make determinations about the received ultrasound image

information at the output layer 330. For example, the neural network 300 may determine whether the received ultrasound images represent one or more clinically desirable views of an organ.

Thus, the cloud-based AI training network 120 is initially trained in order to develop a network and/or image knowledge sufficient to implement in an ultrasound image recognition module 121 in the ultrasound imaging devices 110. The cloud-based AI training network 120 then continues to be further trained based on the acquired ultrasound images 217, which are acquired by ultrasound devices 110 and provided to the AI training network 120 via the communications network 102 (shown in Figure 1, for example, at reference numeral 101). As a result of the continued training of the AI training network 120, the AI training network 120 continues to develop, refine or otherwise generate additional ultrasound image knowledge, which is stored in the ultrasound image knowledge database 122. The ultrasound imaging devices 110 may thus periodically receive updated ultrasound image knowledge stored in the ultrasound image knowledge database 122 (shown in Figure 1, for example, at reference numeral 103), either through updates that are automatically downloaded per a predetermined schedule, or at a particular time desired or requested by a user, or automatically when the database has received a certain threshold number of additional images that has resulted in the network being further trained since the imaging device(s) were last updated.

The neural network 300 of Figure 4 is provided as just one example, among various possible implementations, of an AI training network 120 and/or an ultrasound image recognition module 121 that employs artificial intelligence to make determinations with respect to received ultrasound image information. For example, the AI training network 120 and/or the ultrasound image recognition module 121 may implement any of neural network, deep learning, convolutional neural network, and Bayesian program learning techniques to make determinations with respect to received ultrasound images of a patient.

Moreover, the AI training network 120 may be trained, utilizing a variety of training images 210 and/or acquired ultrasound images 217 (and further may be trained utilizing a variety of sequences of training images 210 and/or acquired ultrasound images 217) to make a variety of determinations relating to received ultrasound image information. For example, the AI training network 120 may be trained or otherwise configured to determine whether a received ultrasound image

represents one or more clinically standard or desirable views or whether the clinically desirable views indicate normal function or a particular pathology. Further, the AI training network 120 may be trained to determine whether a received ultrasound image represents a non-clinically desirable view (and may recognize such non-clinically desirable view as a particular view or angle of a particular organ or other tissue within a patient), and may further determine based on a sequence of received ultrasound images whether the images are approaching or moving away from a clinically desirable view of an organ.

By downloading the AI training network 120 and/or the ultrasound image knowledge developed by the AI training network 120 and stored in the ultrasound image knowledge database 122, the ultrasound image recognition module 121 and local ultrasound image knowledge database 212 in the ultrasound imaging devices 110 may include all of the features and functionality described herein with respect to the trained AI training network 120 and the ultrasound image knowledge database 122.

For example, as discussed above, the AI training network 120 may be trained with training images 210 and/or acquired ultrasound images 217 showing a variety of known, but non-clinically desirable, views of a heart (such as views somewhere between the 2-chamber apical and the 3-chamber apical views), and thus the ultrasound image recognition module 120 in the ultrasound devices 110 may recognize such views (*e.g.*, the ultrasound image recognition module 121 may recognize a view as representing a 35° counterclockwise rotation of the probe 118 with respect to the 2-chamber apical view). Further, the AI training network 120 may be trained with a sequence of recognized, but non-clinically standard or desirable views of a heart. For example, the AI training network 120 may be trained to recognize ultrasound images showing a view of the heart at each degree of counterclockwise rotation between 0° and 60° with respect to the 2-chamber apical view (*i.e.*, every degree between the 2-chamber apical and the 3-chamber apical views). Further, the AI training network 120 may be trained to recognize a sequence of or progression of such non-clinically desirable views toward and/or away from a clinically desirable view (*e.g.*, the training images 210 may include a sequence of ultrasound images representing rotation of the probe 118 from the 2-chamber apical view toward and/or away from the 3-chamber apical view). The AI training network 120 may thus be trained (and the ultrasound image recognition module 121 in the ultrasound imaging devices 110 may thus be implemented) to

recognize that received ultrasound images, while not being representative of a particular clinically desired view, may be getting successively closer to (or moving away from) the clinically desired view.

Further, the AI training network 120 may be trained such that, when implemented as the ultrasound image recognition module 121 in the ultrasound imaging devices 110, the ultrasound image recognition module 121 may determine whether received ultrasound images represent any of a plurality of clinically desirable views of an organ. Such clinically desirable views of an organ may include, for example, suprasternal, subcostal, short- and long-axis parasternal, 2-chamber apical, 3-chamber apical, 4-chamber apical and 5-chamber apical views of a heart.

While Figure 1 illustrates an ultrasound data information system 100 including a cloud-based ultrasound image recognition AI training network 120, in one or more alternative embodiments the ultrasound image recognition AI training network 120 may be included within one or more of the ultrasound devices 110. Accordingly, the AI training network 120 within an ultrasound imaging device 110 may be trained as described above (and shown, for example, in Figure 3) based on the initial training images 210, and further may be trained based on acquired ultrasound images 217 which are acquired by the ultrasound imaging device 110 and further have been labeled and/or modified in some way as to provide training information. For example, an ultrasound image acquired by an ultrasound imaging device 110 may be determined by the ultrasound image recognition module 121 and/or the AI training network 120 as not representing a desirable clinical view of a particular organ, such as a heart. An ultrasound technician operating the ultrasound imaging device 110 may know, for example, that the acquired image does in fact represent the clinically desirable view; however, the patient's heart is has an atypical anatomy and thus the ultrasound image recognition module 121 and/or the AI training network 120 does not correctly recognize the image as being a clinically desirable view. In such a case, the ultrasound technician may label the acquired image as being the clinically desirable view (*e.g.*, by pressing a corresponding button on the ultrasound imaging device 110, by storing the acquired image in the acquired ultrasound image database 215 for labeling by a physician or other trained expert utilizing the ultrasound imaging device 110 and/or a user computer device 130, or the like). Once labeled as properly representing the clinically desirable view, the image is provided as training input (*e.g.*, acquired ultrasound image 217) to further train the AI training network 120 and/or the ultrasound image

recognition module 121 within the ultrasound imaging device 110. Thus, an ultrasound imaging device 110 may include the ability to self-train its ultrasound image recognition module 121 based on images acquired by the ultrasound image device 110.

Further, there may other circumstances in which multiple organizations (*e.g.*, hospitals or clinics) or groups of users of ultrasound imaging devices 110 (*e.g.*, trade associations or informal groups) each have their own AI training network (*e.g.*, a central AI training network 120, or a separate, organization or group AI training network for providing updated image knowledge, based on ultrasound images acquired by ultrasound imaging devices 110 within the organization or group) and/or knowledge database for their organization or group, with updates being generated from ultrasound images acquired by ultrasound imaging devices 110 in the organization or group.

Figure 5 is a flowchart illustrating a method 500, in accordance with one or more embodiments. At block 502, the method 500 includes receiving, by an ultrasound image recognition training network (*e.g.*, the AI training network 120), ultrasound training images 210.

At block 504, the method 500 includes generating, by the ultrasound image recognition training network, ultrasound image knowledge 230 based on the received ultrasound training images 210. The ultrasound image knowledge 230 may be stored, for example, in the ultrasound image knowledge database 122.

At block 506, the method 500 includes transmitting the ultrasound image knowledge 230 to an ultrasound imaging device 110. The ultrasound imaging devices 110 may periodically poll the AI training network 120 for updated knowledge, and the ultrasound image knowledge 230 may be transmitted in response to the polling. Additionally or alternatively, the AI training network 120 may periodically push updated ultrasound image knowledge 230 to the ultrasound imaging devices 110. In one or more embodiments, one or more of the ultrasound imaging devices 110 and/or user computer devices 130 may receive the updated ultrasound image knowledge 130 and then distribute the updated ultrasound image knowledge 130 to one or more other ultrasound imaging devices 110 (*e.g.*, via a peer-to-peer or other local network). For example, one or more user computer devices 130 may be located

within a clinical setting, such as a hospital, and may receive and provide updated ultrasound image knowledge 230 to multiple ultrasound imaging devices 110 located within the same setting.

The ultrasound image knowledge 230 may be transmitted to the ultrasound imaging device 110, for example, directly from the ultrasound image knowledge database 122 or from the AI training network 120. Alternatively, the ultrasound image knowledge 230 may be provided to a user computer device 130, which then transmits the ultrasound image knowledge 230 to one or more ultrasound imaging devices 110. The transmitted ultrasound image knowledge may be stored in the local ultrasound image knowledge database 212, which may be contained within the ultrasound imaging device 110.

At block 508, the method 500 further includes acquiring, by the ultrasound imaging device 110, ultrasound images of a patient. At block 510, the method 500 includes determining by the ultrasound imaging device 110 (*e.g.*, utilizing the ultrasound image recognition module 121) whether the acquired ultrasound images represent a clinically desirable view of an organ. The determining may be performed, for example, based on the ultrasound image knowledge 230.

At block 512, the method 500 includes transmitting the acquired ultrasound images of the patient to the ultrasound image recognition training network for further training. The transmitted acquired ultrasound images of the patient may include training data indicating one or more known characteristics associated with the acquired ultrasound images.

The various embodiments described above can be combined to provide further embodiments. These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

CLAIMS

1. An ultrasound data information system, comprising:

an ultrasound image recognition training network stored at least partially on a computer device having one or more processors, the ultrasound image recognition training network being configured to receive ultrasound training images, and to develop ultrasound image knowledge based on the received ultrasound training images;

an ultrasound imaging device configured to acquire ultrasound images of a patient; and

an ultrasound image recognition module, within the ultrasound imaging device, the ultrasound image recognition module being configured to:

receive the ultrasound image knowledge;

receive the acquired ultrasound images from the ultrasound imaging device; and

determine, based on the ultrasound image knowledge, whether the received ultrasound images represent a clinically desirable view of an organ.

2. The ultrasound data information system of claim 1, wherein the ultrasound image recognition training network is configured to implement at least one of neural network, deep learning, convolutional neural network, and Bayesian program learning techniques to determine whether the received ultrasound images represent the clinically desirable view of the organ.

3. The ultrasound data information system of claim 1, wherein the clinically desirable view of the organ includes at least one of suprasternal, subcostal, short axis parasternal, long axis parasternal, 2-chamber apical, 3-chamber apical, 4-chamber apical and 5-chamber apical views of a heart.

4. The ultrasound data information system of claim 1, wherein the ultrasound image recognition module is operable to determine whether the received ultrasound images represent at least one of a plurality of clinically desirable views of the organ.

5. The ultrasound data information system of claim 1, wherein the ultrasound imaging device is further configured to provide the acquired ultrasound images to the ultrasound image recognition training network for further training the ultrasound image recognition training network and developing updated ultrasound image knowledge.

6. The ultrasound data information system of claim 1, wherein the ultrasound image recognition training network is configured to receive ultrasound training images, the ultrasound training images including initial training images and the ultrasound images acquired by the ultrasound imaging device.

7. The ultrasound data information system of claim 1, wherein the ultrasound image recognition module is configured to determine whether the received ultrasound images are sequentially approaching or moving away from the clinically desirable view of the organ.

8. The ultrasound data information system of claim 1, further comprising:

an ultrasound image knowledge database, communicatively coupled to the ultrasound image recognition training network and configured to store the ultrasound image knowledge; and

a local ultrasound image knowledge database, communicatively coupled to the ultrasound imaging device and configured to store the ultrasound image knowledge.

9. The ultrasound data information system of claim 1, the ultrasound image recognition module being further configured to:

determine, based on the ultrasound image knowledge, whether the received ultrasound images indicate normal function or a particular pathology.

10. A method, comprising:

receiving, by an ultrasound image recognition training network, ultrasound training images;

generating, by the ultrasound image recognition training network, ultrasound image knowledge based on the received ultrasound training images; and

transmitting the ultrasound image knowledge to an ultrasound imaging device that is separate from and located remotely from the ultrasound image recognition training network.

11. The method of claim 10, further comprising:

acquiring, by the ultrasound imaging device, ultrasound images of a patient; and

determining, based on the ultrasound image knowledge, whether the acquired ultrasound images represent a clinically desirable view of an organ.

12. The method of claim 11, further comprising:

transmitting the acquired ultrasound images of the patient to the ultrasound image recognition training network for further training the ultrasound image recognition training network and generating updated ultrasound image knowledge.

13. The method of claim 11, wherein determining whether the received ultrasound images represent a clinically desirable view of an organ includes:

implementing at least one of neural network, deep learning, convolutional neural network, and Bayesian program learning techniques to determine whether the received ultrasound images represent the clinically desirable view of the organ.

14. The method of claim 11, wherein determining whether the received ultrasound images represent a clinically desirable view of an organ includes:

determining whether the received ultrasound images represent at least one of suprasternal, subcostal, short axis parasternal, long axis parasternal, 2-chamber apical, 3-chamber apical, 4-chamber apical and 5-chamber apical views of a heart.

15. The method of claim 12, wherein the transmitted acquired ultrasound images of the patient include training data indicating one or more known characteristics associated with the acquired ultrasound images.

16. The method of claim 11, further comprising:

determining, based on the ultrasound image knowledge, whether the acquired ultrasound images indicate normal function or a particular pathology.

ABSTRACT OF THE DISCLOSURE

Ultrasound image recognition training network systems and methods are provided. An ultrasound data information system includes an ultrasound image recognition training network, stored at least partially on a computer device having one or more processors, the ultrasound image recognition training network being configured to receive ultrasound training images and to develop ultrasound image knowledge based on the received ultrasound training images. An ultrasound imaging device is configured to acquire ultrasound images of a patient, and the device includes an ultrasound image recognition module. The ultrasound image recognition module is configured to receive the ultrasound image knowledge, receive the acquired ultrasound images from the ultrasound imaging device, and determine, based on the ultrasound image knowledge, whether the received ultrasound images represent a clinically desirable view of an organ or whether the clinically desirable views indicate normal function or a particular pathology. The received ultrasound images are transmitted to the ultrasound image recognition training network for further training and development of updated ultrasound image knowledge.

FIG. 1

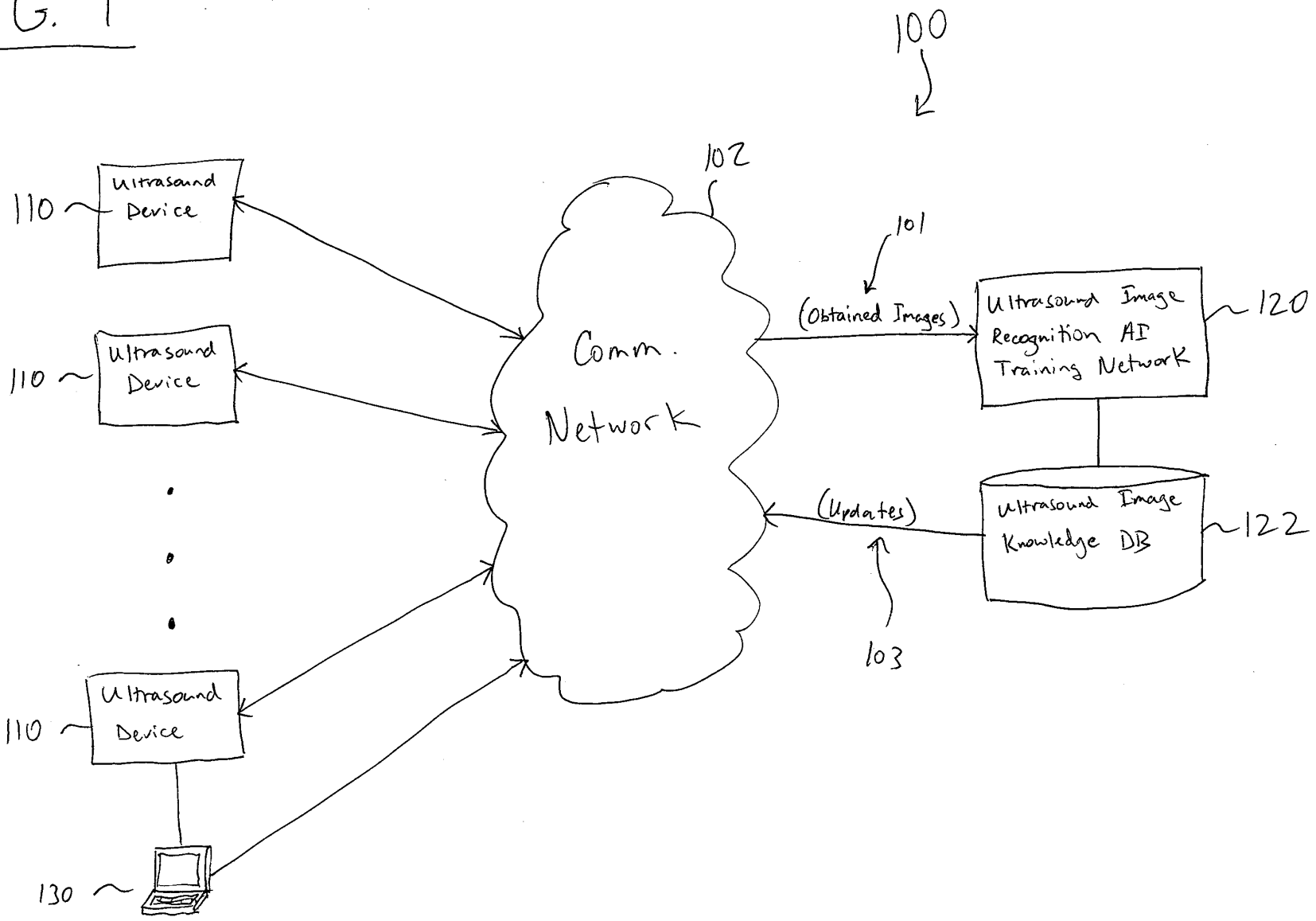


FIG. 2

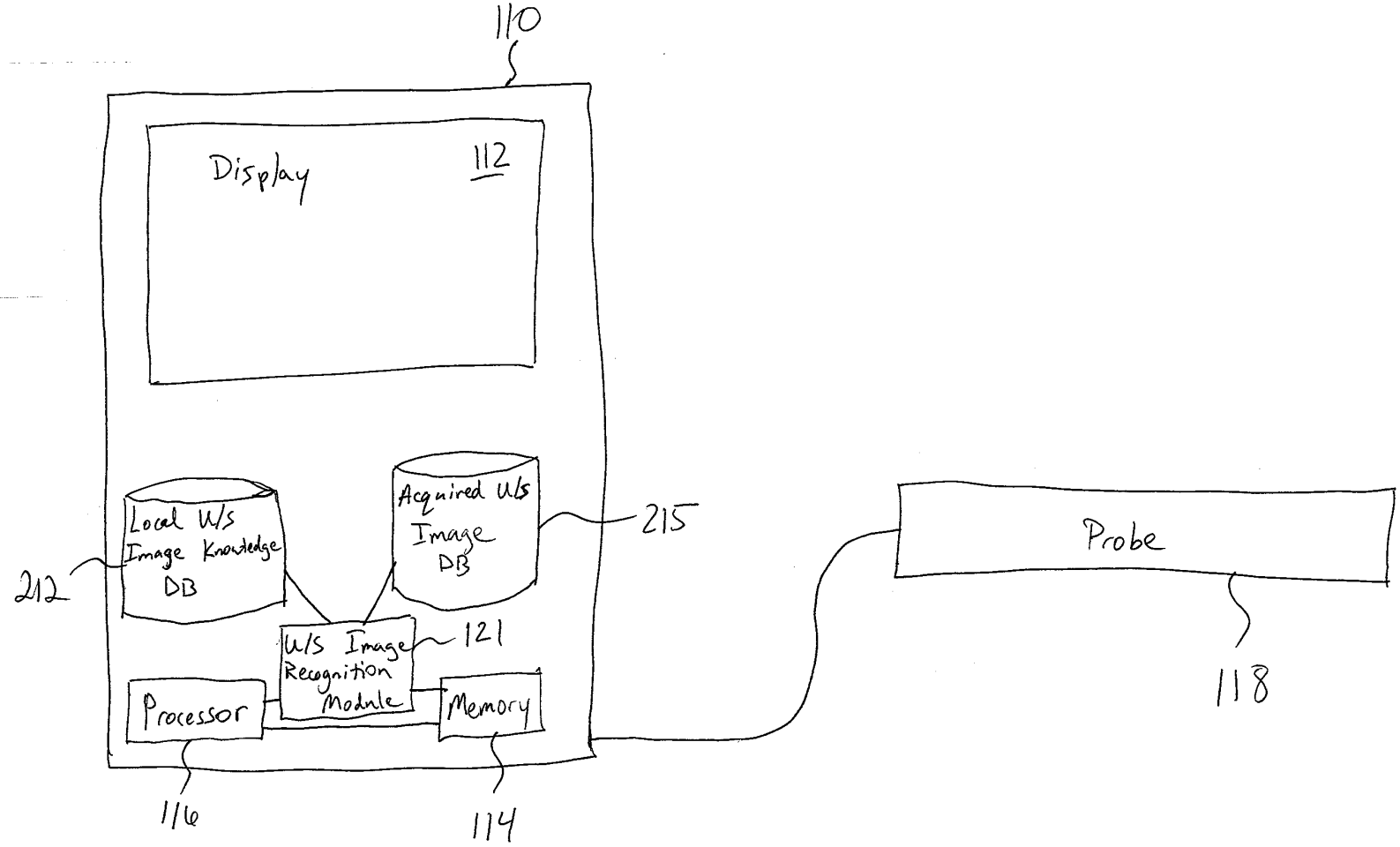


FIG. 3

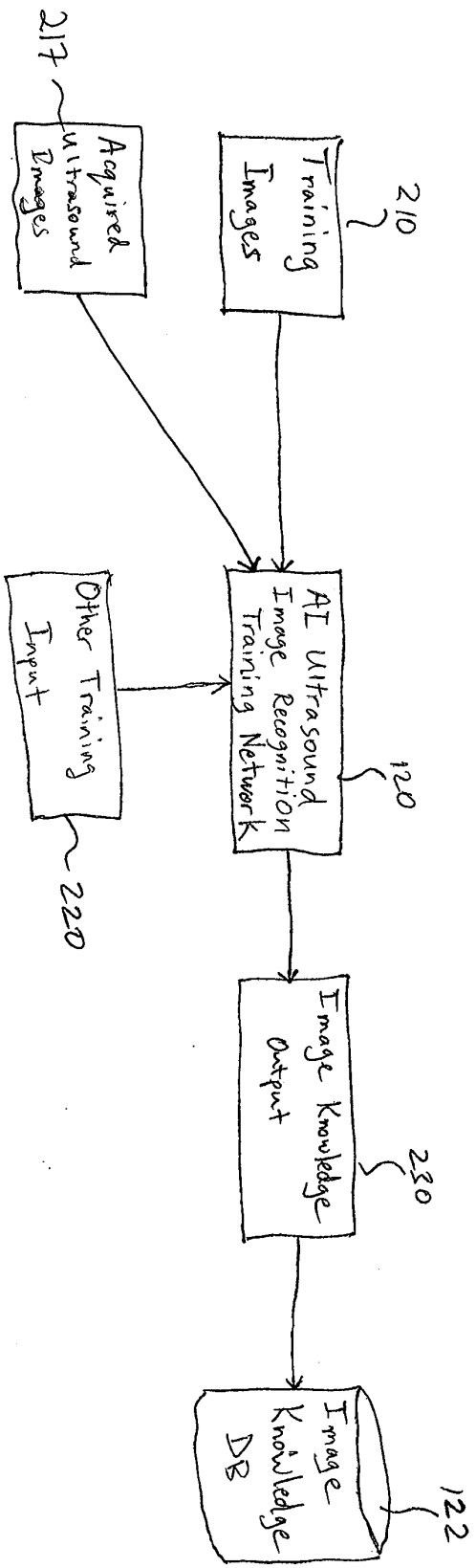


FIG. 4

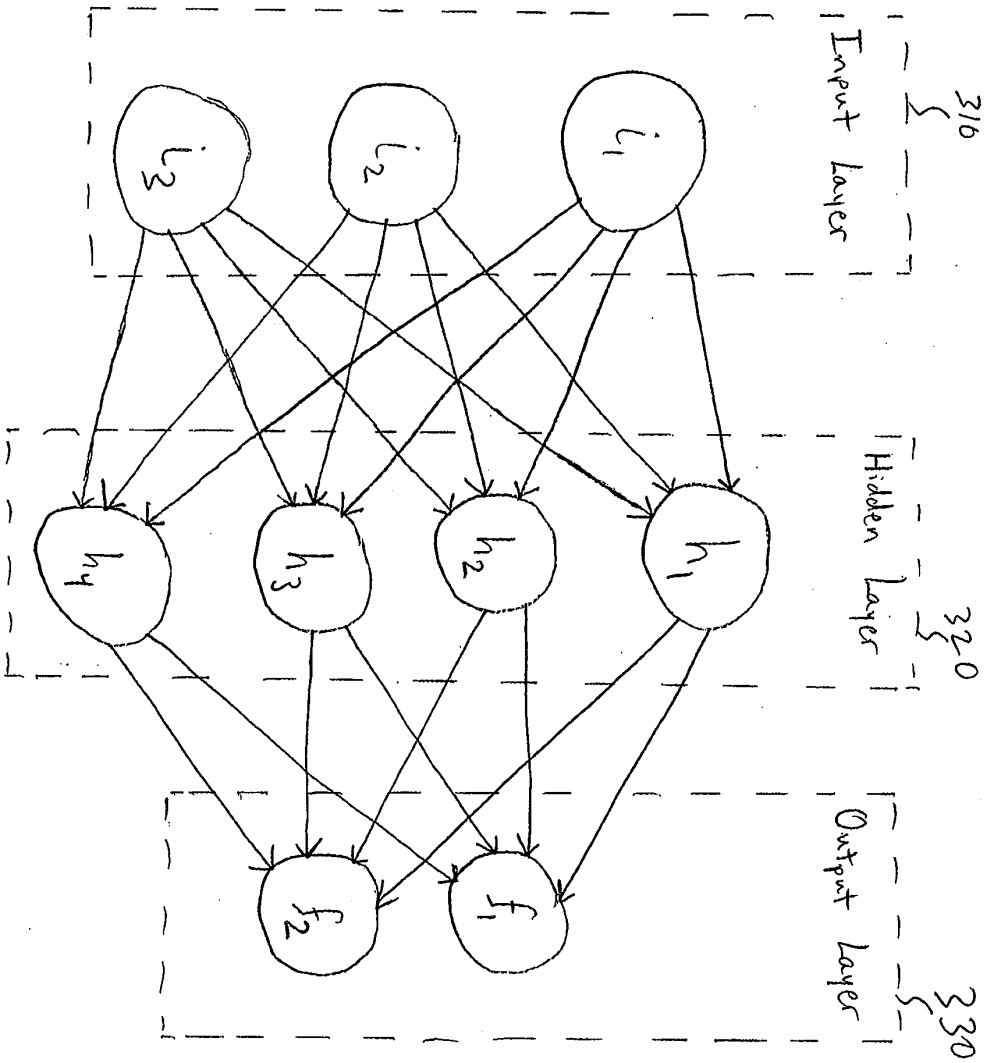
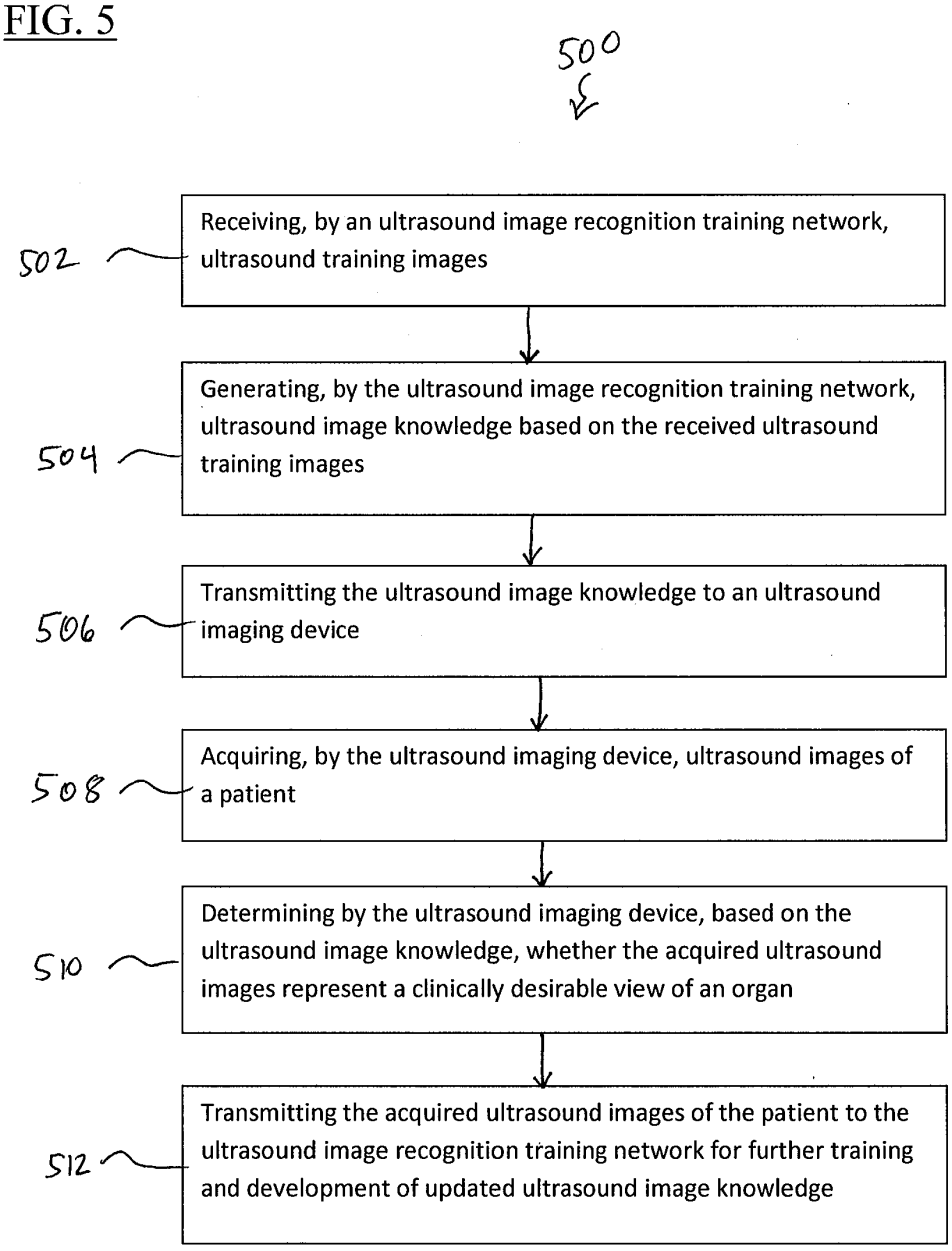

300
310
Input Layer
320
Hidden Layer
330
Output Layer
i_3
i_2
i_1
h_4
h_3
h_2
h_1
f_2
f_1

FIG. 5


500
502
Receiving, by an ultrasound image recognition training network, ultrasound training images
504
Generating, by the ultrasound image recognition training network, ultrasound image knowledge based on the received ultrasound training images
506
Transmitting the ultrasound image knowledge to an ultrasound imaging device
508
Acquiring, by the ultrasound imaging device, ultrasound images of a patient
510
Determining by the ultrasound imaging device, based on the ultrasound image knowledge, whether the acquired ultrasound images represent a clinically desirable view of an organ
512
Transmitting the acquired ultrasound images of the patient to the ultrasound image recognition training network for further training and development of updated ultrasound image knowledge

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62/313,601	03/25/2016		130	290139.403P1		

CONFIRMATION NO. 6103

FILING RECEIPT

500
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OC00000008212343O

Date Mailed: 04/12/2016

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Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

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

Title

ARTIFICIAL INTELLIGENCE NETWORK FOR ULTRASOUND IMAGING

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

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