METHOD AND SYSTEM FOR IDENTIFYING AN OPTIMAL IMAGE FRAME

ABSTRACT

Methods and systems for imaging a subject are presented. One or more candidate structures corresponding to a target feature and one or more supplementary features in each of a plurality of image frames are identified, where the plurality of image frames corresponds to a volume of interest of the subject. One or more spatial configurations corresponding to each of a plurality of combinations of the candidate structures are determined. Each of the spatial configurations is compared with a spatial reference model corresponding to a determined relative position of the target feature and the supplementary features in the volume of interest. A quality indicator corresponding to each of the plurality of image frames is computed based on the comparison. An optimal image frame is selected from the plurality of image frames based on the computed quality indicator.

FIG. 2

We Claim:

1. A method for diagnostic imaging of a subject, comprising:

identifying one or more candidate structures corresponding to a target feature and one or more supplementary features in each of a plurality of image frames, wherein the plurality of image frames corresponds to a volume of interest in the subject;

determining one or more spatial configurations corresponding to each combination in a plurality of combinations of the one or more candidate structures;

comparing each of the one or more spatial configurations with a spatial reference model corresponding to a determined relative position of the target feature and the one or more supplementary features in the volume of interest;

computing a quality indicator corresponding to each of the plurality of image frames based on the comparison; and

selecting an optimal image frame from the plurality of image frames based on the computed quality indicator.

2. The method of claim 1, wherein identifying the one or more candidate structures comprises detecting the one or more candidate structures using gray scale morphology, Otsu thresholding, geometry statistics based classification, or combinations thereof.

3. The method of claim 1, wherein identifying the one or more candidate structures comprises:

tracking a position, an orientation, or both of the one or more candidate structures in a first subset of image frames corresponding to the plurality of image frames; and

detecting the one or more candidate structures in a second subset of image frames of the plurality of image frames based on the tracked position, the tracked orientation, or both of the one or more candidate structures.

4. The method of claim 3, wherein detecting the one or more candidate structures comprises:

generating a first set of processing windows that enclose the one or more candidate structures in the first subset of image frames;

generating a second set of processing windows in the second subset of image frames based on the first set of processing windows; and

evaluating the one or more candidate structures within the second set of processing windows to identify the target feature and the one or more supplementary features in the second subset of image frames.

5. The method of claim 4, wherein generating the second set of processing windows comprises determining a size, an orientation, or both of the second set of processing windows based on a determined variation in the tracked position, the tracked orientation, or both of the one or more candidate structures in the first subset of image frames.

6. The method of claim 3, wherein the one or more spatial configurations corresponding to each combination in the plurality of combinations in the second

subset of image frames is determined based on the tracked position, the tracked orientation, or both of the one or more candidate structures in the first subset of image frames.

7. The method of claim 1, wherein the spatial reference model corresponds to a non-parametric prior distribution of the target feature and the one or more supplementary features in the volume of interest.

8. The method of claim 7, further comprising generating the spatial reference model, wherein generating the spatial reference model comprises:

receiving an input indicative of a relative positioning of the target feature and the one or more supplementary features in a plurality of previously acquired image frames corresponding to the volume of interest of one or more subjects;

aligning regions corresponding to the target feature and the one or more supplementary features in each of the plurality of previously acquired image frames; and

determining a mean and a standard deviation of determined locations of each of the target feature and the one or more supplementary features in the plurality of previously acquired image frames to generate the spatial reference model.

9. The method of claim 1, wherein the spatial reference model is an active shape model.

10. The method of claim 9, further comprising generating the active shape model, wherein generating the active shape model comprises:

receiving an input corresponding to the reference configuration associated with a plurality of previously acquired image frames corresponding to one or more subjects;

aligning the target feature and the one or more supplementary features in each of the plurality of previously acquired image frames; and

determining a mean and a standard deviation of the reference configuration in the plurality of previously acquired image frames to generate the active shape model.

11. The method of claim 1, wherein determining the one or more spatial configurations comprises:

iteratively selecting a first subset of candidate structures from the one or more candidate structures corresponding to the target feature; and

iteratively selecting a second subset of candidate structures from the one or more candidate structures corresponding to the one or more supplementary features disposed in a determined region of each of the plurality of image frames.

12. The method of claim 1, further comprising communicating the quality indicator.

13. The method of claim 1, further comprising:

determining a difference between each spatial configuration in the one or more spatial configurations and the reference configuration; and

selecting a spatial configuration from the one or more spatial configurations such that the determined difference between the selected spatial configuration and the reference configuration is reduced.

14. The method of claim 9, further comprising reducing the determined difference between the selected spatial configuration and the reference configuration in a subsequent image acquisition.

15. A system for imaging a subject, comprising:

an acquisition subsystem configured to obtain a plurality of image frames corresponding to a volume of interest in the subject;

a processing unit in operative association with the acquisition subsystem and configured to:

identify one or more candidate structures corresponding to a target feature and one or more supplementary features in each of the plurality of image frames;

determine one or more spatial configurations corresponding to each of a plurality of combinations of the one or more candidate structures;

compare each of the one or more spatial configurations with a spatial reference model corresponding to a determined relative position of the target feature and the one or more supplementary features in the volume of interest;

compute a quality indicator corresponding to each of the plurality of image frames based on the comparison; and

select an optimal image frame from the plurality of image frames based on the computed quality indicator.

16. The imaging system of claim 15, wherein the imaging system is an ultrasound imaging system, a contrast enhanced ultrasound imaging system, an optical imaging system, or combinations thereof.

Dated this 13th day of Dec 2013

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Name: General Electric Company
Application Number:

No. of sheets: 7
Sheet No: 1

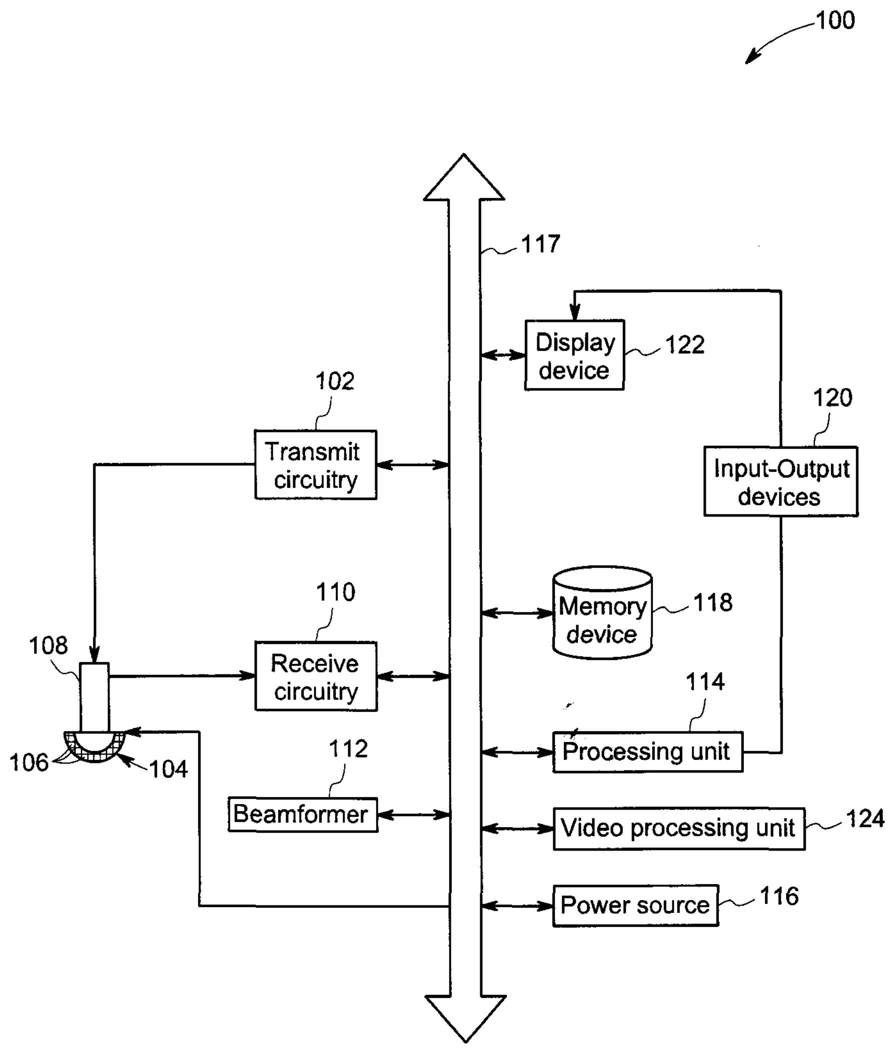

FIG. 1

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Sheet No: 2

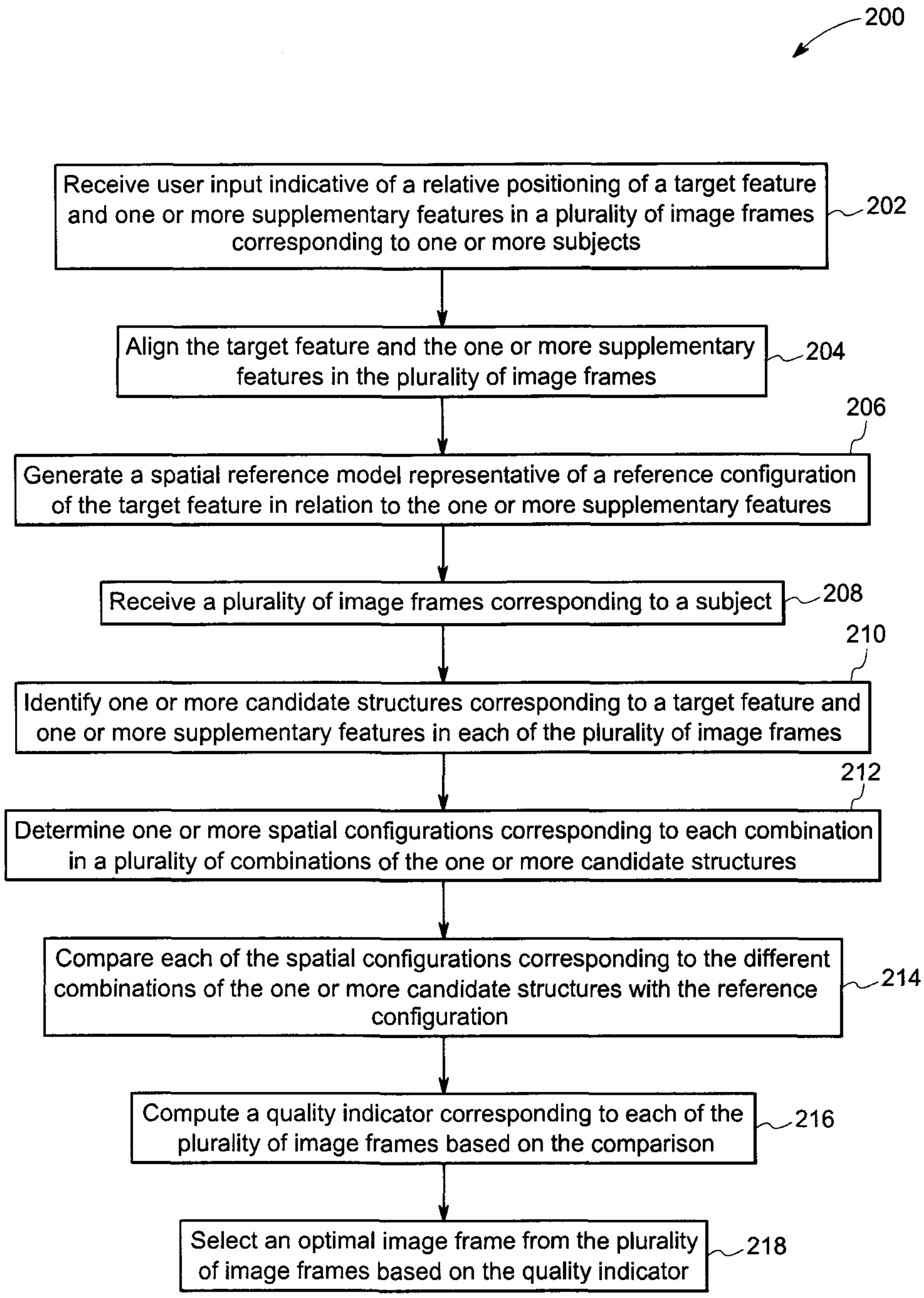

FIG. 2

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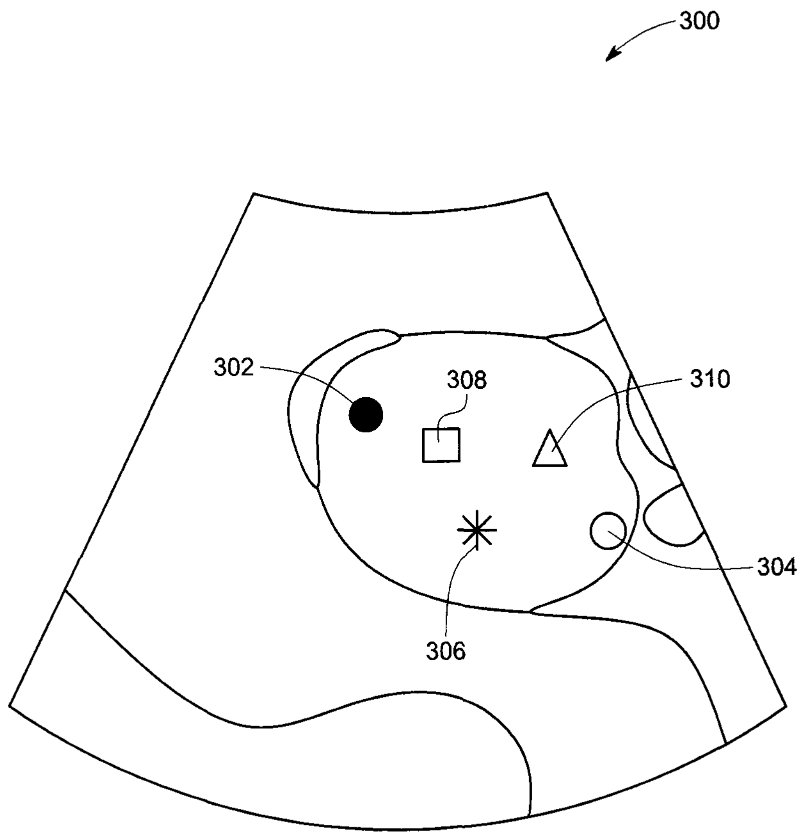

FIG. 3

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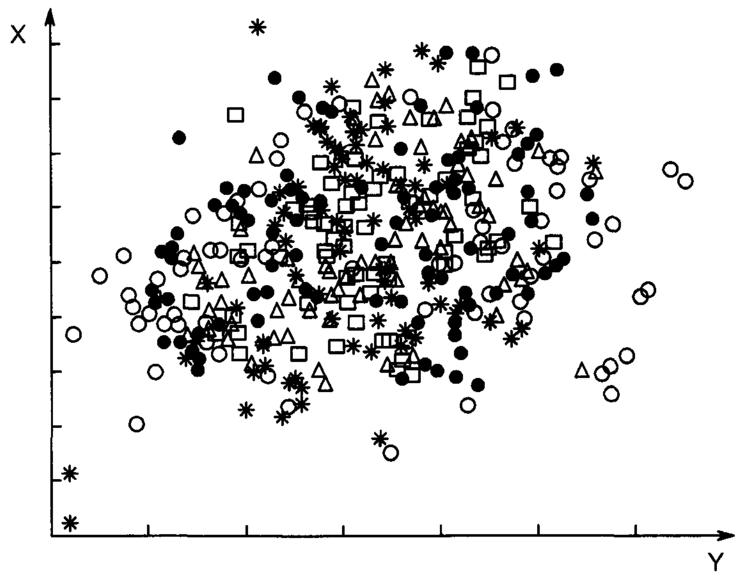

FIG. 4

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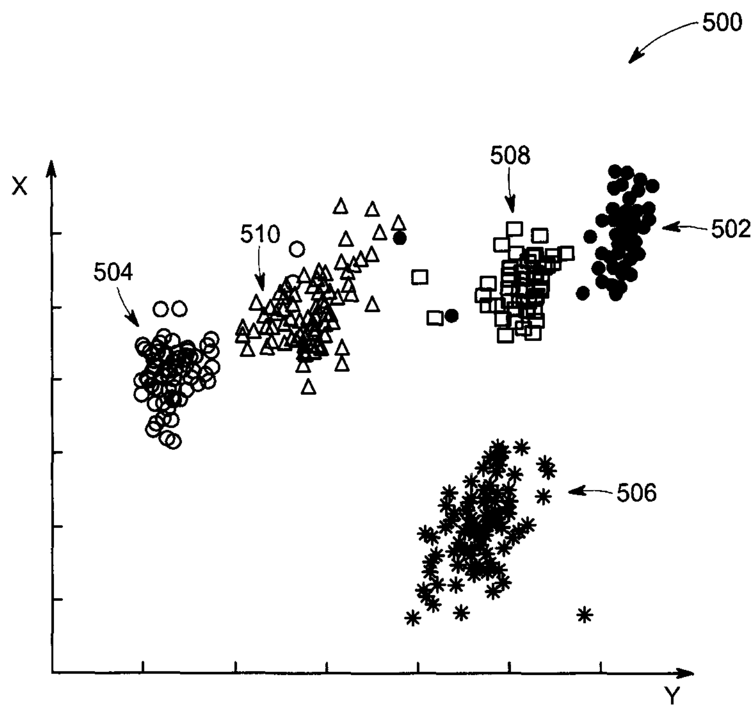

FIG. 5

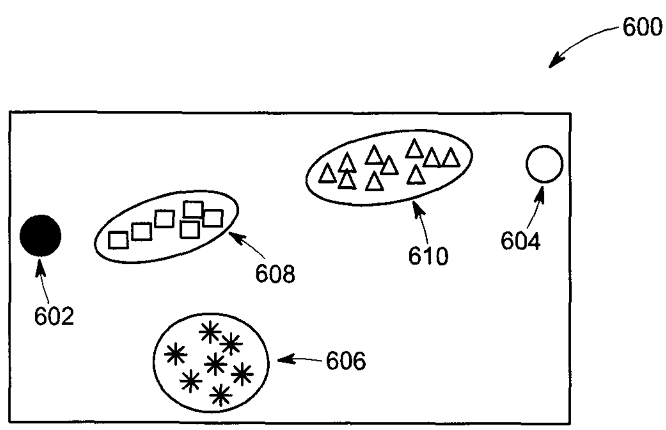

FIG. 6

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Sheet No: 6

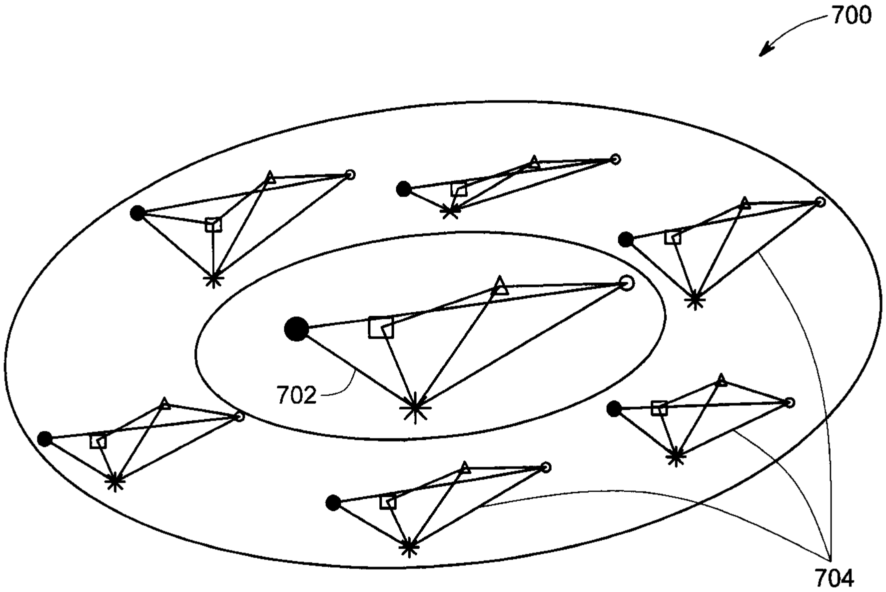

FIG. 7

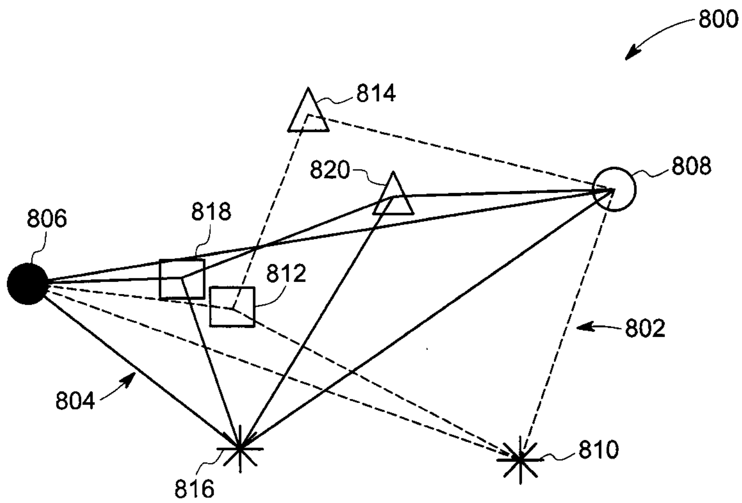

FIG. 8

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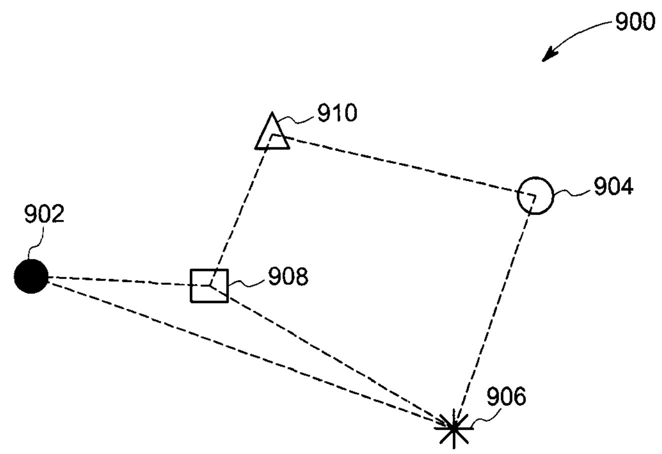

FIG. 9

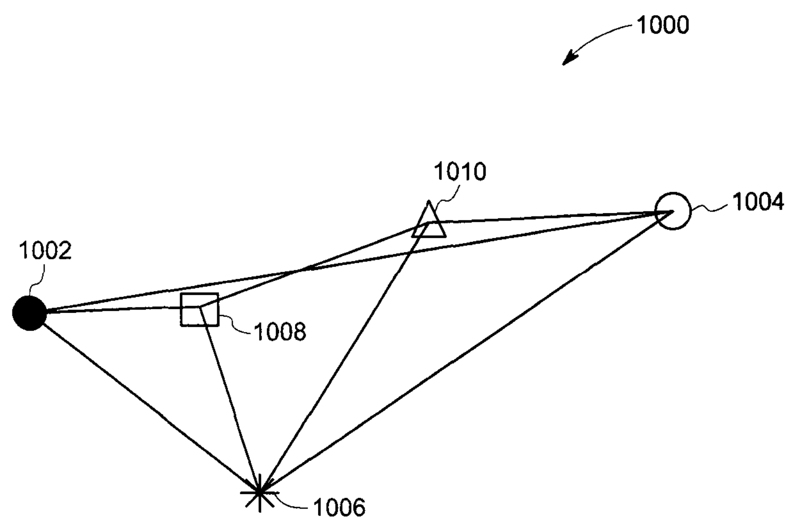

FIG. 10

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METHOD AND SYSTEM FOR IDENTIFYING AN OPTIMAL IMAGE FRAME

BACKGROUND

[0001] Embodiments of the present specification relate generally to diagnostic imaging, and more particularly to a method and system for identifying an optimal image frame.

[0002] Medical diagnostic ultrasound is an imaging modality that employs ultrasound waves to probe the acoustic properties of biological tissues and produces corresponding images. Particularly, diagnostic ultrasound systems are used to provide an accurate visualization of muscles, tendons, and other internal organs to assess their size, structure and any pathological lesions using near real-time images. Certain ultrasound systems also find use in therapeutics where an ultrasound probe is used to guide interventional procedures such as biopsies or to track an interventional device.

[0003] Additionally, ultrasound systems also find extensive use in prenatal imaging. For example, ultrasound images may be used for assessing gestational age (GA) and weight of a fetus. In particular, two-dimensional (2D) and/or three-dimensional (3D) ultrasound images may allow for measurement of one or more desired features of fetal anatomy such as the head, abdomen, and/or femur. Measurement of the desired features, in turn, may allow for determination of the GA, assessment of growth patterns, and/or identification of anomalies in the fetus. By way of example, measurement of an abdominal circumference in the second and third trimesters of pregnancy provides a significant indication of fetal growth and/or weight. Furthermore, the measurement of an abdominal circumference may also provide an indication of intrauterine growth restriction that causes an increased risk of perinatal fetal distress.

[0004] In common clinical practice, the abdominal circumference may be measured by manually tracing a perimeter of the abdomen that includes a fat layer. Particularly, a radiologist may strive to select a desired scan plane to allow for an accurate measurement of the abdominal circumference by repeatedly repositioning a transducer probe over an abdomen of the patient. In the desired scan plane, the abdominal circumference is visualized in a transverse image that includes the stomach, the left portal vein at an umbilical region, and the spine in a true transverse plane. Accurate measurements of the abdominal circumference in the desired scan plane allows for accurate fetal weight and/or size measurements, which in turn, aid in efficient diagnosis and prescription of treatment for the patient.

[0005] Acquisition of an optimal image frame that includes the desired scan plane for satisfying prescribed clinical guidelines, however, may be complicated. For example, acquisition of the optimal image frame may be confounded due to imaging artifacts caused by shadowing effect of bones, near field haze resulting from subcutaneous fat layers, unpredictable patient movement, and/or ubiquitous speckle noise. Additionally, an unfavorable fetal position, fetus orientation, and/or change in shape of the abdomen due to changes in the transducer pressure may also confound the measurement of the abdominal circumference.

[0006] Moreover, operator and/or system variability may also limit reproducibility of the measurement of the abdominal circumference. For example, sub-optimal ultrasound image settings such as gain compensation and dynamic range may reduce an ability to visualize internal structures of the human body. Similarly, even small changes in positioning of the ultrasound transducer may lead to significant changes in the visualized image frame, thus leading to incorrect measurements. Accurate ultrasound measurements, thus, typically entail meticulous and lengthy acquisitions by experienced radiologists. However, accuracy of the ultrasound measurements using conventional methods may depend upon on the skill and experience of the radiologist, thus limiting an availability of quality imaging services, for example, to large hospitals and urban areas. Scarcity of skilled and/or experienced radiologists in remote or rural regions, thus, may cause these regions to be poorly or under-served.

[0007] Accordingly, certain conventional ultrasound imaging methods have been known to employ training algorithms and/or semi-automated methods that use image-derived characteristics for use in diagnosis and treatment. These conventional methods typically rely on the radiologist's selection of the optimal image frame from a plurality of image frames. In a conventional clinical workflow, the radiologist may continue to search for a better image frame even after identifying an acceptable image frame in the hope of determining measurements that are more accurate. However, upon failing to find a better image frame, the radiologist may have to manually scroll back to an originally acceptable frame, thus prolonging imaging time and hindering reproducibility. Ultrasound imaging using conventional methods and/or by a novice radiologist, therefore, may not allow for measurements suited for real-time diagnosis and treatment.

BRIEF DESCRIPTION

[0008] In accordance with an exemplary aspect of the present specification, a method for diagnostic imaging of a subject is presented. The method includes identifying one or more candidate structures corresponding to a target feature and one or more supplementary features in each of a plurality of image frames, where the plurality of image frames corresponds to a volume of interest of the subject. The method further includes determining one or more spatial configurations corresponding to each of a plurality of combinations of the one or more candidate structures. The method also includes comparing each of the spatial configurations with a spatial reference model corresponding to a determined relative position of the target feature and the one or more supplementary features in the volume of interest. Moreover, the method includes computing a quality indicator corresponding to each of the plurality of image frames based on the comparison. The method also includes selecting an optimal image frame from the plurality of image frames based on the computed quality indicator.

[0009] In accordance with another aspect of the present specification, a system for imaging a subject is disclosed. The system includes an acquisition subsystem configured to obtain a plurality of image frames corresponding to a volume of interest of the subject. The system further includes a processing unit in operative association with the acquisition subsystem. The processing unit is configured to identify one or more candidate structures corresponding to a target feature and one or more supplementary features in each of the plurality of image frames. Further, the processing unit is configured to determine one or more spatial configurations corresponding to each of a plurality of combinations of the one or more candidate structures. Additionally, the processing unit is configured to compare each of the spatial configurations with a reference configuration corresponding to a determined relative position of the target feature and the one or more supplementary features in the volume of interest. The processing unit is also configured to compute a quality indicator corresponding to each of the plurality of image frames based on the comparison. Further, the processing unit is also configured to select an optimal image frame from the plurality of image frames based on the computed quality indicator.

DRAWINGS

[0010] These and other features and aspects of embodiments of the present specification will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0011] FIG. 1 is a schematic representation of an exemplary ultrasound imaging system, in accordance with aspects of the present specification;

[0012] FIG. 2 is a flow chart illustrating an exemplary method for ultrasound imaging, in accordance with aspects of the present specification;

[0013] FIG. 3 is an exemplary image of a fetus depicting manual markings received from a user such as a radiologist, in accordance with aspects of the present specification;

[0014] FIG. 4 is an exemplary scatter plot representative of an exemplary distribution of features that are manually marked by a skilled radiologist on a plurality of image frames prior to an alignment of the features in the plurality of image frames, in accordance with aspects of the present specification;

[0015] FIG. 5 is an exemplary scatter plot representative of an exemplary distribution of features that are manually marked by the skilled radiologist on the plurality of image frames subsequent to the alignment of the features in the plurality of image frames, in accordance with aspects of the present specification;

[0016] FIG. 6 is a diagrammatical representation of an exemplary spatial reference model for use in the method of FIG. 2, in accordance with aspects of the present specification;

[0017] FIG. 7 is a diagrammatical representation of another exemplary spatial reference model for use in the method of FIG. 2, in accordance with aspects of the present specification;

[0018] FIG. 8 is a diagrammatical representation depicting certain exemplary combinations of candidate structures detected in an image frame for use in identifying a target feature and/or one or more supplementary features in the image frame, in accordance with aspects of the present specification;

[0019] FIG. 9 is an exemplary spatial configuration corresponding to a first set of candidate structures detected in an image frame, in accordance with aspects of the present specification; and

[0020] FIG. 10 is an exemplary spatial configuration corresponding to a second set of candidate structures detected in an image frame, in accordance with aspects of the present specification.

DETAILED DESCRIPTION

[0021] The following description presents systems and methods for identifying an optimal image frame. The optimal image frame includes one or more features of interest in a desired scan plane that optimizes visualization of the features of interest for measurement and/or diagnosis. Particularly, certain embodiments presented herein describe the systems and methods that accurately detect the one or more features of interest in a plurality of image frames and identify an optimal image frame that includes the one or more features of interest in the desired scan plane. As used herein, the term "desired scan plane" may correspond to a cross-sectional slice of a target anatomy that satisfies clinical, user-defined, and/or application-specific guidelines to provide accurate and reproducible measurements of the one or more features of interest.

[0022] Further, embodiments of the present systems and methods allow for communication of the optimal image frame including the one or more features of interest in the desired scan plane to a user for use in obtaining accurate measurements of the one or more features of interest. The features of interest, for example, may include one or more anatomical regions and/or features such as an abdomen, a spine, veins, arteries, a femur bone corresponding to a fetus, and/or an interventional device such as a catheter or needle within the body of a patient.

[0023] Specifically, embodiments described herein allow for communication of a determined suitability of an input ultrasound image for biometry based on a determined spatial reference model. The spatial reference model may be representative of a reference configuration of one or more features of interest corresponding to a volume of interest (VOI) that allows for accurate biometric measurements corresponding to the one or more features of interest.

[0024] In one embodiment, the reference configuration may correspond to a determined relative positioning of anatomical features such as a spine, a stomach, a portal vein, and/or liver in a fetus for use in prenatal and/or perinatal evaluation. As a position and orientation of the fetus may vary over time, the reference configuration may define a mean configuration and/or a range of variation in a position and/or orientation that may be expected for each of the different anatomical features. To that end, the reference configuration, for example, may be determined via expert knowledge applied to a plurality of ultrasound images corresponding to the VOI. Furthermore, use of the reference configuration may allow for efficient detection of an anatomical feature such as the fetal abdomen that has low acoustic impedance and is not easily detectable using conventional feature detection techniques.

[0025] In addition, a comparison of a spatial configuration of anatomical features detected in an input image frame with the reference configuration aids in determining a quality indicator corresponding to the input image frame. The quality indicator may be representative of a probability of each of the image frames generated in real-time to provide measurements of the feature of interest that satisfy the clinical, user-defined, and/or application-specific guidelines. Accordingly, certain embodiments described herein may also allow communication of the quality indicator corresponding to each image frame, thereby aiding in the selection of the optimal image frame for desired biometric measurements.

[0026] Although the following description includes embodiments relating to medical diagnostic ultrasound imaging, these embodiments may also be implemented in other medical imaging systems. These systems, for example, may include optical imaging systems, and/or systems that monitor targeted drug and gene delivery. In certain embodiments, the present systems and methods may also be used during non-medical imaging, for example, during nondestructive testing of elastic materials that may be suitable for ultrasound imaging and/or security screening. An exemplary environment that is suitable for practising various implementations of the present system is described in the following sections with reference to FIG. 1.

[0027] FIG. 1 illustrates an exemplary ultrasound system 100 for identifying an optimal image frame for use in diagnosis of a subject. To that end, the system 100 may be configured as a console system or a cart-based system. Alternatively, the system 100 may be configured as a portable system, such as a hand-held, laptop-based, and/or smartphone-based system. Particularly, implementing the system 100 as a portable system may allow for pervasiveness of ultrasound imaging in rural regions, where skilled and experienced radiologists are typically in short supply.

[0028] In one embodiment, the system 100 may be configured to automatically identify an optimal image frame from a plurality of image frames for determining accurate measurements corresponding to a feature of interest. Particularly, the system 100 may be configured to determine the measurements corresponding to the feature of interest using a reference configuration that may be generated based on expert knowledge. These measurements may then be used to assess a pathological condition of the subject.

[0029] For clarity, the present specification is described with reference to identifying an optimal image frame for accurate measurement of an abdominal circumference of a fetus. However, certain embodiments may allow for automatic identification of optimal image frames for measuring other bright and dark features of interest such as the femur or aorta corresponding to the fetus. Embodiments of the present specification may also be employed for real-time detection, segmentation, and/or tracking of bright and dark non-biological structures such as manufactured parts, catheters, or needles used during interventional procedures.

[0030] Conventional ultrasound systems may employ supervised learning and/or semi-automated segmentation for detection of a target feature, which may entail prolonged image processing time. However, embodiments of the present specification allow for efficient identification of the target feature using a spatial reference model that defines the reference configuration corresponding to the target feature in relation to one or more supplementary features in a VOI of the subject. In one embodiment, for example, the reference configuration corresponds to a known anatomical configuration that is representative of a location of stomach in relation to a spine, an aorta, and/or a portal vein in an abdominal cavity of a fetus.

[0031] Typically, an accurate assessment of growth and well-being of the fetus entails accurate measurements of fetal characteristics, such as a length of a femur, biparietal diameter, and/or size of a stomach. However, as the stomach primarily includes soft tissues, the stomach is poorly visualized in the ultrasound images. Embodiments of the present specification, however, allow for detection and accurate measurement of the stomach using a reference configuration.

[0032] Accordingly, in one embodiment, the stomach may correspond to the target feature in the reference configuration, whereas the spine, the aorta, and/or the portal vein may correspond to one or more supplementary features. In certain embodiments, the number of the supplementary features may vary based on a VOI being imaged, user input, application specific requirements, and/or prescribed clinical guidelines. Additionally, the number of the supplementary features that may be included in the reference configuration may be selectively varied to allow for a desired computational efficiency during imaging.

[0033] Further, the reference configuration may be used to accurately localize the target feature and/or the supplementary features in the image frame. Additionally, the reference configuration may be used to determine a quality indicator corresponding to each image frame to aid in the selection of the optimal image frame from a plurality of image frames such that the optimal image frame includes the feature of interest in a desired scan plane. As used herein, the term "optimal image frame" is used to refer to an image frame that is most suitable for determining measurements that satisfy one or more prescribed guidelines.

[0034] In one embodiment, the plurality of image frames may be acquired by imaging a VOI of the subject such as a patient or a fetus. To that end, in certain embodiments, the system 100 may include transmit circuitry 102 that may be configured to generate a pulsed waveform to drive an array 104 of the transducer elements 106 housed within a transducer probe 108. Particularly, the pulsed waveform may be configured to drive the array 104 of transducer elements 106 to emit ultrasonic pulses into a body or the VOI corresponding to the subject. At least a portion of the ultrasonic pulses generated by the transducer elements 106 back-scatter from the VOI to produce echoes that return to the transducer array 104 and are received by receive circuitry 110 for further processing.

[0035] In one embodiment, the receive circuitry 110 may be operatively coupled to a beamformer 112 that may be configured to process the received echoes and output corresponding radio-frequency (RF) signals. Although, FIG. 1 illustrates the transducer array 104, the transmit circuitry 102, the receive circuitry 110, and the beamformer 112 as distinct elements, in certain embodiments, one or more of these elements may be implemented together as an independent acquisition subsystem in the system 100. The acquisition subsystem may be configured to acquire image data corresponding to the subject, such as the patient or the fetus, for further processing.

[0036] Further, the system 100 may include a processing unit 114 configured to receive and process the acquired image data according to a plurality of selectable ultrasound imaging modes. Particularly, the processing unit 114 may be configured to receive and process the acquired image data in near real-time and/or in an offline mode. To that end, the processing unit 114 may be operatively coupled to the beamformer 112, the transducer probe 108, and/or the receive circuitry 110. Moreover, the processing unit 114 may include devices such as one or more general-purpose or application-specific processors, digital signal processors, microcomputers, microcontrollers, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGA), or other suitable devices in communication with other components of the system 100.

[0037] In certain embodiments, the processing unit 114 may be configured to provide control and timing signals for configuring one or more imaging parameters for imaging the VOI. By way of example, the imaging parameters may include a sequence of delivery of different pulses, frequency of the pulses, a time delay between two different pulses, intensity of the pulses, and/or other such imaging parameters. Particularly, in one embodiment, the processing unit 114 may be operatively coupled to a power source 116, for example through a communication link 117, to drive one or more components of the system 100. Accordingly, the power source 116 may include, for example, a fixed current outlet and/or a battery to provide drive voltage to the components of the system 100 for imaging the VOI.

[0038] Moreover, in one embodiment, the processing unit 114 may be configured to store the delivery sequence, frequency, time delay, and/or beam intensity in a memory device 118 for use in imaging the VOI. The memory device 118 may include storage devices such as a random access memory, a read only memory, a disc drive, solid-state memory device, and/or a flash memory. In certain embodiments, the processing unit 114 may be configured to use the stored information for configuring the transducer elements 106 to direct one or more groups of pulse sequences toward the VOI corresponding to the subject such as the fetus.

[0039] Additionally, the processing unit 114 may be configured to track displacements in the VOI caused in response to the incident pulses to determine characteristics of underlying tissues. These characteristics, for example, may include size of a head, an abdomen, or a femur that allow determination of gestational age (GA), assessment of growth patterns, and identification of anomalies in the fetus. The displacements and characteristics, thus determined, may be stored in the memory device 118. Additionally, the displacements and/or the determined characteristics may be communicated to a user, such as a radiologist, for further assessment.

[0040] In certain embodiments, the processing unit 114 may also be coupled to one or more user input-output devices 120 for receiving commands and inputs from the user. The input-output devices 120, for example, may include devices such as a keyboard, a touchscreen, a microphone, a mouse, a control panel, a display device 122, a foot switch, a hand switch, and/or a button. In one embodiment, the display device 122 may include a graphical user interface (GUI) for providing the user with configurable options for imaging desired regions of the subject. By way of example, the configurable options may include a selectable image frame, a selectable region of interest (ROI), a desired scan plane, a delay profile, a designated pulse sequence, a desired pulse repetition frequency, and/or other suitable system settings to image the desired ROI. Additionally, the configurable options may further include a choice of diagnostic information to be communicated to the user. The diagnostic information, for example, may include a length of the femur, abdominal circumference, strain, and/or stiffness in the VOI. In one embodiment, the diagnostic information may be estimated from the received signals.

[0041] Further, in one embodiment, the processing unit 114 may be configured to process the received signals to prepare image frames and to generate the requested diagnostic information based on user input. Particularly, the processing unit 114 may be configured to process the RF signal data to generate 2D, 3D, and/or four-dimensional (4D) datasets corresponding to different imaging modes. By way of example, the processing unit 114 may be configured to generate B-mode, color Doppler, power Doppler, M-mode, anatomical M-mode, strain, strain rate, and/or spectral Doppler image frames based on specific scanning and/or user-defined requirements.

[0042] In certain embodiments, the processing unit 114 may be configured to generate the image frames in real-time while scanning the VOI and receiving corresponding echo signals. As used herein, the term "real-time" may be used to refer to an imaging rate upwards of about 30 image frames per second (fps) with a delay of less than 1 second. In addition, in one embodiment, the processing unit 114 may be configured to customize the delay in reconstructing and rendering the image frames based on system-specific and/or imaging requirements. Further, the processing unit 114 may be configured to process the RF signal data such that a resulting image is rendered, for example, at the rate of 30 fps on the associated display device 122 that is communicatively coupled to the processing unit 114.

[0043] In one embodiment, the display device 122 may be a local device. Alternatively, the display device 122 may be remotely located to allow a remotely located medical practitioner to track diagnostic information corresponding to the subject. In certain embodiments, the processing unit 114 may be configured to update the image frames on the display device 122 in an offline and/or delayed update mode. Particularly, the image frames may be updated in the offline mode based on the echoes received over a determined period of time. Alternatively, the processing unit 114 may be configured to dynamically update the image frames and sequentially display the updated image frames on the display device 122 as and when additional frames of ultrasound data are acquired.

[0044] With continued reference, to FIG. 1, in certain embodiments, the system 100 may further include a video processing unit 124 that may be configured to digitize the received echoes and output a resulting digital video stream on the display device 122. In one embodiment, the video processing unit 124 may be configured to store the image frames corresponding to the VOI for later review and analysis. Alternatively, the video processing unit 124 may be configured to communicate the image frames to a remote location for allowing the remotely located medical practitioner to diagnose a patient condition and/or to prescribe treatment. Although, FIG. 1 depicts the video processing unit 124 as an independent device, in certain embodiments, the video processing unit 124 may not be employed. In such embodiments, the processing unit 114 may be configured to perform one or more functions of the video processing unit 124, thereby enhancing a cost-effectiveness of the system 100. Alternatively, in applications that entail extensive use of real-time video stream, use of an independent and dedicated video processing unit 124 may be more optimal.

[0045] Furthermore, in certain embodiments, the video processing unit 124 may be configured to display the video stream along with patient-specific diagnostic and/or therapeutic information in real-time while the patient is being imaged. Particularly, in one embodiment, the video processing unit 124 may be configured to automatically identify an image frame that depicts the feature of interest in a desired scan plane. The desired scan plane may correspond to a scan plane that, in view of prescribed guidelines, is most suitable for measuring one or more desired characteristics corresponding to the feature of interest. For example, when imaging the fetal abdomen, the desired scan plane may allow visualization of the fetal abdomen with an umbilical vein positioned at about one-third of a distance from a hepatic vein in an image frame.

[0046] In another embodiment, the video processing unit 124 may be configured to determine a quality indicator representative of a probability of each of the image frames to provide accurate measurements corresponding to the target feature. The video processing unit 124 may be configured to determine the quality indicator corresponding to each image frame in real-time by identifying the target feature and/or the supplementary features from the image frame. Additionally, the video processing unit 124 may be configured to determine a spatial configuration of the target feature relative to one or more supplementary features in the image frame. The video processing unit 124 may also be configured to compute the quality indicator based on a comparison between a reference configuration and a detected spatial configuration of the target feature relative to the one or more supplementary features in the image frame.

[0047] Moreover, in certain embodiments, the video processing unit 124 may be configured to generate and store a spatial reference model corresponding to the reference configuration of the target feature and the supplementary features based on expert knowledge. In one embodiment, the spatial reference model may be employed to provide a template against which spatial configurations of candidate structures detected in an input image frame may be compared for accurately classifying and localizing the target feature and the supplementary features.

[0048] To that end, in certain embodiments, the spatial reference model may be generated in an offline mode based on a plurality of manually marked image frames. In one embodiment, for example, an experienced and/or skilled radiologist may manually mark the target feature and the one or more supplementary features on a plurality of image frames corresponding to the VOI. Further, the plurality of image frames may correspond to one or more subjects. In certain embodiments, the radiologist may also indicate an absence of the target feature and/or one or more of the supplementary features while labeling the image frames.

[0049] Particularly, in one embodiment, the video processing unit 124 may be configured to generate the spatial reference model based on a plurality of the manually marked image frames that indicate a presence of the target feature and the supplementary features. Particularly, the video processing unit 124 may be configured to arrange the plurality of the manually marked image frames, for example, using Procrustes analysis such that the target feature and the supplementary features in each of the image frames is aligned with the target feature and the supplementary features in the other image frames. For discussion purposes, the present specification describes the use of Procrustes analysis for aligning the image frames in a real-time or offline mode. However, in certain embodiments, any other suitable method of analysis may be used for aligning the image frames in the real-time and/or offline mode.

[0050] It may be noted that the Procrustes analysis corresponds to a statistical shape analysis that may be used to analyze the distribution of a set of shapes detected in the image frame. An exemplary method for aligning the plurality of manually marked image frames using the Procrustes analysis for offline generation of the spatial reference model will be described in greater detail with reference to FIGs. 2-4. In certain embodiments, the video processing unit 124 may be configured to perform the Procrustes analysis to align and/or group similarly shaped features in the image frames. Such a grouping, in turn, may aid in determining a reference configuration of the target feature and/or supplementary features in the image frames.

[0051] In certain embodiments, the spatial reference model may be representative of a mean and a standard deviation of relative locations of the target feature and/or supplementary features in a desired scan plane. The relative locations may correspond to those positions in the image frame that allow for accurate measurements of the target feature and/or supplementary features. In one embodiment, the video processing unit 124 may be configured to generate the spatial reference model based on a non-parametric prior probability distribution of the relative locations of the target feature and the supplementary features in the reference configuration. In such a spatial reference model, the relative locations of the target feature and the supplementary features may not be assumed to belong to any fixed class of distributions (e.g., a Gaussian distribution).

[0052] However, in another embodiment, the video processing unit 124 may be configured to employ an active shape spatial reference model that may be used to encode an expected shape corresponding to the reference configuration and corresponding modes of variation. In certain further embodiments, the video processing unit 124 may be configured to generate the spatial reference model using a Euclidean distance matrix analysis that accounts for growth and form differences across a plurality of subjects. The spatial reference model, thus generated, may be stored in the memory device 118 for use in real-time identification of the incoming image frames. Certain exemplary methods of generating the spatial reference model representative of the reference configuration will be described in greater detail with reference to FIG. 2 and FIGs. 6-7.

[0053] In one embodiment, the stored spatial reference model may be used to assess a quality of incoming image frames. The images frames may correspond to the VOI of the patient and may be displayed on the display device 122 in a cine loop. Further, the video processing unit 124 may be configured to identify one or more candidate structures corresponding to the target feature and one or more supplementary features in each of the received image frames. In one embodiment, the candidate structures may be identified, for example, using gray scale morphology, Otsu thresholding, and/or geometrical statistics based classification.

[0054] Typically, differences in a position and/or orientation of the target feature and/or the supplementary features in consecutive image frames are marginal. Accordingly, in certain embodiments, the video processing unit 124 may be configured to employ a tracking procedure that uses position and orientation information corresponding to an identified target feature and/or supplementary features in a first subset of image frames to identify candidate structures corresponding to the target feature and one or more supplementary features in a second subsequent subset of image frames. Such a tracking of the target features and/or the supplementary features may substantially reduce complexity and/or computational effort involved in identifying the target features and/or the supplementary features in each image frame. An exemplary tracking procedure for expediting identification of the target feature and/or the supplementary features in each of the plurality of image frames will be described in greater detail with reference to FIG. 2.

[0055] Additionally, in certain embodiments, the video processing unit 124 may be configured to determine spatial configurations corresponding to different combinations of the one or more candidate structures in each of the plurality of image frames. In one embodiment, for example, if a reference configuration includes five features, the video processing unit 124 may be configured to determine different combinations including at least five of the identified candidate structures in the received image frames. Further, the video processing unit 124 may be configured to determine a spatial configuration corresponding to each of these different combinations. In one example, the video processing unit 124 may be configured to employ the tracking procedure to determine the spatial configurations in a subsequent subset of image frames based on spatial configurations identified from one or more previous image frames. An exemplary tracking procedure for expediting a determination of spatial configurations corresponding to different combinations of the one or more candidate structures in each of the plurality of image frames will be described in greater detail with reference to FIG. 2.

[0056] Each of the spatial configurations corresponding to the different combinations of the one or more candidate structures may then be compared with the reference configuration. Moreover, the video processing unit 124 may be configured to compute a quality indicator corresponding to each of the plurality of image frames based on the comparison. The VPU 124 may be configured to select an optimal image frame from the plurality of image frames based on the quality indicator. Particularly, in one embodiment, the video processing unit 124 may be configured to automatically select the image frame having the highest quality indicator as the optimal image frame.

[0057] Furthermore, in certain embodiments, the video processing unit 124 may be configured to communicate the quality indicator to a user to indicate a suitability of the image frame for biometric measurements. The quality indicator may be representative of a determined difference between the reference configuration and a spatial configuration of candidate structures detected in the image frame. In one embodiment, the determined difference may allow for identification of remedial actions that may be employed in a subsequent scan to acquire an optimal image frame such that the determined difference is reduced. The remedial actions, for example, may include adapting one or more system parameters and/or varying a position and/or orientation of a transducer probe used for imaging. In some embodiments, certain predetermined remedial actions corresponding to a determined difference may be stored in the memory device 118. Alternatively, the video processing unit 124 may be configured to determine recommended remedial actions in real-time based on the VOI and/or a type of scan being performed.

[0058] Accordingly, in one embodiment, the video processing unit 124 may be configured to communicate the quality indicator visually using the display device 122. For example, the quality indicator may be represented visually on the display device 122 using a color bar, a pie chart, and/or a number. Alternatively, the video processing unit 124 may be configured to communicate the quality indicator using an audio and/or a video feedback. The audio feedback, for example, may include one or more beeps or speech in a language of choice.

[0059] In certain embodiments, the video processing unit 124 may be configured provide the audio and/or video feedback to allow for a semi-automated user-based selection of an optimal image frame that includes the feature of interest in the desired scan plane. The audio and/or video feedback may also provide the user with the recommended remedial actions in case the spatial configuration of candidate structures detected in the image frame differs substantially from the reference configuration. Alternatively, the VPU 124 may be configured to transmit control signals to the system 100 to reinitiate scanning of the VOI, automatically or based on user input, if the quality indicators corresponding to the image frames is less than a clinically acceptable threshold. In certain embodiments, the video processing unit 124 may be configured to 'auto-freeze' the image frame having the highest quality indicator for measuring one or more characteristics of the target feature. Additionally, the video processing unit 124 may be configured to trigger automated measurements corresponding to the target feature once the optimal image frame is identified.

[0060] Such real-time computation and/or communication of the quality indicator preclude switching back and forth between different image frames in a cine loop for identifying the optimal image frame. Further, use of the reference configuration generated via expert knowledge allows for greater accuracy in real-time detection of the target feature and corresponding biometric measurements. Embodiments of the present specification, thus, allow repeatability and reproducibility in biometry measurements, thereby resulting in consistent imaging performance even when performed by novice radiologists. An exemplary method for automatically identifying a target feature in an image frame and computing a quality indicator representative of suitability of the image frame to allow for accurate measurements corresponding to the target feature will be described in greater detail with reference to FIG. 2.

[0061] FIG. 2 illustrates a flow chart 200 depicting an exemplary method for ultrasound imaging. In the present specification, embodiments of the exemplary method may be described in a general context of computer executable instructions on a computing system or a processor. Generally, computer executable instructions may include routines, programs, objects, components, data structures, procedures, modules, functions, and the like that perform particular functions or implement particular abstract data types.

[0062] Additionally, embodiments of the exemplary method may also be practised in a distributed computing environment where optimization functions are performed by remote processing devices that are linked through a wired and/or wireless communication network. In the distributed computing environment, the computer executable instructions may be located in both local and remote computer storage media, including memory storage devices.

[0063] Further, in FIG. 2, the exemplary method is illustrated as a collection of blocks in a logical flow chart, which represents operations that may be implemented in hardware, software, or combinations thereof. The various operations are depicted in the blocks to illustrate the functions that are performed, for example, during steps of generating a spatial reference model, identifying one or more candidate structures, and/or computing a quality indicator corresponding to the exemplary method. In the context of software, the blocks represent computer instructions that, when executed by one or more processing subsystems, perform the recited operations.

[0064] The order in which the exemplary method is described is not intended to be construed as a limitation, and any number of the described blocks may be combined in any order to implement the exemplary method disclosed herein, or an equivalent alternative method. Additionally, certain blocks may be deleted from the exemplary method or augmented by additional blocks with added functionality without departing from the spirit and scope of the subject matter described herein. For discussion purposes, the exemplary method will be described with reference to the elements of FIG. 1.

[0065] Embodiments of the present specification allow for automatic detection of a target feature and identification of the optimal image frame that includes the target feature in a desired scan plane. As previously noted, the desired scan plane may correspond to a cross-sectional slice of a VOI that satisfies clinical, user-defined, and/or application-specific guidelines to provide accurate and reproducible measurements of the target feature.

[0066] Particularly, certain embodiments of the present method provide for the automatic identification of an optimal image frame that allows for efficient measurement of the target feature that corresponds to a region having high and/or low acoustic impedance in the body. For clarity, the present method is described with reference to detection and identification of the abdominal region in image frames corresponding to a fetus. However, it may be appreciated that other bright and/or dark structures may similarly be identified using embodiments of the present method.

[0067] The method begins at step 202, where user input indicative of a relative positioning of a target feature and one or more supplementary features in a plurality of image frames corresponding to one or more subjects may be received. In one embodiment, an experienced and/or skilled radiologist may manually mark regions corresponding to the target feature and the one or more supplementary features on the plurality of image frames. The video processing unit 124 of FIG. 1, for example, may be configured to receive the image frames with the manually marked regions as user input. An example of a manually marked regions corresponding to the target feature and the one or more supplementary features in an image frame is depicted in FIG. 3.

[0068] FIG. 3 illustrates a diagrammatic representation of an exemplary image 300 of a fetus depicting manual markings received from a user such as a radiologist. Although the image 300 may include several regions of high and/or low acoustic impedance, the radiologist may identify only select candidate structures that are of interest to an ongoing patient evaluation by manually marking the select candidate structures on the image 300. In particular, the image 300 depicts manual markings corresponding to a spine 302, an opposing wall 304, a stomach 306, an aorta 308, and/or a vein 310. In certain embodiments, these candidate structures may be used in fetal biometry to assess a health and well-being of the fetus.

[0069] With returning reference to FIG. 2, at step 204, the target feature and the one or more supplementary features corresponding to each of the plurality of image frames may be aligned. In one embodiment, the video processing unit 124 may be configured to align the target feature and the one or more supplementary features corresponding to each of the plurality of image frames using Procrustes analysis. As previously noted, the Procrustes analysis corresponds to a statistical shape analysis that may be used to analyze the distribution of a set of shapes detected in the image frame. Particularly, in certain embodiments, a processing unit such as the video processing unit 124 of FIG. 1 may be configured to perform the Procrustes analysis by superimposing the plurality of image frames onto each other. In particular, the plurality of image frames may be superimposed such that the target feature and the one or more supplementary features in each of the plurality of image frames are substantially aligned with each other. In one example, the video processing unit 124 may be configured to normalize, translate, rotate, and/or uniformly scale the image frames such that the target feature and the one or more supplementary features in each image frame are suitably aligned with the corresponding target feature and the one or more supplementary features in other image frames. An exemplary distribution of manually marked features in a plurality of image frames prior to and post alignment of the features is depicted in FIGs. 4 and 5, respectively.

[0070] FIG. 4 illustrates a scatter plot 400 representative of an exemplary distribution of features that are manually marked by a skilled radiologist on a plurality of image frames prior to an alignment of the features in the plurality of image frames. Specifically, the scatter plot 400 depicts a representation of data points, such as the regions 302-310 of FIG. 3, corresponding to the manually marked regions prior to an alignment of the plurality of image frames. Accordingly, the scatter plot 400 is representative of data points that are typically employed by conventional feature detection techniques. As is evident from the depictions of FIG. 4, the data points are scattered and may not provide definitive information for identifying and/or distinguishing between different anatomical features of interest in subsequently received image frames. Certain conventional techniques employ machine learning to attempt classification of the subsequently received image frames. However, due to a lack of a clear separation between the different anatomical features in the image frame, these techniques may not provide desired classification performance.

[0071] FIG. 5 illustrates an exemplary scatter plot 500 representative of an exemplary distribution of features that are manually marked by the skilled radiologist on the plurality of image frames following the alignment of the features in the plurality of image frames. For example, the image frames may be processed via statistical shape analysis to suitably align the target features and the one or more supplementary features in each of the plurality of image frames. As previously noted, in one embodiment, the image frames may be normalized, translated, rotated, and/or uniformly scaled such that the target feature and the one or more supplementary features in each image frame are suitably aligned with the corresponding target feature and the one or more supplementary features in other image frames. Such a suitable alignment of the target feature and the one or more supplementary features results in a definitive separation between the plotted data points corresponding to the target feature and the one or more supplementary features, thereby providing a robust classification threshold.

[0072] Furthermore, in certain embodiments, the suitable alignment of the features defines a reference configuration of the target feature and/or the supplementary features under evaluation. In one example, these features may include a spine 502, an opposing wall 504, a stomach 506, an aorta 508, and/or a vein 510. In certain embodiments, the reference configuration corresponds to a relative positioning of each of these anatomical features that is naturally found in the human body. The steps 202-204, thus, result in the generation of the reference configuration.

[0073] With returning reference to FIG. 2, subsequent to aligning the target feature and the supplementary features in each of the plurality of image frames to generate the reference configuration, a spatial reference model representative of the reference configuration of the target feature in relation to the one or more supplementary features may be generated, as depicted by step 206. More specifically, the spatial reference model representative of a relative positioning of the target feature and/or supplementary features in a desired scan plane may be generated to allow for accurate measurements corresponding to the target feature and/or supplementary features.

[0074] In one embodiment, the video processing unit 124 (see FIG. 1) may be configured to generate the spatial reference model based on a non-parametric prior probability distribution of relative locations of the target feature and the supplementary features in the reference configuration. It may be noted that in the embodiment of the present method illustrated in FIG. 2, steps 202-206 may correspond to a model generation phase. In certain embodiments, the model generation phase may be implemented offline. Furthermore, in one embodiment, the model generation may be performed only once during system and/or application setup. Certain exemplary spatial reference models for use in the method described with reference to FIG. 2 will be described in greater detail with reference to FIGs. 6-7.

[0075] FIG. 6 illustrates a graphical representation 600 of an exemplary spatial reference model representative of a reference configuration corresponding to a determined relative positioning of a target feature and one or more supplementary features in a VOI. In particular, FIG. 6 depicts a non-parametric prior probability distribution of relative locations of the target feature and the one or more supplementary features in the reference configuration. When using the non-parametric prior probability distribution spatial reference model, the video processing unit 124 (see FIG. 1) may be configured to initially localize a relatively easily discernible anatomical feature as a point of reference. Generally, the non-parametric models may be used when spatial locations marked by an expert in the training images do not conform to known statistical distributions.

[0076] For example, a non-parametric model may be used when locations of the spine that are manually marked by an expert on a plurality of image frames indicate that the spine locations are not normally distributed around a mean location. In such a scenario, the video processing unit 124 (see FIG. 1) may be configured to identify the point of reference such as a spine 602. It may be noted that the spine 602 has high acoustic impedance and may be easily detected as a bright object in the image frame. Further, a dark structure located opposite the spine 602 may be identified as an opposing wall 604. Once locations of the spine

602 and the opposing wall 604 have been established, locations of other anatomical features such as a stomach 606, an aorta 608, and/or a vein 610 may be identified, for example, based on expert knowledge.

[0077] Further, FIG. 7 illustrates a graphical representation 700 of another example of a spatial reference model representative of a reference configuration 702 of a target feature in relation to supplementary features in a VOI. In particular, FIG. 7 depicts an active shape model that encodes an expected shape of the reference configuration 702 and corresponding modes of variation. As depicted in FIG. 7, a mean and standard deviation of the reference configuration 702 as a whole may be determined. The determined mean and standard deviation may be indicative of different modes of variations 704 that may be exhibited by the reference configuration 702 during different imaging scenarios. The different modes of variations 704, in turn, may define a variation in relative positioning and/or orientation of the reference configuration 702 to account for different imaging views. Particularly, in one embodiment, the different modes of variations 704 may be representative of a Gaussian distribution of spatial configurations, in which any implausible configuration may be substantially different from the mean or reference configuration 702.

[0078] With returning reference to FIG. 2, following the generation of the spatial reference model, a plurality of image frames corresponding to a subject may be received, as indicated by step 208. In one embodiment, the image frames may be received from an acquisition subsystem, such as the ultrasound system 100 of FIG. 1. The acquisition subsystem may be configured to acquire imaging data corresponding to a VOI of the subject, for example, a fetus. Alternatively, the image frames may be received from a storage repository such as the memory device 118 of FIG. 1. The received image frames, for example, may include 2D, 3D, and/or 4D image data. Additionally, in certain embodiments, the image frames may correspond to cine loops that include a series of 2D images acquired over a determined period of time.

[0079] It may be desirable to determine a presence of one or more features of interest in the plurality of image frames for use in diagnosis. Accordingly, at step 210, one or more candidate structures corresponding to the target feature and one or more supplementary features in each of the plurality of image frames may be identified. In one embodiment, a processing subsystem such as the processing unit 114 of FIG. 1 may be configured to identify the candidate structures corresponding to the target feature and/or the supplementary features such as a fetal abdomen, a portal vein, and/or a spine. Particularly, in one embodiment, the processing unit 114 may be configured to apply a sequence of processing steps to each image frame in the plurality of image frames to detect the candidate structures of interest. In one example, the candidate structures may be identified using gray scale morphology, Otsu thresholding, and/or a geometrical statistics based classification.

[0080] Furthermore, in certain embodiments, candidate structures disposed only in specific imaging planes may be evaluated. For example, when imaging the fetal abdomen, the imaging planes that correspond to a rectangular region between the spine and the opposing wall may be evaluated. In other examples, however, the imaging planes corresponding to other geometric and/or freeform shapes may be determined to include a set of desired candidate structures for a subsequent evaluation. Limiting the evaluation of the structures to specific imaging planes may aid in avoiding unnecessary computation, thereby improving the performance of the system 100.

[0081] Additionally, the system performance may be further improved by tracking the target features and the supplementary features across a plurality of image frames. Typically, the acquired image frames are displayed on the display device in a cine loop. The cine loop includes a plurality of image frames corresponding to a desired subject at different points during a determined period of time. In one example, the cine loop may include about two hundred image frames corresponding to a fetus that may be acquired over about five seconds. As about 40 image frames may be acquired per second, a difference in a position and/or orientation of the target features and/or the supplementary features in consecutive image frames may be assumed to be marginal.

[0082] Accordingly, in one embodiment, the processing unit 114 (see FIG. 1) may be configured to employ a tracking procedure that uses information derived from a previous image frame while processing a subsequent image frame. Specifically, the processing unit 114 may be configured to use position and orientation information corresponding to an identified target feature and/or supplementary features derived from a first subset of image frames, for example, first twenty image frames in a cine loop, to identify candidate structures corresponding to the target feature and one or more supplementary features in a second subset of image frames, for example, next forty image frames in the cine loop. Such tracking of the target features and/or the supplementary features substantially reduces complexity and/or computational effort involved in identifying the target features and/or the supplementary features in each image frame.

[0083] Once identified, it may be determined whether the candidate structures are visualized in a desired scan plane that is clinically acceptable for biometric measurements. To that end, at step 212, one or more spatial configurations corresponding to each combination in a plurality of combinations of the one or more candidate structures in each of the plurality of image frames may be determined. The plurality of combinations of the one or more candidate structures may be selected based on a number of fetal parameters that are under evaluation. Further, in certain embodiments, the spatial configurations corresponding to only those combinations that lie within specific imaging planes may be determined for computational efficiency. Certain exemplary combinations of candidate structures in an image frame are depicted in FIGs. 8-10.

[0084] Moreover, in certain embodiments, the tracking procedure may be employed to reduce computational effort involved in determining spatial configurations corresponding to different combinations of the one or more candidate structures in each of the plurality of image frames. In one embodiment, for example, a first subset of image frames from the plurality of image frames may be evaluated to determine a trajectory of positions and/or orientations of the spatial configurations identified in the first subset of image frames. Thus, the trajectory may be analyzed to determine a variation in a position and/or orientation of the target feature and/or the supplementary features identified at step 210 in the first subset of image frames. The determined variation in the position and/or the orientation, in turn, may provide a motion model that may be representative of an expected direction and velocity of the variation of the position and/or orientation of the target feature and/or the supplementary features in a second subset of image frames.

[0085] Accordingly, in one embodiment, a first set of processing windows of a suitable shape and size may be used to enclose the target feature and/or the supplementary features individually or as a whole in the first subset of image frames. Further, a second set of processing windows of a suitable shape and size may be generated based on the expected an expected direction and velocity of the variation determined from the first subset of image frames. Specifically, the shape and size of the second set of processing windows, for example, may depend upon a maximum expected variation in the position and/or orientation of the target feature and/or the supplementary features determined from the first subset of image frames.

[0086] Further, in one embodiment, the tracking procedure may be configured to evaluate the candidate structures within the bounds of the second set of processing windows corresponding to the second subset of image frames for determining the spatial configurations. Limiting a detection and analysis of the spatial configurations corresponding to the target feature and/or the supplementary features within the second set of processing windows in the second subset of image frames allows for a substantial reduction in computational effort. Furthermore, unexpected changes in a position and/or orientation of candidate structures corresponding to the target feature and/or the supplementary features outside the second set of processing windows may allow for elimination of the candidate structures from further evaluation. Alternatively, the tracking procedure may be reinitialized for use in determining the spatial configurations corresponding to different combinations of the one or more candidate structures in each of the plurality of image frames.

[0087] FIG. 8 illustrates a graphical representation 800 depicting certain exemplary combinations 802 and 804 of candidate structures that may be evaluated for identifying a target feature and/or one or more supplementary features in an image frame. As depicted in FIG. 8, the combination 802 includes a spine 806, a wall 808, a first stomach candidate 810, a first aorta candidate 812, and a first vein candidate 814. Further, the combination 804 includes the spine 806, the wall 808, a second stomach candidate 816, a second aorta candidate 818, and a second vein candidate 820. Thus, the spine 806 and the wall 808 that are common to both combinations 802 and 804 may be used as points of reference when evaluating the target feature and the other supplementary features.

[0088] In one embodiment, rigid candidate structures such as those corresponding to a spine 806 and a wall 808 may be used as the points of reference as these structures may be highly discernible in image frames, and thus, may be easily identified. The rigid candidate structures, for example, may be identified based on a morphological operation and/or shadow-based detection. Identifying candidate structures corresponding to soft tissues, however, is often challenging for conventional ultrasound imaging applications due to poor visualization of the soft tissue candidates such as the first stomach candidate 810 and/or the second stomach candidate 816. Embodiments of the present specification, however, allow for accurate identification and/or measurement of soft tissue regions in addition to the rigid structures via use of the reference configuration.

[0089] Referring again to FIG. 2, at step 214, a comparison between each of the one or more spatial configurations and configuration spatial reference model may be performed. It may be noted that the comparison may be used to determine a match between a spatial configuration corresponding to a particular combination of candidate structures (hereinafter referred to as "candidate spatial configuration") and the spatial reference model determined at step 206.

[0090] Furthermore, at step 216, a quality indicator corresponding to each of the plurality of image frames may be computed based on the comparison performed at step 214. In one embodiment, the quality indicator may be representative of an extent of overlap between each of the candidate spatial configurations and the reference configuration.

[0091] FIGs. 9 and 10 illustrate exemplary spatial configurations 900 and 1000 corresponding to different combinations of candidate structures that may be evaluated using embodiments of the present method described with reference to FIG. 2. Particularly, FIG. 9 illustrates an exemplary spatial configuration 900 corresponding to a first set of candidate structures detected in an image frame. The spatial configuration 900, for example, may correspond to the combination 802 of FIG. 8. Specifically, in the spatial configuration 900, reference numeral 902 may be representative of a spine such as the spine 806 of FIG. 8, while reference numeral 904 is representative of a wall such as the wall 808 of FIG. 8. Additionally, reference numeral 906 is representative of a stomach candidate similar to the first stomach candidate 810 of FIG. 8. Moreover, reference numeral 908 is representative of an aorta candidate such as the first aorta candidate 810 of FIG. 8, while reference numeral 910 is representative of a vein candidate such as the first vein candidate 814 of FIG. 8.

[0092] Further, FIG. 10 illustrates an exemplary spatial configuration 1000 corresponding to a second set of candidate structures detected in an image frame. The spatial configuration 1000, for example, may correspond to the combination 804 of FIG. 8. Particularly, in the spatial configuration 1000, reference numeral

1002 may be representative of a spine such as the spine 806 of FIG. 8, while reference numeral 1004 is representative of a wall such as the wall 808 of FIG. 8. Additionally, reference numeral 1006 is representative of a stomach candidate similar to the second stomach candidate 816 of FIG. 8. Moreover, reference numeral 1008 is representative of an aorta candidate such as the second aorta candidate 818 of FIG. 8, while reference numeral 1010 is representative of a vein candidate such as the second vein candidate 820 of FIG. 8.

[0093] Moreover, in one embodiment, the spatial configuration represented by the model 702 of FIG. 7 may be selected as the reference configuration. Accordingly, both the spatial configurations 900 of FIG. 9 and 1000 of FIG. 10 may be compared with the reference configuration 702 of FIG. 2. In one embodiment, a comparison of each of the spatial configurations 900 and 1000 with the reference configuration 702 may be performed in a higher dimensional configuration space. When the reference configuration 702 corresponds to a Gaussian distribution, a cluster of points, each representative of a candidate configuration, may be present around a determined mean configuration. However, the spatial configuration 900 appears to be at a greater distance from the mean configuration represented by the reference configuration 702 as compared to the spatial configuration 1000. As such, it is evident from the depictions of FIGs. 7-9 that the spatial configuration 1000 of FIG. 10 matches the reference configuration 702 more than the spatial configuration 900 of FIG. 9. The spatial configuration 1000 of FIG. 10, thus, is more likely to correspond to the target feature and the supplementary features as opposed to the spatial configuration 900 of FIG. 9.

[0094] Typically, a greater extent of correspondence between a candidate spatial configuration and the reference configuration corresponds to a higher value of the quality indicator. In one embodiment, a higher value of the quality indicator, in turn, may be indicative of a better quality of the image frame for biometric measurements. Accordingly, in certain embodiments, a candidate spatial configuration whose correspondence with the reference configuration is greater than a determined threshold may be determined to include the candidate structures in the desired scan plane. In one example, the threshold may be predefined during system set up, and/or may be determined based on user input, and/or historical information. In such an embodiment, the correspondence may be used as a measure of the quality indicator. However, in certain other embodiments, the quality indicator may correspond to a determined score or a joint likelihood estimate that is indicative of the usefulness of the image frame for making accurate biometric measurements.

[0095] With returning reference to FIG. 2, at step 218, an optimal image frame may be selected from the plurality of image frames based on the computed quality indicator. In certain embodiments, the optimal image frame may correspond to the image frame that includes a spatial configuration of a combination of candidate structures that substantially matches the reference configuration representative of the desired scan plane for imaging the target feature. Moreover, in one embodiment, the optimal image frame may be selected automatically, for example, based on the highest value of the quality indicator. Alternatively, the quality indicator may be communicated to the user in real-time to allow the user to select the optimal image frame. In certain embodiments, the quality indicator may be communicated visually, for example, using a color bar, a pie chart, and/or a number. Alternatively, the quality indicator may be communicated using an audio and/or video feedback, for example, as beeps, speech, and/or printed message.

[0096] Moreover, in one embodiment, the video processing unit 124 may be configured to 'auto-freeze' the image frame having the highest quality indicator. The optimal image frame may then be used for determining medically relevant measurements corresponding to the target feature. For example, in one embodiment, the video processing unit 124 may be configured to trigger automated measurements of the abdominal circumference of a fetus once the fetal abdomen with an umbilical vein positioned at about one-third of a distance from a hepatic vein is visualized in an image frame. Use of the expert knowledge based spatial reference model to determine the optimal image frame, thus, allows for robust and reproducible measurements of the target feature in real-time without resorting to use of time-consuming manual selection and/or learning algorithms.

[0097] Embodiments of the present specification, thus, provide systems and methods that allow for accurate detection and/or evaluation of the scan plane and measurement of the feature of interest automatically and in real-time. Such an automated and real-time detection of the desired scan plane and/or communication of the quality indicator allow the user to avoid switching back and forth between different image frames in a cine loop for identifying the optimal image frame.

[0098] Moreover, embodiments of the present specification allow for a reduction in imaging time, while providing enhanced performance over conventional learning and segmentation based methods. Particularly, the automated detection and identification of the optimal image frame allows for robust and reproducible measurements of the feature of interest irrespective of the skill and/or experience level of the user. The embodiments of the present methods and systems, thus, may also aid in extending quality ultrasound imaging services over large geographical areas including rural regions that are traditionally under-served owing to lack of trained radiologists.

[0099] It may be noted that the foregoing examples, demonstrations, and process steps that may be performed by certain components of the present systems, for example by the processing unit 114 and/or the video processing unit 124 of FIG. 1, may be implemented by suitable code on a processor-based system. To that end, the processor-based system, for example, may include a general-purpose or a special-purpose computer. It may also be noted that different implementations of the present specification may perform some or all of the steps described herein in different orders or substantially concurrently.

[00100] Additionally, the functions may be implemented in a variety of programming languages, including but not limited to Ruby, Hypertext Preprocessor (PHP), Perl, Delphi, Python, C, C++, or Java. Such code may be stored or adapted for storage on one or more tangible, machine-readable media, such as on data repository chips, local or remote hard disks, optical disks (that is, CDs or DVDs), solid-state drives, or other media, which may be accessed by the processor-based system to execute the stored code.

[00101] Although specific features of embodiments of the present specification may be shown in and/or described with respect to some drawings and not in others, this is for convenience only. It is to be understood that the described features, structures, and/or characteristics may be combined and/or used interchangeably in any suitable manner in the various embodiments, for example, to construct additional assemblies and methods for use in diagnostic imaging.

[00102] While only certain features of the present specification have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.