



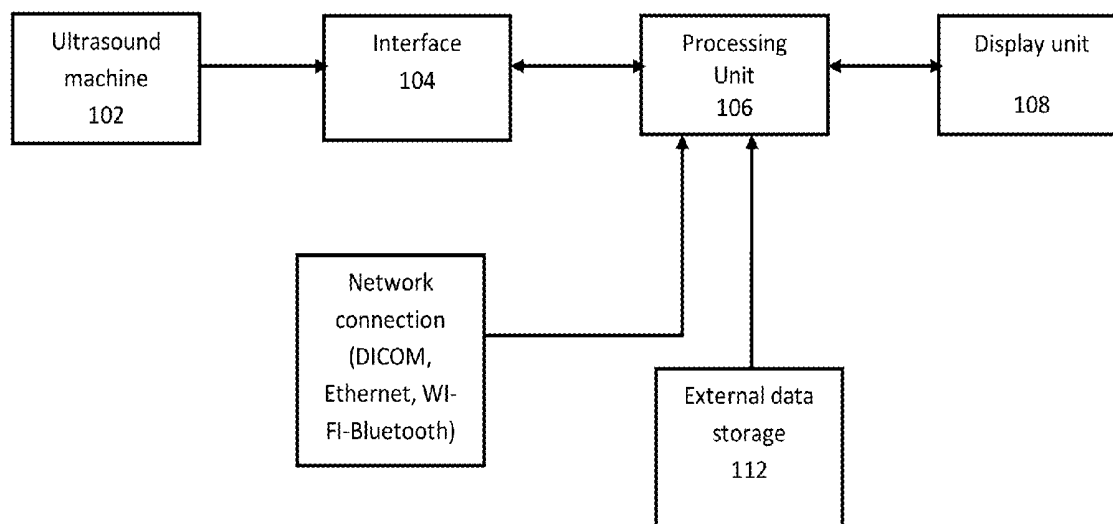
US 20180132830A1

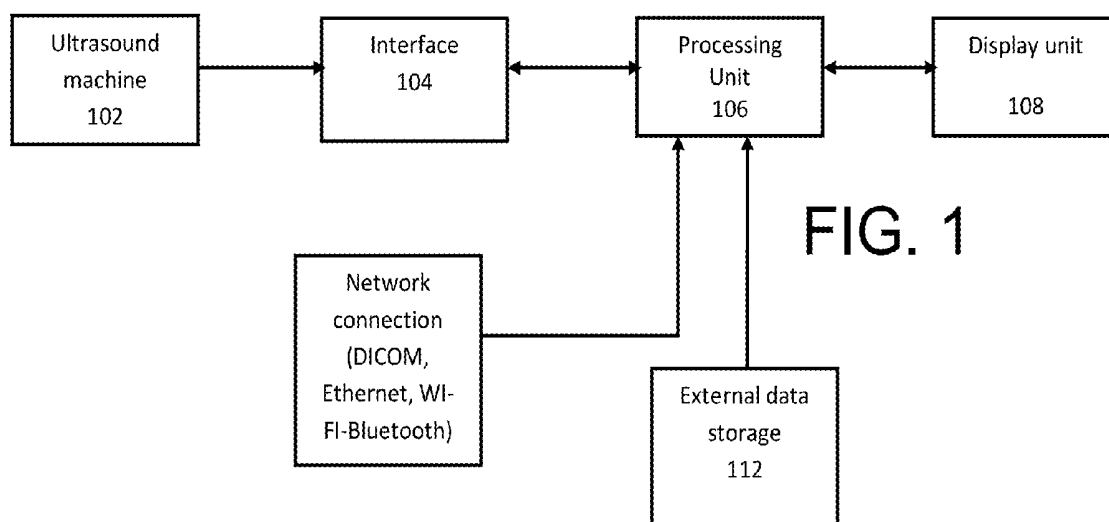
(19) **United States**(12) **Patent Application Publication**
Mahmoud et al.(10) **Pub. No.: US 2018/0132830 A1**(43) **Pub. Date: May 17, 2018**(54) **METHOD AND APPARATUS TO MEASURE
TISSUE DISPLACEMENT AND STRAIN**(71) Applicants: **Ahmed M Ehab Mahmoud**, Giza
(EG); **Mohamed Tarek Mohamed Ali**,
Cairo (EG)(72) Inventors: **Ahmed M Ehab Mahmoud**, Giza
(EG); **Mohamed Tarek Mohamed Ali**,
Cairo (EG)(21) Appl. No.: **15/396,699**(22) Filed: **Jan. 2, 2017****Related U.S. Application Data**(60) Provisional application No. 62/274,265, filed on Jan.
2, 2016.**Publication Classification**(51) **Int. Cl.**
A61B 8/08 (2006.01)
A61B 8/00 (2006.01)
A61B 5/00 (2006.01)
A61B 6/00 (2006.01)
G01R 33/563 (2006.01)(52) **U.S. Cl.**CPC **A61B 8/485** (2013.01); **A61B 8/5223**
(2013.01); **A61B 8/565** (2013.01); **G01R**
33/56358 (2013.01); **A61B 6/4258** (2013.01);
A61B 5/0048 (2013.01); **A61B 5/0059**
(2013.01)

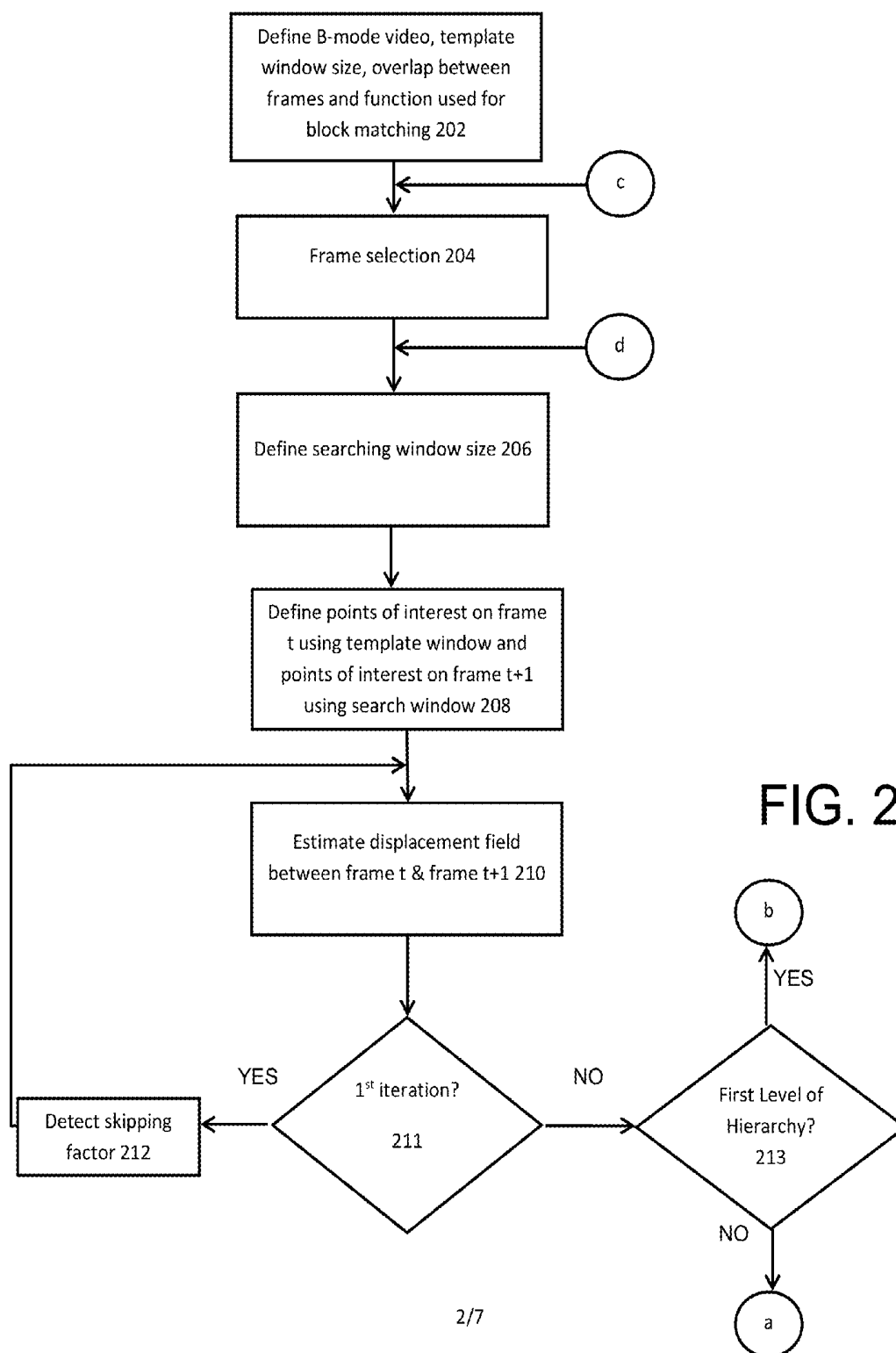
(57)

ABSTRACT

A method for reconstructing displacement and strain maps of human tissue of a subject in vivo or other objects includes applying a mechanical deformation for a target area, imaging tissues while deformation is applied on the target area, measuring the axial and lateral displacements and axial, lateral, and shear strains of tissue in the target area, differentiating between tissues of different stiffness and strain responses, and labeling tissues of different stiffness and strain responses. In some embodiments, displacement and strain imaging are performed using a high-resolution, high-speed, highly-accuracy hierarchy recursive displacement tracking from conventional ultrasound brightness mode images. Particularly, this invention relates to the reconstruction of displacement and strain images from conventional ultrasound B-mode images acquired using any ultrasound machine of different manufacturers without the need to use carrier signals.







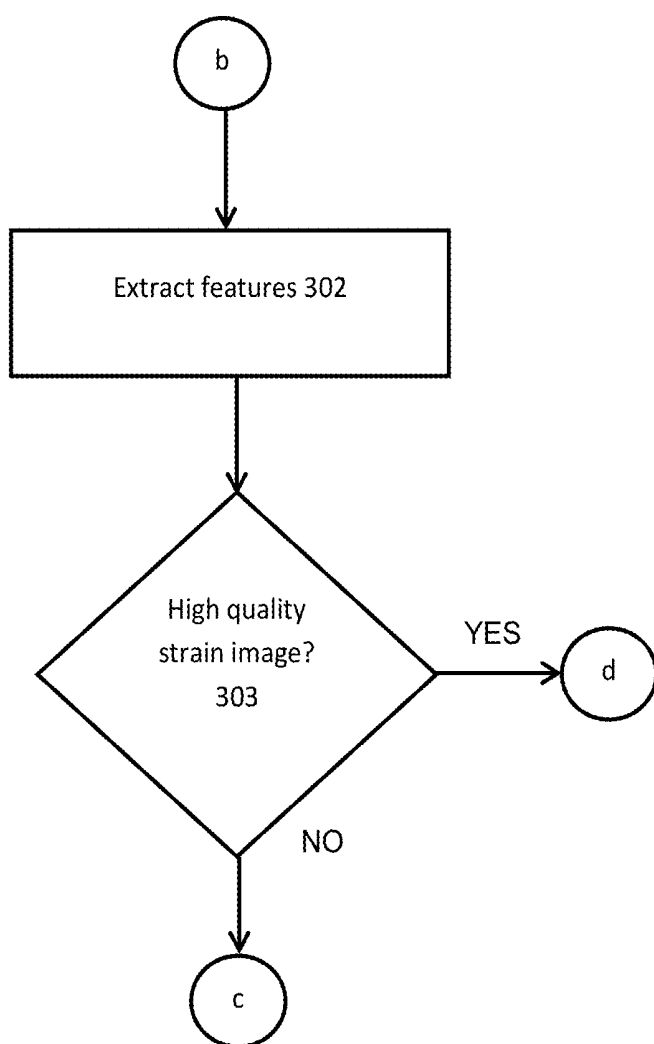


FIG. 3

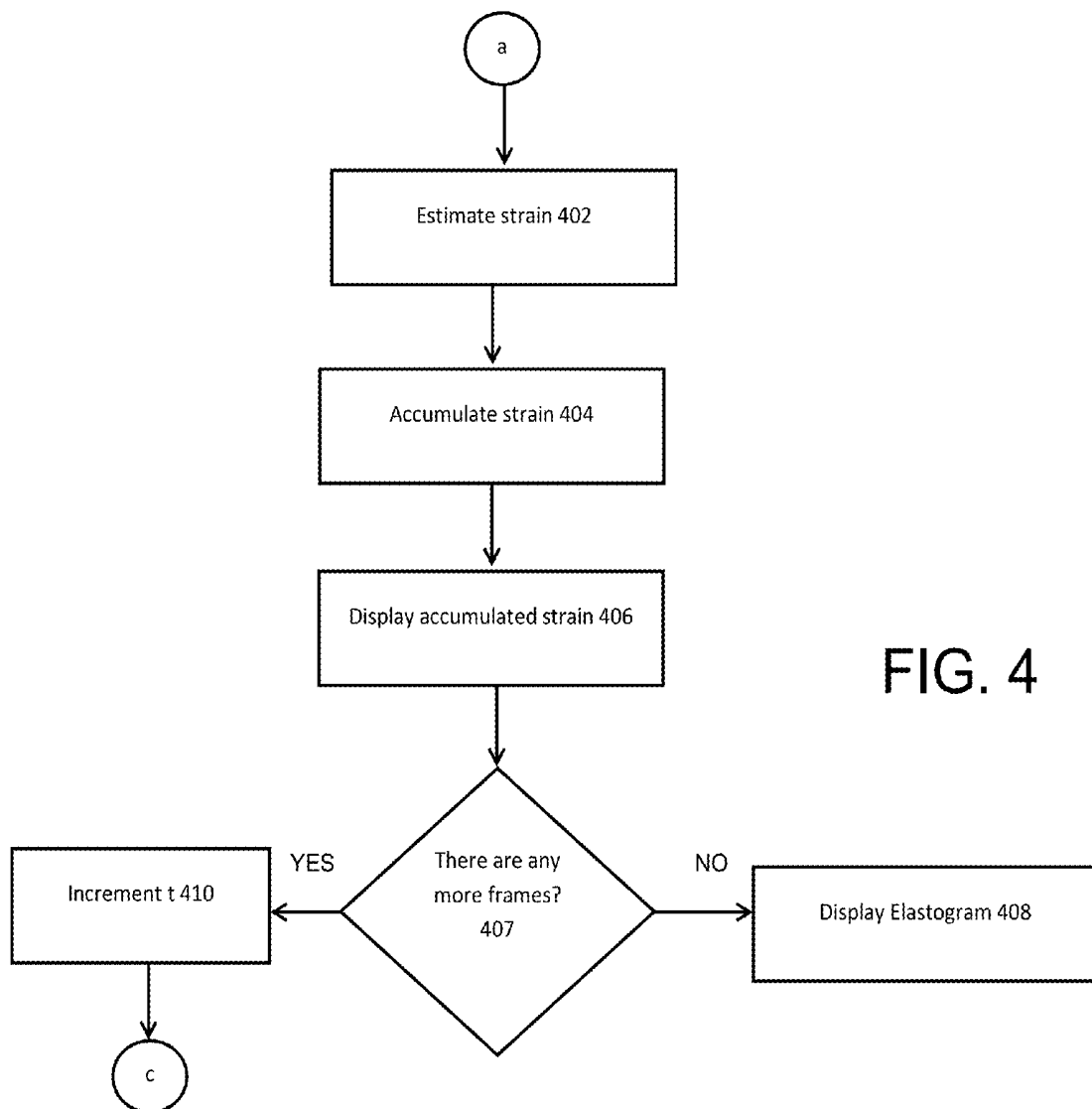


FIG. 5A

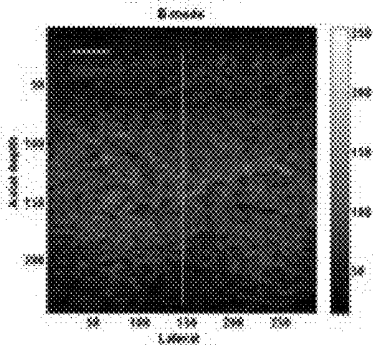


FIG. 5B

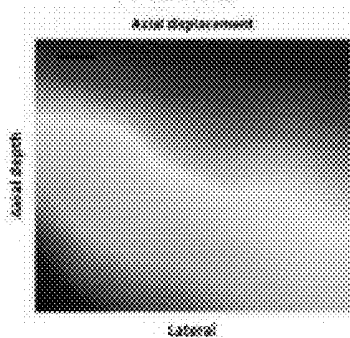


FIG. 5C

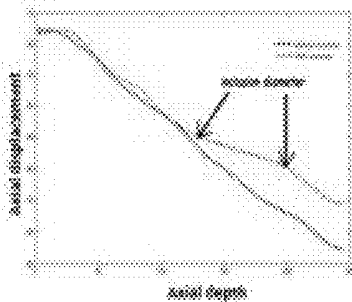


FIG. 5D

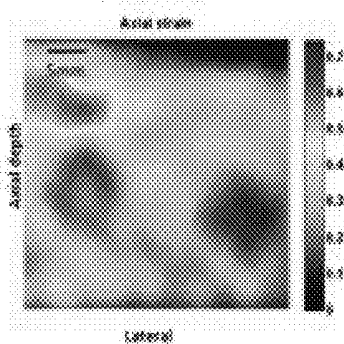


FIG. 5E

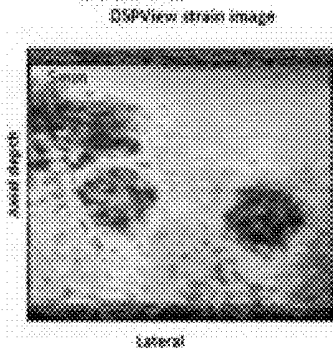


FIG. 6A

Bmode

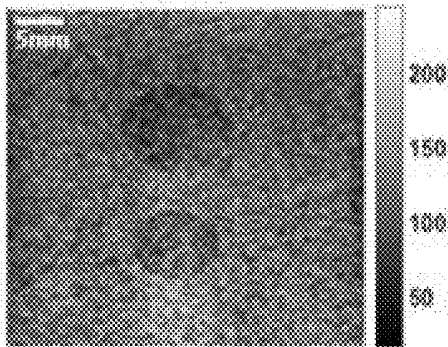


FIG. 6B

Axial displacement

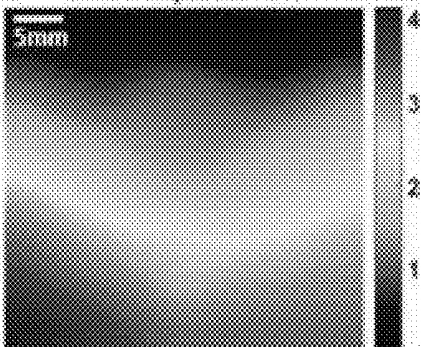


FIG. 6C

Axial strain

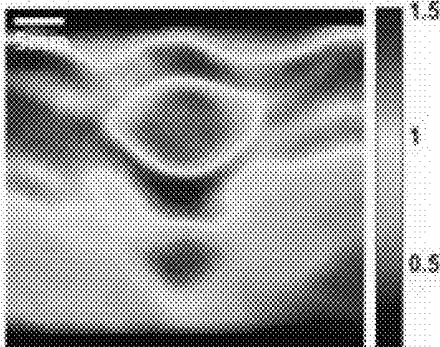


FIG. 6D

Superimposed

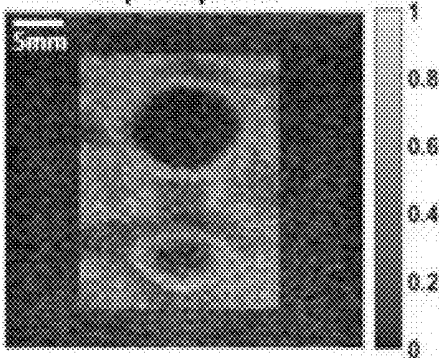


FIG. 7A
Bmode

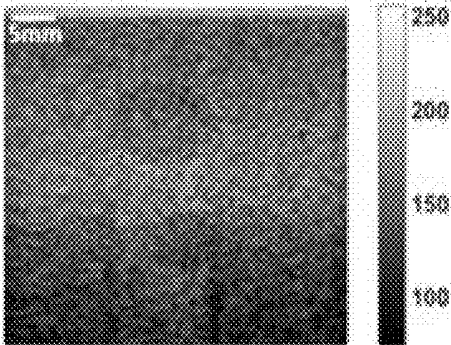


FIG. 7B
Axial displacement

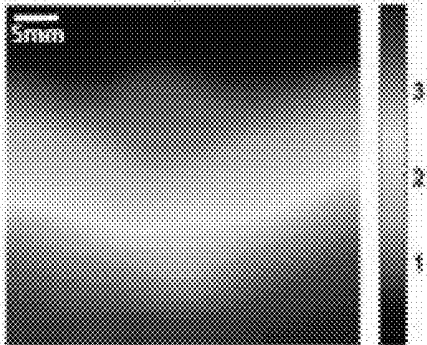


FIG. 7C
Axial strain

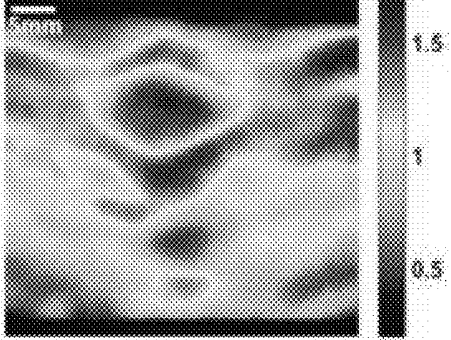
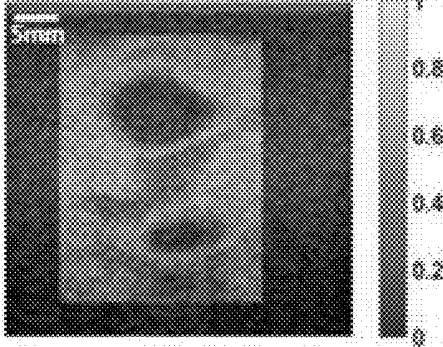


FIG. 7A
Superimposed



METHOD AND APPARATUS TO MEASURE TISSUE DISPLACEMENT AND STRAIN

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/274, 265, which was filed on Jan. 2, 2016.

FIELD OF THE INVENTION

[0002] This invention relates to a method and system for the reconstruction of displacement and strain images from conventional ultrasound brightness mode (B-mode) images. Particularly, this invention relates to the reconstruction of displacement and strain images from conventional ultrasound B-mode images acquired using any ultrasound machine of different manufacturers without the need to use carrier signals. More particularly, the invention relates to a manufacturer-independent method and system for the acquisition of conventional ultrasound B-mode images from ultrasound machines and the generation of displacement and strain images from those images. Specifically, the invention relates to a constrained recursive motion tracking technique with a feature extraction algorithm that ensures a real-time high quality displacement and strain images from conventional ultrasound B-mode images acquired directly from ultrasound machines, transferred via data storage devices either optical devices (CD or DVD), hard drives, floppy drives, or any suitable device, or sent remotely via the internet or network via DICOM, Ethernet card, Bluetooth or WI-FI. The processing can be done either on personal computer, servers, clouds or any device having a processing unit and the results can be sent back to users via any of the transferring devices mentioned before to their smart phones, e-mails, website or any reachable media viewer. The invention is also further applicable to generate displacement and strain images using images acquired by other modalities such as magnetic resonance, nuclear medicine, x-ray and optical imaging methods for medical and non-medical applications to track the motion and measure strain tensors of any material.

BACKGROUND OF THE INVENTION

[0003] Ultrasound brightness mode (B-mode) noninvasive imaging is commonly used in various healthcare facilities including hospitals, medical centers, and clinics. Ultrasound B-mode provides mainly information about the anatomy of human body organs and tissue motion that can be used for medical screening and diagnosis. B-mode gray scale ultrasound images is considered the first choice when diagnosing many diseases due to its safety, high-resolution, mobility, and cost-effectiveness compared to other imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI). However, conventional ultrasound B-mode does not provide information about the mechanical characteristics, or stiffness, of tissue that is essential for diagnosing several diseases including liver disease, atherosclerosis, and tumors. Ultrasound elastography is an emerging technology that has been used to interrogate the mechanical characteristics of soft tissues via measuring tissue strain and elasticity to describe their hardness or stiffness. Although some ultrasound companies have developed this new mode (elastography) on few of their premium and high-end ultrasound

machines, this imaging mode is still not available on most ultrasound machines and ultrasound machines developed before year 2003.

[0004] This elastography mode is only compatible with these specific machines and cannot be used on other machines from the same manufacturer, i.e. until now it is a machine dependent mode and there is not machine independent elastography processing unit. Additionally, the output of elastography imaging varies from an ultrasound manufacturer to another one due to different algorithms and platforms. Both low- to medium-end and old machines do not provide access to raw radiofrequency (RF) ultrasound signals that is commonly used to reconstruct elastography in all machines. On the other hand, B-mode images are available on any commercial ultrasound machine and can be extracted via the digital video interface (DVI), high-definition multimedia interface (HDMI), video graphics adapter (VGA), S-Video, composite video out, BNC, or the universal serial bus (USB) port. Additionally, B-mode images can be sent or transferred by any data storage device like disks, or via the internet or other networks.

[0005] It is an object of the present invention to provide a method and a system for generating displacement and strain images. It is also an object of the present invention to provide a manufacturer-independent method and a system that can be used with any ultrasound machine for reconstructing displacement and strain images. Another object of this invention is to provide a commercially practicable, remote, and flexible system generating displacement and strain images from conventional B-mode ultrasound images using a machine learning algorithm to ensure the quality of the estimated Elastogram at real-time. Conventional B-mode ultrasound images acquired by any ultrasound machine, particularly those that do not have this capability. A specific object of the invention is to provide a flexible, standard and cost-effective method for generating displacement and strain images from B-mode images, cine-loop and videos acquired directly from ultrasound machines via Digital Video Interface (DVI), High-Definition Multimedia Interface (HDMI), video graphics adapter (VGA), S-Video, composite video out, BNC, or the universal serial bus (USB) or indirectly transferred through the Ethernet, WI-FI, or other data exchange or storage methods and send back the results through any of the previously mentioned ways to any internet connected device with media viewer, e-mails or a website (server) to show results. A further object of the present invention is to provide a system and technique that is computationally and time efficient, safe, standard, cost-effective and accurate for reconstructing displacement and strain images from conventional gray scale images acquired by different machines and enables the digital archiving and electronic transfer of data from machines. These and other objects of the invention will be apparent to those skilled in the art from the description that follows.

SUMMARY OF THE INVENTION

[0006] The method and the system of this invention center around the innovative concept of providing flexible, standard, manufacturer-independent, cost-effective and accurate means for displacement and strain image reconstruction for tissues or other materials in response to a mechanical, thermal, and/or other stimulation. Conventional gray scale ultrasound B-mode images can be acquired directly via the system and/or can be processed using the method described

here. Image sequences acquired during stimulus can be acquired directly from machines via the DVI, HDMI, VGA, S-Video, composite video out, BNC, USB, or other output ports or transferred through the Ethernet, WI-FI, or other data storage and exchange methods. Images can be transferred remotely via the internet. Images are then fed into a computationally efficient method to measure displacements. This novel method relies on block matching of subsequent images using hierarchy recursive displacement tracking (HR-DT), with several constraints for the searching method based on physical assumptions to ensure the low computation complexity that take this algorithm to the real-time implementation and with a machine learning technique that ensures the high quality of the estimated Elastogram. A minimum of 2 levels HR-DT is used where larger kernels and search windows are used in the 1st level to estimate preliminary displacement fields with high SNR and low resolution producing coarse estimation to the displacement fields with coarse strain images. In the 2nd level, a smaller template and search windows are used to increase the resolution of estimated displacements using the priori information of level-1 HR-DT to estimate finer displacement fields and thus, high resolution and accurate strain image. Similar process will be used in the 3rd or subsequent levels of HR-DT, if needed. A HR-DT with only 1 level is applied on few frames to determine the required skipping factor in order to produce high SNR and CNR strain images with strain range that ensures a high quality Elastogram either in the linear or nonlinear range. To enhance SNR and CNR of the output strain image, we apply a frame selection criteria that was based on observations and some physical assumptions related to Poisson ratio and how should lateral motion relate to axial motion at ideal axial stress and other assumptions that make us pick those frames that already contains enough strain to show contrast between different tissue or objects and this is only an opening for any skilled in art to expand the idea more and apply more physical constraints according to the applications. We have used WEKA [9] software for data mining and those skilled in the art can use other data mining stuff that helps them to select features or build their own. To overcome computational complexity, hierarchical constraint and axial and lateral, continuity constraints were applied in all levels of HR-DT. Although, these 3 constraints are based on physical assumptions of tissue motion like the smoothness of motion, moving at the same direction of the applied stress and the lateral motion should be much less than the axial one, we still believe that skilled in art can apply more to speed the algorithm up based on physical constraints or experiment based constraints. Strain is then evaluated as the spatial gradient of displacement maps.

[0007] In some embodiments, the system and method be integrated with any ultrasound machine regardless the manufacturer and reconstruct displacement and strain images from standard B-mode imaging sequences.

[0008] In other embodiments, the method can be applied to imaging sequences acquired from ultrasound, magnetic resonance imaging, x-ray and optical methods, PET/SPECT, OCT, and directly processed, transferred, or sent remotely from other locations via the internet or other wired or wireless data transfer protocol.

[0009] The method of this invention is particularly suited for reconstructing the displacement and strain images of objects in response to stimulation using ultrasound imaging;

however the method is also suited for imaging using magnetic resonance imaging, optical and laser imaging methods, etc.

[0010] The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A clear understanding of the key features of the invention summarized above may be had by reference to the appended drawings, which illustrate the method and system of the invention, although it will be understood that such drawings depict preferred embodiments of the invention and, therefore, are not to be considered as limiting its scope with regard to other embodiments which the invention is capable of contemplating. Accordingly:

[0012] FIG. 1 is an illustration of the system schematic of the ultrasound elastography add-on module system for providing non-invasive displacement and strain measurements.

[0013] FIG. 2 is an illustration of the first part of the displacement estimation algorithm starting from acquiring the ultrasound images to initial displacement values and determining skipping frames factor.

[0014] FIG. 3 is an illustration for the feature extraction and frame selection part in the algorithm.

[0015] FIG. 4 is an illustration for last part of the algorithm where elastogram is generated.

[0016] FIGS. 5A-5E illustrates (A) is a B-mode gray scale ultrasound image of breast phantom including 2 masses with a dashed line passing through the inclusion (red) and solid line on background material (blue), (B) axial displacement image estimated by HR-DT, (C) graph showing gradient of axial displacement along axial depth at the two lines (red and blue) shown (A), (D) axial strain by the HR-DT technique, and (E) axial strain by DSPview code [2] that used RF signals. Both (D) and (E) show the two masses in low strain values (blue). Ultrasound B-mode images were acquired using the Sonix RP machine by Ultrasonix (Canada).

[0017] FIGS. 6A-6D illustrates (A) B-mode gray scale ultrasound image of breast phantom including 2 masses B-mode, (B) axial displacement map, (C) axial strain map, (D) superimposed pseudo-strain image. Ultrasound B-mode images were acquired using Acuson machine by Siemens (Germany).

[0018] FIGS. 7A-7D illustrates (A) B-mode gray scale ultrasound image of breast phantom including 2 masses B-mode, (B) axial displacement map, (C) axial strain map, (D) superimposed pseudo-strain image. Ultrasound B-mode images were acquired using Digison machine by IBE (Egypt).

DETAILED DESCRIPTION OF THE INVENTION

[0019] Referring to FIG. 1 images are captured from the ultrasound machine (102) using a hardware interface (104) such as video capture device then they are processed by our method in the processing unit (106) where displacements and strains between different frames are measured and displayed on the display unit (108). Images can be transferred to the processing unit by means of network connections (110) through Ethernet or WI-FI and/or external data storage (112).

[0020] FIG. 2 refers to the first part of the displacement estimation algorithm where ultrasound images, cine-loop, or videos the region of interest (ROI) is automatically segmented at which there are imaging data (scan lines) acquired by the transducer. In the first block (202) the imaging depth is entered or determined automatically for processing successive or selected frames (204) acquired after time t . Template and search window size (206) are determined automatically by taking a ratio from the imaging frame size (such as 10-20% for 1st HR and 5-10% for the 2nd FIR) and or it can be adjusted manually by the user and also it's considered to not violate the minimum size of template based on speckle size and this is why we all user interfere. The template window is a vector of length equals to 2 or 3 elements and determines the template window size as well as the levels of the hierarchy used. Overlap percentage between template windows is determined to enhance the spectral resolution of the estimated displacement field between chosen imaging frames. There are two objective functions that can be used for the block matching. These functions are computationally efficient and/or accurate including first the Zero-mean normalized cross correlation (ZMCC)

$$R(\Delta x, \Delta y) = \frac{\sum_{x=\frac{tx}{2}}^{\frac{tx}{2}-1} \sum_{y=\frac{ty}{2}}^{\frac{ty}{2}-1} (f(x+\Delta x, y+\Delta y) - \bar{f}) \times (g(x, y) - \bar{g})}{\sqrt{\left(\sum_{x=\frac{tx}{2}}^{\frac{tx}{2}-1} \sum_{y=\frac{ty}{2}}^{\frac{ty}{2}-1} f(x+\Delta x, y+\Delta y) - \bar{f} \right)^2 \times \left(\sum_{x=\frac{tx}{2}}^{\frac{tx}{2}-1} \sum_{y=\frac{ty}{2}}^{\frac{ty}{2}-1} (g(x, y) - \bar{g}) \right)}} \quad (1)$$

[0021] where (x, y) is point of interest, f is the template area around the point of interest in the reference frame at t , g is the search area around the point of interest in the compressed frame at $t+1$, $\bar{g}$ is the mean of the search window, $\bar{f}$ is the mean of the template window, ty and tx are the axial and lateral template window size, respectively. The second function is the sum of absolute difference (SAD)

$$R(\Delta x, \Delta y) = \sum_{x=\frac{tx}{2}}^{\frac{tx}{2}-1} \sum_{y=\frac{ty}{2}}^{\frac{ty}{2}-1} |f(x+\Delta x, y+\Delta y) - g(x, y)| \quad (2)$$

[0022] Enhanced Hierarchy displacement estimator

[0023] The frame selection described in block 204 is trivial such as frame t and $t+1$. However, the selection of frames used in elastography calculations depends on the frame rate used while acquiring the B-mode ultrasound images and the compression rate done by the user's hand. Frames are included in Elastography calculations whenever the strain between them is within a valid range to show a high quality Elastogram, i.e. if the average strain between two successive frames (t and $t+1$) is outside this range, frame $t+1$ is excluded and will be replace by $t+2$. If the strain between frame t and $t+2$ is between that range, frame $t+2$ will be included, and will be excluded otherwise, and so on. This technique assumes a maximum compression of 3% axial strain is applied with typically 1 Hz compression-relaxation cycles as example illustrated in [1], also skilled in the art can expand or shrink the range according to the requirements. The first run of the algorithm is reserved for determining the frame skipping rate and this is done by

considering the average displacement and average strain between every 2 successive frames i.e. t & $t+1$ and then determine the skipping factor that is based on axial displacement and strain between frames to ensure us having a pure axial motion with efficient strain and this is what takes place in block 212.

[0024] The size and location of searching window relative to the template window have critical roles in determining the speed and accuracy of the algorithm and that is where we apply our constrains (axial, lateral, and hierarchical). At the 1st iteration of the hierarchical model (level 1) we choose search window size so that

$$\begin{aligned} sx &= tx + \text{offset}_x \\ sy &= ty + \text{offset}_y \end{aligned} \quad (3)$$

where sx is the lateral dimension of the search window, sy is the axial dimension of the search window, tx is the lateral dimension of the template window, and ty is the axial dimension of the template window, offset_x and offset_y are chosen to form the search area. For example, these offsets can be 22 pixels in the axial direction and 12 pixels in the lateral direction assuming and with a displacement greater than 11 pixels in the axial direction and 6 pixels in the lateral dimension, we will get a bad quality strain image. This has speed up our algorithm since at the 1st level of the hierarchy we usually choose a larger template window and it is frequent to choose the search window $\approx 1.5 \sim 2$ of the template window and this is computationally expensive specially for a large template window size.

[0025] Estimating the displacement field between two frames is performed using block matching techniques. As mentioned before, we can use mainly 2 equation (SAD & ZMCC). SAD is a fast and accurate function that we usually use for block matching so most of results are recorded using SAD function. In another embodiment, ZMCC can be used. In order to improve the processing speed and render a high quality axial strain image at almost real time processing, we adopt a smart algorithm to optimize the trade off between accuracy and speed for estimating high quality axial strain images. The 3 constrains (axial, lateral and hierarchical) are included in the hierarchy recursive (HR) speckle tracking. Axial and lateral constrains have been used before [2] but on estimating axial strain image using RF data not B-mode gray scale ultrasound images like this application. Here we are introducing a hybrid or merged technique involving the power of HR in estimating an accurate and high resolution displacement image along the high computational power added with the axial and lateral constrains based on our application. In one embodiment, we have observed that the 2nd levels of HR tracking lead to a high quality strain image at a reasonable time. At first level we may choose a large template window enough to divide our reference frame (pre-compression) into 10~15 overlapping template windows at most, then we start to search for these template windows inside the second frame (post-compression) in a search window with the criteria discussed and we search row by row. After finishing the 1st row, we apply the lateral constrain by assuming that compression is mostly axial so the motion in the lateral direction is just due to poisson effect as described in equation (4).

$$\epsilon_{lateral} = \epsilon_{axial} \quad (4)$$

[0026] This lateral strain is due to very small displacements, so we just determine the displacement of the pixel

from the above row as pixel (x,y) and the point in the next row is (x,y+1) and let us assume that point (x,y) moved with displacement (dx,dy) where dx is the lateral displacement and dy is the axial displacement. Then by applying the lateral constrain on the searching window, the search window in the second frame will be centered at (x+dx,y+1+dy) with size equals to x+4 pixels the template window lateral size, so that it allows only searching x+2 pixels to the right and x+2 pixels to the left. Extending this criteria to the axial constrain, the search window will be equal to the template window axial size x+5, and here it starts to examine if this is a compression cycle or relaxation cycle (motion is upward or downward) and we search only in the direction of motion. Applying these 2 constrains has minimized the required computations as below

$$k=m-n+1 \quad (5)$$

where k is the number of operations, m the size of searching window, and n the size of template window. Using equation (5), if a template window size of 32x32 is used along with a search window size with just 1.5 of template window size (48x48), then we have k=17 axial operations and 17 lateral operations with total 289 operations for each tracking point. After applying axial and lateral displacement constrains for the same example we have template window with 32x32 and search window with 36x37, so we will have a total of 20 operations for each tracking point, i.e. the computational complexity reduced with about 14 times than the exhaustive search. After estimating the displacement of each row, we apply a 2D median filter to smooth and avoid any spurious displacement vectors.

[0027] After finishing the first level of enhanced HR tracking, displacement estimations between two frames will be obtained with high SNR and low resolution. This displacement field will be used to decide whether these frames underwent enough and valid compression to cause good contrast between tissues or not and that is done by extracting many features that have been studied and reported [4]-[6] besides what we have assumed based on Poisson ratio that the later displacement should be symmetric around the axis of the axial compressions and others based on our observation like the entropy of the axial displacement and it's relation with the computed axial strain. To demonstrate that some features may affect the quality of the axial strain image and also features that we have found usefull according to what we have observed from WEKA. To take such decision, we have built a database containing many elastography videos that have been acquired using ultrasound breast phantom (Model 059, CIRS Inc., Norfolk, Va.) and many ultrasound machines of different manufacturers including, and not limited to, IBE, Siemens, Samsung, Philips, GE, Toshiba, Mindray, and Ultrasonix and then we have applied our algorithm over all frames with frame skipping factor equals one i.e. frames to be processed are at t & t+1 and selected good frames (qualitatively) manually (good frames are frames that produce high quality strain image) to extract features and then we have built a data set containing good and bad frames to start feature selection using information gain algorithm included in WEKA. After selecting frames we have trained many classifier with different number of features to see how accurate we can classify good frames from bad frames, we have used KNN, SVM, Naïve bayes that are already implemented in WEKA.

[0028] For the second HR level, we apply procedures similar to the first level but with some hierarchy constrains. There is no need to estimate all the first row as we have done in the first level using exhaustive search, because we already know a priori info about its displacement field. We have a higher resolution 2nd level grid to track. First we obtain an initial estimate for the displacement at each point of interest in the 1st row of the new grid using the estimated displacement field of level 1 HR, and then the searching area is shifted with a step equals to estimated displacement. The size of this searching area becomes smaller than the one used in the first HR level and we use the small offset used in the axial and lateral constrains based on our calculations of the different displacements and strains from the 1st HR level that's implicitly a characteristic feature for the person applying this compression. For the subpixel accuracy in both levels, skilled in the art can use any algorithm based on his accuracy and computation speed requirements, we have used 3 point gaussian fit but still there are plenty of ways like 4-point gaussian estimator, interpolating the original images, center of mass, etc. Also, in addition to our constraints that avoids false peaks in the correlation field, we have used multi-correlation validation technique that is based on applying correlation equation several times on the same searching area but with little shifted or resized template window and multiply all correlation field with each others considering the difference between the template windows location and this can provide us with a correlation field with suppressed noise and amplitude true peak compared with other correlation fields.

[0029] After the second HR level is completed, a high resolution and accurate displacement field is reconstructed which can be used directly to estimate a high quality strain image. In one embodiment, we have used different techniques for strain estimation including the least-Square method [7], Savitzky-Golay filter [8], direct displacement gradient. All strain estimation techniques have produced good results since it depends mainly on the quality of the displacement estimation (strain is the gradient of the displacement).

[0030] Accumulation of axial strain to produce a higher quality image and increase the SNR. Accumulation depends mainly on the way we are computing strain if it is a lagrange strain then its characterized by higher contrast to noise ratio (CNR) at accumulation and if an Euler strain then its characterized by higher SNR that depends mainly on either we are tracking an object or a pixel. Last step, and this is also based on the physical assumptions that allow us to enhance our results, is applying adaptive normalization to the resulting strain image at which we move with a very wide window that normalize all tissue on the same horizontal level and this is to avoid stress leakage with the depth, since this would lead us to fake decisions thinking that there are hard tissue at high depth.

[0031] Also to be stated that the 2nd Hierarchical level can totally different than the first one according to matching equation (ZMCC, SAD, SSD), also it can be different algorithm/technique such as using optical flow for the 2nd Hierarchical level or using different different form or data to be tracked (register pre-compression image using the estimated displacement field). Also, we can use more number of Hierarchical level and do at each level something different than the previous one, with considering the results estimated from the previous one to enhance and speed up the estima-

tion in the current level and so on until maximum accuracy is achieved at the last level of hierarchy.

[0032] While the present invention has been described in terms of particular embodiments and applications, in both summarized and detailed forms, it is not intended that these descriptions in any way limit its scope to any such embodiments and applications, and it will be understood that many substitutions, changes and variations in the described embodiments, applications and details of the method and system illustrated herein and of their operation can be made by those skilled in the art without departing from the spirit of this invention. Rather, the scope of the invention is defined by the following claims. We therefore claim as our invention all that comes within the scope and spirit of these claims.

We claim:

1. A method for reconstructing displacement and strain maps of objects under stimulus comprising:

Applying a mechanical deformation for a target area of a body organ in a subject;

imaging tissues while deformation is applied on the target area;

measuring the axial and lateral displacements and axial, lateral, and shear strains of tissue in the targeted organ within human body in vivo due to the mechanical deformation using high-resolution, high-speed, highly-accuracy hierarchy recursive displacement tracking (HR-DT);

differentiating between tissues of different stiffness and strain responses; and

labeling tissues of different stiffness and strain responses.

2. The method of claims 1, wherein the variation of strain comprises:

varying the strain by at least 0.5%.

3. The method of claim 1, wherein input images are acquired directly from ultrasound scanners using DICOM, Digital Video Interface (DVI), High-Definition Multimedia Interface (HDMI), video graphics adapter (VGA), S-Video, composite video out, BNC, or the universal serial bus (USB).

4. The method of claim 1, wherein input images are sent via DICOM, Ethernet, WI-FI, Bluetooth or other data exchange method.

5. The method of claim 1, wherein the mechanical deformation can be applied from outside or inside the body comprises deforming the target area.

6. The method of claim 1, wherein the deformation in tissue can be due to a thermal stimulus applied comprises changing the temperature of the target area.

7. The method of claim 1, wherein the mechanical deformation is applied by a transducer coupled to the ultrasound scanner.

8. The method of claim 1 can be applied to measure displacements and/or strains in objects using images from nuclear medicine cameras, optical cameras, x-ray based imaging, and magnetic resonance imaging.

9. A system for measuring the displacement and strain maps of objects under stimulus, the system comprising:

a stimulating device to apply a mechanical deformation for a target area of a body organ in a subject;

an ultrasound device to image tissues while deformation is applied on the target area using an ultrasound scanner;

a device connected to ultrasound machine for measuring the axial and lateral displacements and axial, lateral, and shear strains of tissue in the targeted organ within human body in vivo due to the mechanical deformation using high-resolution, high-speed, highly-accuracy hierarchy recursive displacement tracking (HR-DT);

a device to differentiate between tissues of different stiffness and strain responses; and

a labelling device for tissues of different stiffness and strain responses.

10. The system in claim 9 uses conventional gray scale images of B-mode images, cine-loop and videos acquired directly from ultrasound machines via DICOM, Digital Video Interface (DVI), High-Definition Multimedia Interface (HDMI), video graphics adapter (VGA), S-Video, composite video out, BNC, or the universal serial bus (USB).

11. The system in claim 9 uses conventional gray scale images of B-mode images, cine-loop and videos sent via the DICOM, Ethernet, WI-FI, or Bluetooth.

12. The system in claim 9 uses conventional gray scale images of B-mode images, cine-loop and videos transferred via a data storage device.

13. The system of claim 9, wherein the displacement and strain change comprises a a mechanical deformation.

14. The system of claim 9, wherein the displacement and strain change comprises a thermal stimulus due to a temperature change.

15. The system of claim 9, is coupled to and integrated with the ultrasound imaging device.

16. The system of claim 9, is not coupled to nor integrated with the imaging device, wherein images are transferred remotely via network or data storage devices.

17. The system of claim 9, can be used to measure displacements and/or strains in objects using images from nuclear medicine cameras, optical cameras, x-ray based imaging, and magnetic resonance imaging.

18. The system of claim 9, can has his processing unit inside or outside the system like on an internal/external processor, cloud computing system, personal computer, laptop or smartphone or any other processing unit that can be supported with a display or already having one.

* * * * *

专利名称(译)	测量组织位移和应变的方法和设备		
公开(公告)号	US20180132830A1	公开(公告)日	2018-05-17
申请号	US15/396699	申请日	2017-01-02
[标]发明人	MAHMOUD AHMED M EHAB ALI MOHAMED TAREK MOHAMED		
发明人	MAHMOUD, AHMED M EHAB ALI, MOHAMED TAREK MOHAMED		
IPC分类号	A61B8/08 A61B8/00 A61B5/00 A61B6/00 G01R33/563		
CPC分类号	A61B8/485 A61B8/5223 A61B8/565 A61B5/0059 A61B6/4258 A61B5/0048 G01R33/56358 A61B5/0077 A61B5/055 A61B6/00 A61B6/5217 G16H50/30		
优先权	62/274265 2016-01-02 US		
其他公开文献	US10675002		
外部链接	Espacenet USPTO		

摘要(译)

用于重建受试者体内人体组织或其他物体的位移和应变图的方法包括对目标区域应用机械变形，在对目标区域施加变形的同时对组织成像，测量轴向和侧向位移以及轴向，侧向，以及目标区域的组织剪切应变，区分不同刚度和应变反应的组织，以及标记不同刚度和应变反应的组织。在一些实施例中，使用来自常规超声亮度模式图像的高分辨率，高速度，高精度分级递归位移跟踪来执行位移和应变成像。特别地，本发明涉及从不同制造商的任何超声机器采集的常规超声B模式图像的位移和应变图像的重构，而不需要使用载波信号。

