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(54) **ULTRASOUND STRAIN IMAGING BASED ON LATERAL DISPLACEMENT COMPENSATION**

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(57) **ABSTRACT**

Embodiments for forming a strain image by compensating for displacement in a later direction in an ultrasound system are disclosed. In one embodiment, an ultrasound system includes: an ultrasound data acquisition unit configured to acquire first ultrasound data where compression is not applied to a target object and second ultrasound data where compression is applied to the target object; and a processing unit configured to compensate for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data, the processing unit being further configured to form a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

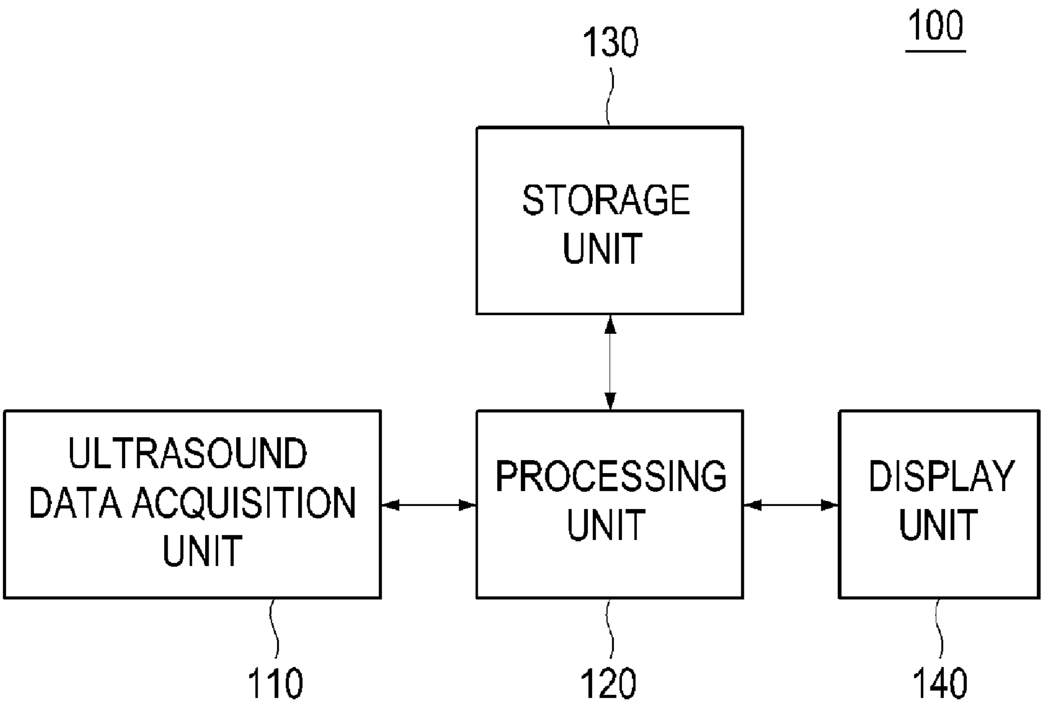


FIG. 1

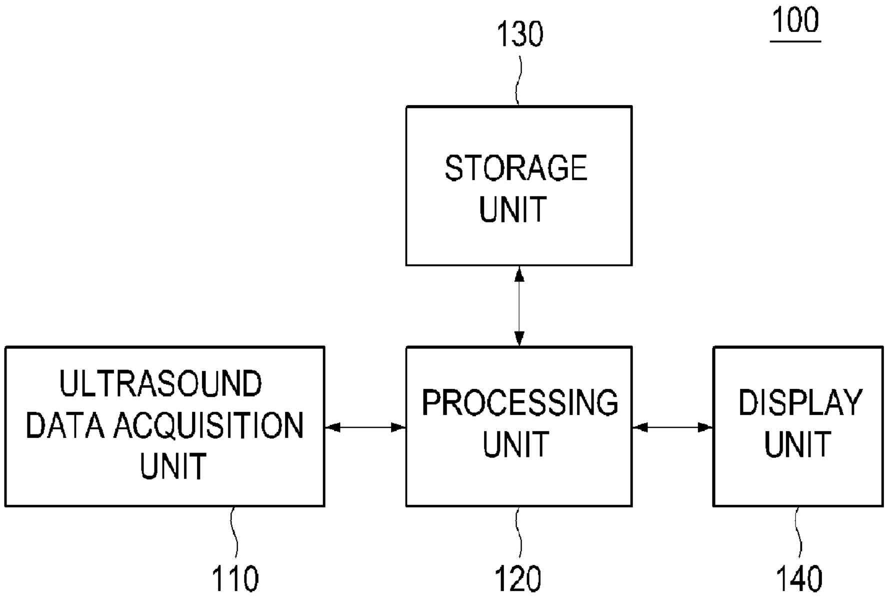

100
130
STORAGE UNIT
ULTRASOUND DATA ACQUISITION UNIT
PROCESSING UNIT
DISPLAY UNIT
110
120
140

FIG. 2

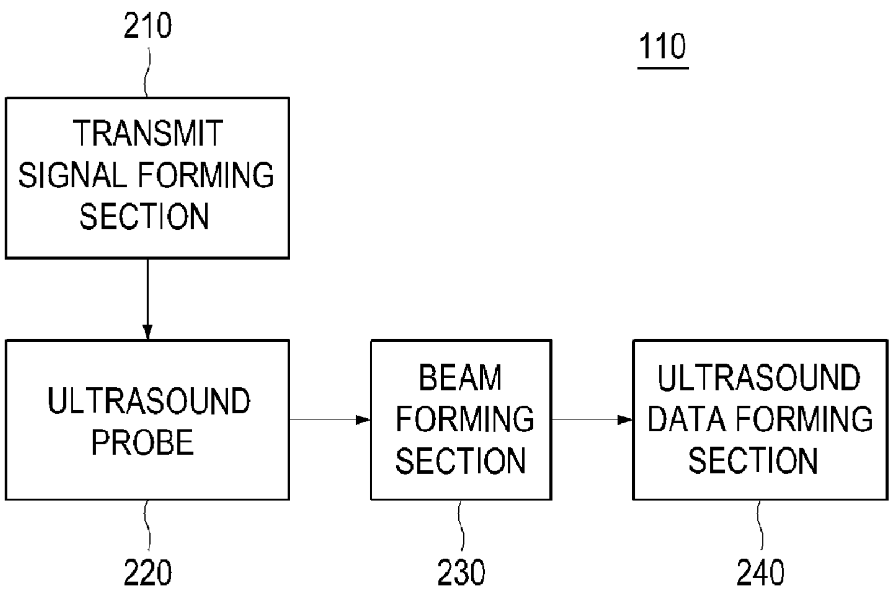
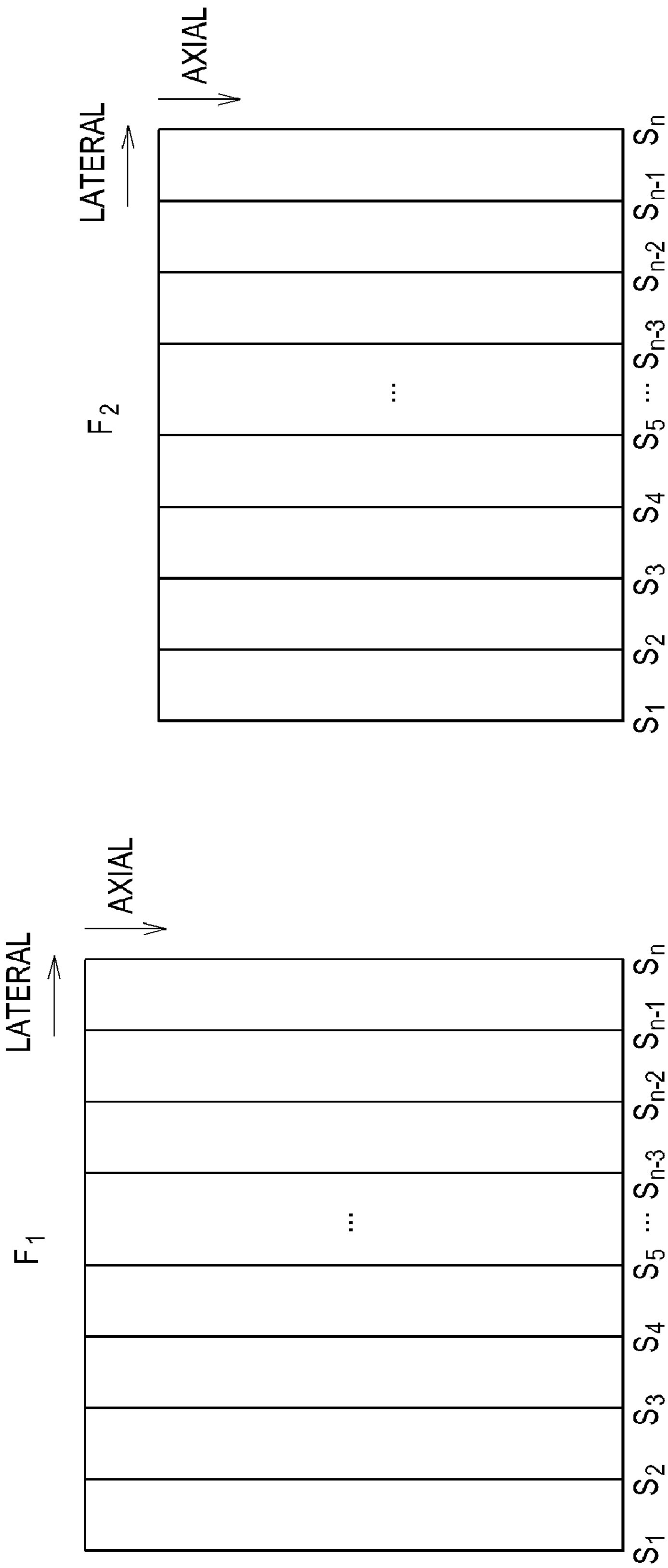

210
110
TRANSMIT SIGNAL FORMING SECTION
ULTRASOUND PROBE
BEAM FORMING SECTION
ULTRASOUND DATA FORMING SECTION
220
230
240

FIG. 3



AXIAL
LATERAL
F2
S1
S2
S3
S4
S5 ⋯ Sn-3
Sn-2
Sn-1
Sn
AXIAL
LATERAL
F1
S1
S2
S3
S4
S5 ⋯ Sn-3
Sn-2
Sn-1
Sn

FIG. 4

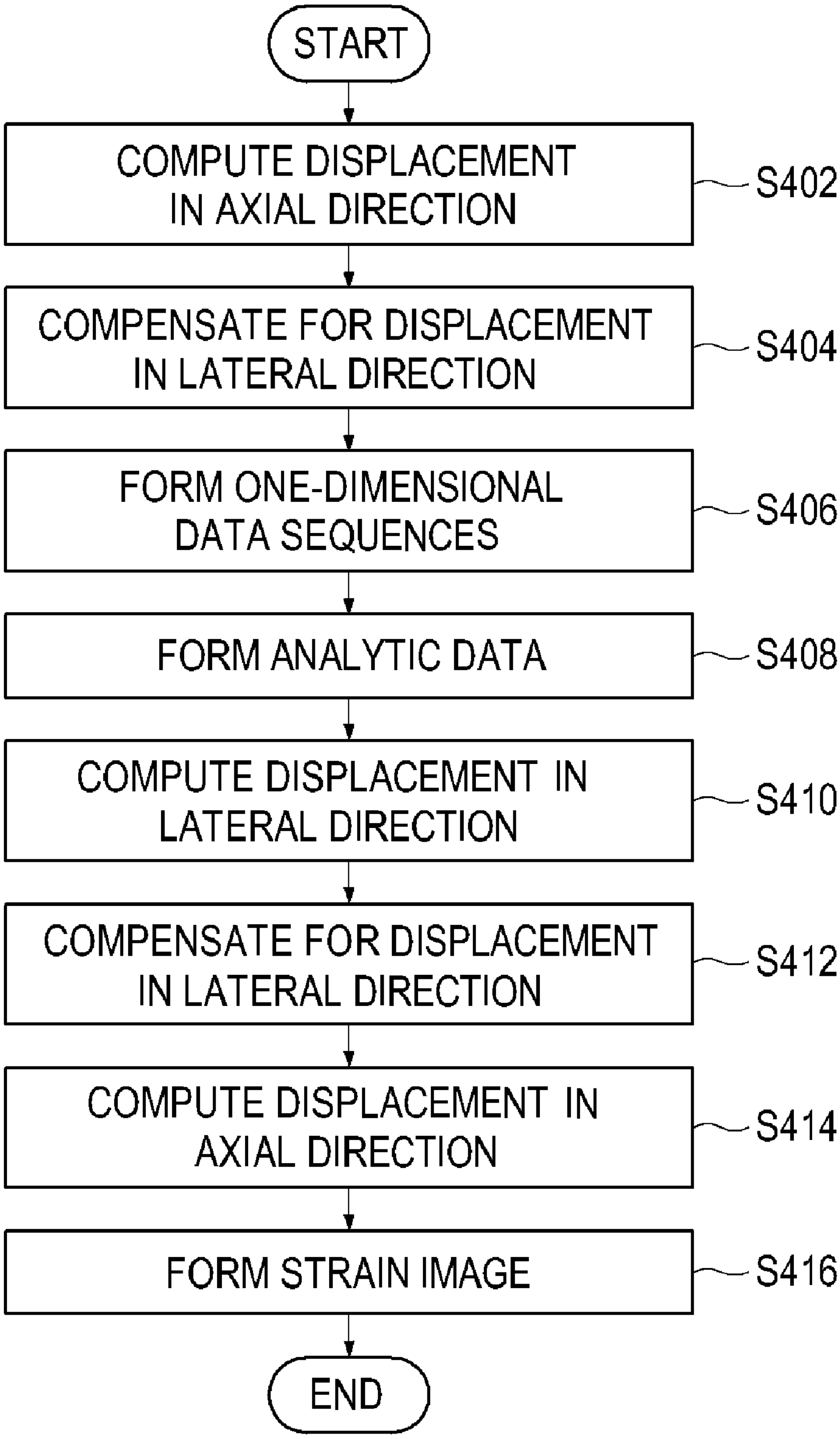

START
COMPUTE DISPLACEMENT IN AXIAL DIRECTION
S402
COMPENSATE FOR DISPLACEMENT IN LATERAL DIRECTION
S404
FORM ONE-DIMENSIONAL DATA SEQUENCES
S406
FORM ANALYTIC DATA
S408
COMPUTE DISPLACEMENT IN LATERAL DIRECTION
S410
COMPENSATE FOR DISPLACEMENT IN LATERAL DIRECTION
S412
COMPUTE DISPLACEMENT IN AXIAL DIRECTION
S414
FORM STRAIN IMAGE
S416
END

FIG. 5

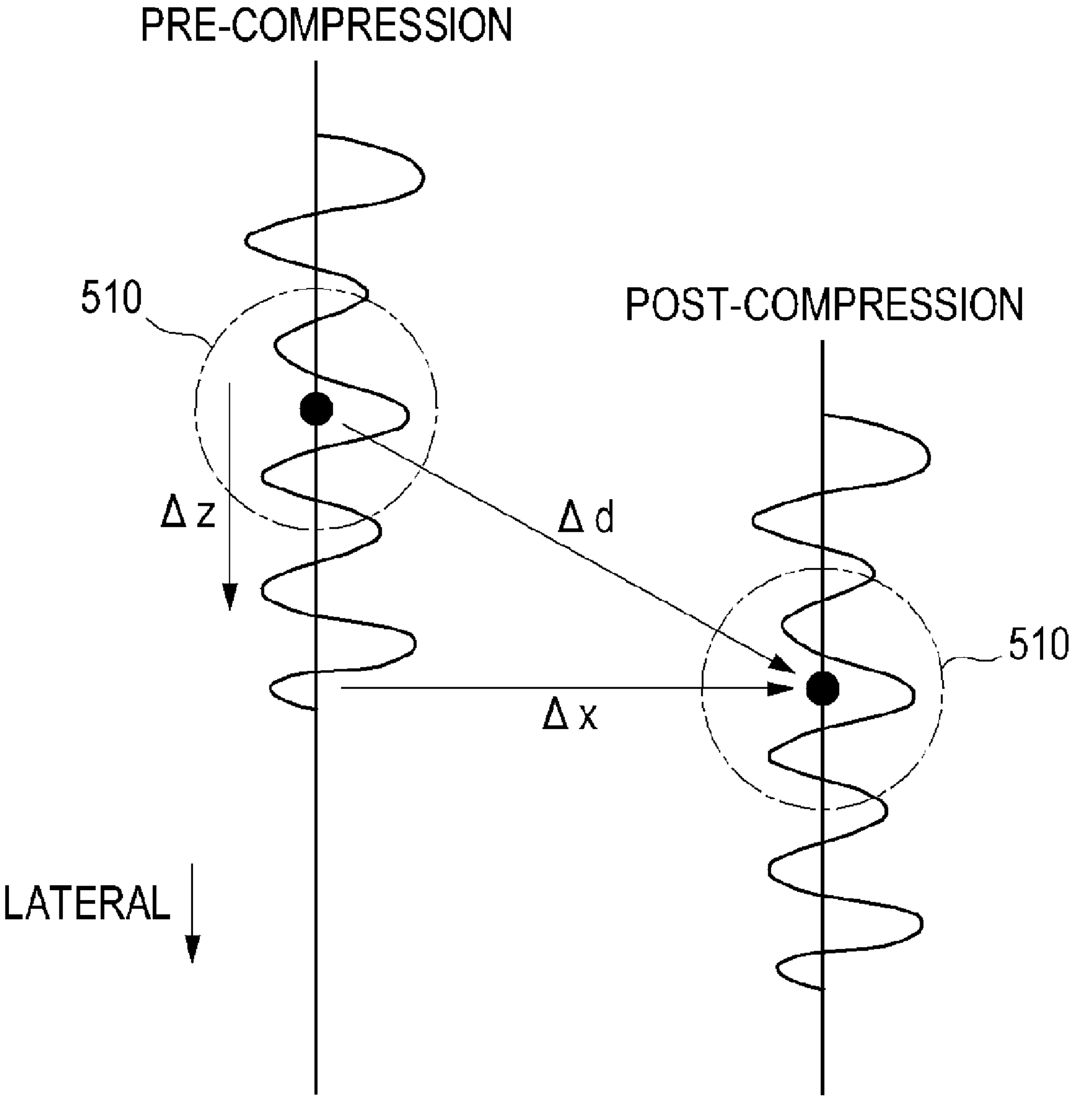


FIG. 6

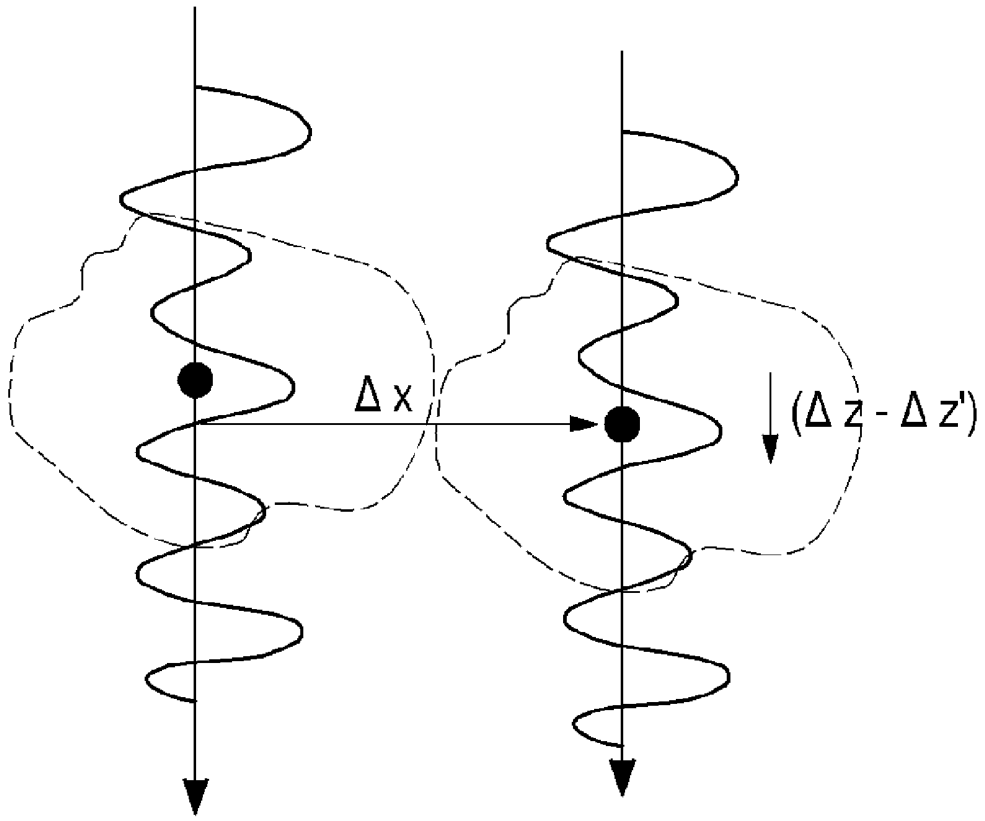


FIG. 7

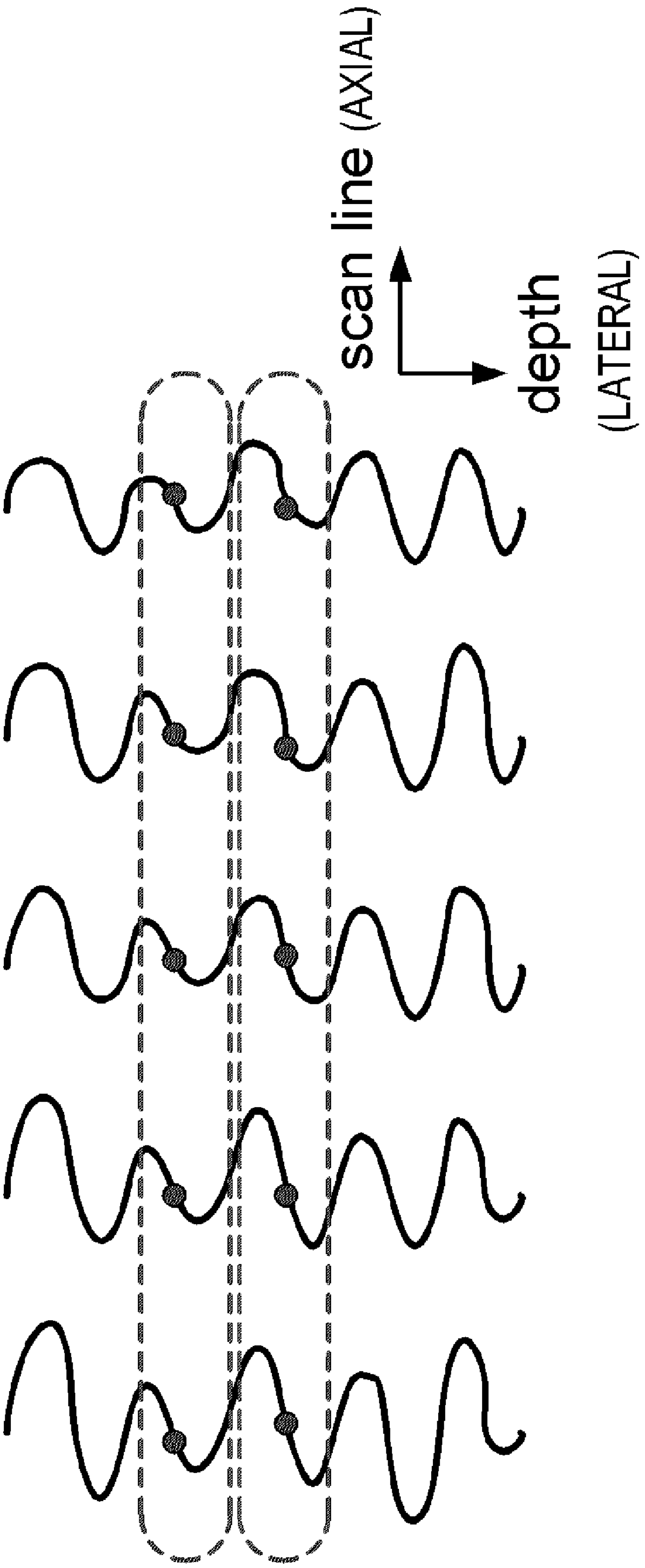
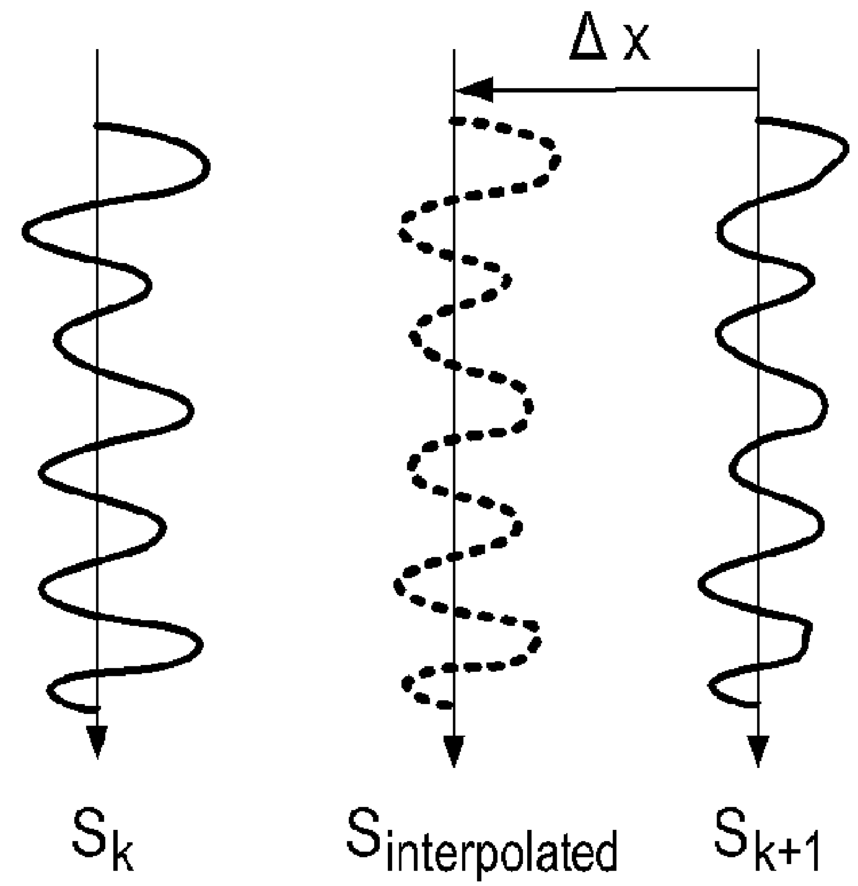


FIG. 8



ULTRASOUND STRAIN IMAGING BASED ON LATERAL DISPLACEMENT COMPENSATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority from Korean Patent Application No. 10-2010-0090655 filed on Sep. 15, 2010, the entire subject matter of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to ultrasound strain imaging, and more particularly to ultrasound strain imaging based on lateral displacement compensation in an ultrasound system.

BACKGROUND

[0003] An ultrasound system has become an important and popular diagnostic tool since it has a wide range of applications. Specifically, due to its non-invasive and non-destructive nature, the ultrasound system has been extensively used in the medical profession. Modern high-performance ultrasound systems and techniques are commonly used to produce two or three-dimensional images of internal features of an object (e.g., human organs).

[0004] Generally, the ultrasound image is displayed in a Brightness-mode (B-mode) by using reflectivity caused by an acoustic impedance difference between the tissues of the target object. However, if the reflectivity of the target object is hardly different from those of the neighboring tissues such as tumor, cancer or the like, then it is not easy to recognize the target object in the B-mode image.

[0005] To cope with the problem of recognizing the tumor, cancer and the like in the B-mode, an ultrasound elasticity imaging has been developed to visualize the mechanical characteristics of the tissues based on differences responsive to pre-compression and post-compression. Such imaging proved very helpful for diagnosing lesions such as tumor and cancer, which otherwise are hardly recognized in the B-mode image, in soft tissues (e.g., breast). The ultrasound elasticity imaging may utilize the scientific property that the elasticity of the tissues is related to a pathological phenomenon. For example, the tumor or cancer is relatively stiffer than the surrounding normal tissues. Thus, when stress is uniformly applied, a strain of the tumor or cancer may be typically smaller than those of the surrounding tissues. Strain refers to deformation of a target object due to stress applied per area and Young's modulus may be defined as a ratio of stress over strain.

[0006] Generally, if the stress is applied to a target object, then tissues in the target object may be compressed in an axial direction and moved out in a lateral direction. The conventional ultrasound elasticity imaging may use only the displacements in an axial direction to form a strain image without considering the movement in a lateral direction. Thus, there is a problem that an accurate strain image may not be formed due to a calculation error of the displacements.

SUMMARY

[0007] Embodiments for ultrasound strain imaging based on lateral displacement compensation in an ultrasound system are disclosed herein. In one embodiment, by way of non-limiting example, an ultrasound system comprises: an ultrasound data acquisition unit configured to acquire first ultrasound data where compression is not applied to a target object and second ultrasound data where compression is applied to the target object; and a processing unit configured to compensate for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data, the processing unit being further configured to form a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

[0008] In another embodiment, a method of forming a strain image in an ultrasound system, comprises: a) acquiring first ultrasound data where compression is not applied to a target object; b) acquiring second ultrasound data where compression is applied to the target object; c) compensating for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data; and d) forming a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

[0009] In another embodiment, a computer-readable storage medium storing instructions that, when executed by a computer, cause the computer to perform a method of forming a strain image, is provided. The method comprises: a) acquiring first ultrasound data where compression is not applied to a target object; b) acquiring second ultrasound data where compression is applied to the target object; c) compensating for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data; and d) forming a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

[0010] The Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in determining the scope of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a block diagram showing an illustrative embodiment of an ultrasound system.

[0012] FIG. **2** is a block diagram showing an illustrative embodiment of an ultrasound data acquisition unit of FIG. **1**.

[0013] FIG. **3** is a schematic diagram showing frames of pre-compression and post-compression.

[0014] FIG. **4** is a flowchart showing an illustrative embodiment of forming a strain image.

[0015] FIG. **5** is a schematic diagram showing an example of medium movement in a target object due to compression applied thereto.

[0016] FIG. **6** is a schematic diagram showing an example of ultrasound data of post-compression in which displacements in a lateral direction are approximately compensated.

[0017] FIG. **7** is a schematic diagram showing an example of forming a one-dimensional data sequence in a lateral direction.

[0018] FIG. **8** is a schematic diagram showing an example of post-compression ultrasound data in which displacement in a lateral direction are compensated.

DETAILED DESCRIPTION

[0019] A detailed description may be provided with reference to the accompanying drawings. One of ordinary skill in the art may realize that the following description is illustrative only and is not in any way limiting. Other embodiments of the present invention may readily suggest themselves to such skilled persons having the benefit of this disclosure.

[0020] Referring to FIG. **1**, an ultrasound system constructed in accordance with one embodiment is shown. The ultrasound system **100** may include an ultrasound data acquisition unit **110**, a processing unit **120**, a storage unit **130** and a display unit **140**.

[0021] The ultrasound data acquisition unit **110** may be configured to transmit ultrasound beams to a target object and receive ultrasound echoes reflected from the target object to thereby form ultrasound data representative of the target object. An operation of the ultrasound acquisition unit will be described in detail by referring to FIG. **2**.

[0022] FIG. **2** is a block diagram showing an illustrative embodiment of the ultrasound data acquisition unit **110**. Referring to FIG. **2**, the ultrasound data acquisition unit **110** may include a transmit signal forming section **210**. The transmit signal forming section **210** may generate a plurality of transmit signals and apply delays to the transmit signals.

[0023] The ultrasound data acquisition unit **110** may further include an ultrasound probe **220**, which is coupled to the transmit signal forming section **210**. The ultrasound probe **220** may include an array transducer containing a plurality of transducer elements for reciprocal conversion between electric signals and ultrasound signals. The ultrasound probe **220** may be configured to transmit ultrasound signals in response to the transmit signals. The ultrasound probe **220** may be further configured to receive ultrasound echoes reflected from the target object to thereby output receive signals. As shown in FIG. **3**, the receive signals may include first receive signals corresponding to a plurality scan lines S_1 to S_N, which are obtained without applying compression to the target object, and second receive signals corresponding to a plurality scan lines S_1 to S_N, which are obtained with applying compression to the target object, wherein N is an integer greater than 1. The compression may be applied by using the ultrasound probe **220**. In such a case, a compression plate may be mounted around a front side of the ultrasound probe **220**. In another embodiment, an additional device for compressing the target object may be employed.

[0024] The ultrasound data acquisition unit **110** may further include a beam forming section **230**, which is coupled to the ultrasound probe **220**. The beam forming section **230** may be configured to digitize the electrical receive signals into digital signals. The beam forming section **230** may also apply delays to the digital signals in consideration of distances between the elements of the ultrasound probe **220** and focal points. The beam forming section **230** may further sum the delayed digital signals to form receive-focused signals. In one embodiment, the beam forming section **230** may form first receive-focused signals based on the first receive signals and second receive-focused signals based on the second receive signals.

[0025] The ultrasound data acquisition unit **110** may further include an ultrasound data forming section **240**, which is coupled to the beam forming section **230**. The ultrasound data forming section **240** may be configured to form ultrasound data corresponding to a plurality of frames based on the receive-focused signals. The ultrasound data may include RF data sets or in-phase/quadrature (IQ) data sets. However, the ultrasound data may not be limited thereto. The ultrasound data forming section **240** may be further configured to perform a variety of signal processing (e.g., gain adjustment, filtering, etc.) upon the receive-focused signals. In one embodiment, the ultrasound data may include a first ultrasound data corresponding to scan lines S_i, which are formed based on the first receive-focused signals, and a second ultrasound data corresponding to scan lines S_i that are formed based on the second receive-focused signals, wherein $1 \leqq I \leqq N$.

[0026] Referring back to FIG. **1**, the processing unit **120**, which is coupled to the ultrasound data acquisition unit **110**, may be embodied with at least one of a central processing unit, a microprocessor, a graphic processing unit and the like. However, the processing unit **120** may not be limited thereto.

[0027] FIG. **4** is a flowchart showing an illustrative embodiment of forming the strain image. Referring to FIG. **4**, the processing unit **120** may be configured to compute displacement in an axial direction by using the first and second ultrasound data, which are provided from the ultrasound data acquisition unit **110**, at S**402**.

[0028] FIG. **5** is a schematic diagram showing an example of medium movement in a target object due to compression applied thereto. As shown in FIG. **5**, when the target object is compressed by applying the stress, a medium **510** may be moved by Δz in an axial direction and Δx in a lateral direction. That is, the medium **510** may be two-dimensionally moved by Δd.

[0029] The ultrasound data obtained without applying compression to the target object, i.e., the first ultrasound data, and the ultrasound data obtained with applying compression to the target object, i.e., the second ultrasound data, are defined by the following equations for modeling the compression of medium within the target object.

$$S_{pre}(z,x)=r(z,x)\ S_{post}(z,x)=r(z-\Delta z,x-\Delta x) \quad (1)$$

wherein $S_{pre}(z, x)$ represents the first ultrasound data, $S_{post}(z, x)$ represents the second ultrasound data, r(z, x) and r(z−Δz, x−Δx) represent envelopes of the first and second data.

[0030] As indicated in Equation (1), the displacement of the lateral direction should be accurately computed in addition to the displacement of the axial direction. That is, the data moved by Δd should be accurately computed to compute an accurate displacement. When computing the displacement of the axial direction without considering the displacement of the lateral direction, a displacement Δz' of the axial direction including an error is merely computed.

[0031] The processing unit **120** may be configured to approximately compensate for the displacement of the axial direction in the post-compression ultrasound data, i.e., the second ultrasound data, based on the displacement Δz' of the axial direction including an error, at S**404**. In one embodiment, the processing unit **120** may be configured to apply the displacement Δz' of the axial direction including an error to Equation (1) to thereby compensate for the displacement Δz of the axial direction, as the following equation (2).

$$S_{pre}(z,x)=r(z,x)\ S_{post}(z+\Delta z',x)=r(z+\Delta z',x-\Delta x) \quad (2)$$

[0032] In Equation (2), assuming that Δz'≈Δz, the displacement of the lateral displacement is merely remained. FIG. **6** is a schematic diagram showing an example of ultrasound data of post-compression in which displacements in a lateral direction are approximately compensated.

[0033] The processing unit **120** may be configured to form a one-dimensional data sequence in a lateral direction for the second ultrasound data whose displacement of the axial direction has been approximately compensated, as shown in

FIG. **7**, and to form one-dimensional data sequence in a lateral direction for the first ultrasound data, at S**406**. The one-dimensional data sequence may be formed by various well-known methods. Thus, detailed description thereof will be omitted herein.

[0034] The processing unit is configured to perform Hilbert transform upon the one-dimensional data sequence corresponding to the first ultrasound data and the one-dimensional data sequence corresponding to the second ultrasound data to form first analytic data corresponding to the first ultrasound data and second analytic data corresponding to the second ultrasound data, as S**408**. In one embodiment, the first analytic data and the second analytic data are complex data.

[0035] The processing unit **120** may be configured to compute the displacement Δx of the lateral direction by using a phase between the first analytic data and the second analytic data, at S**410**. The processing unit **120** may be configured to compensate for the displacement of the lateral direction in the second ultrasound data based on the computed Ax of the lateral direction, at S**412**. In one embodiment, the processing unit **120** may be configured to form interpolation data for compensating movement in a lateral direction by using the computed Δx of the lateral direction, as shown in FIG. **8**. For example, the processing unit **120** may be configured to determine two scan lines S_k and S_{k+1} from scan lines of the second ultrasound data based on the computed Δx of the lateral direction, as shown in FIG. **8**. The processing unit **120** may be configured to interpolate ultrasound data corresponding to the determined two scan lines from S_k and S_{k+1} from the second ultrasound data in which the displacement of the axial direction is approximately compensated, thereby forming interpolation data corresponding to an interpolation scan line $S_{interpolation}$.

[0036] The processing unit **120** may be configured to perform auto-correlation upon the first ultrasound data and the interpolation data to compute a displacement in an axial direction, at **5414**. The processing unit **120** may be configured to form the strain image by using the computed displacement of the axial direction, at **5416**.

[0037] Referring to FIG. **1**, the storage unit **130**, which is coupled to the ultrasound data acquisition unit **110** via the processing unit **120**, is configured to store the ultrasound data acquired in the ultrasound data acquisition unit **110**. Also, the storage unit **130** may be configured to store the computed displacements. The display unit **140** may display the strain image, which has been formed in the processing unit **120**. The display unit **140** may include at least one of a cathode ray tube (CRT) display, a liquid crystal display (LCD), an organic light emitting diode (OLED) display and the like.

[0038] In another embodiment, a computer-readable storage medium storing instructions that, when executed by a computer, cause the computer to perform a method of forming a strain image, is provided. The method comprises: acquiring first ultrasound data where compression is not applied to a target object; acquiring second ultrasound data where compression is applied to the target object; compensating for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data; and forming a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

[0039] Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, numerous variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

1. An ultrasound system, comprising:

an ultrasound data acquisition unit configured to acquire first ultrasound data where compression is not applied to a target object and second ultrasound data where compression is applied to the target object; and

a processing unit configured to compensate for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data, the processing unit being further configured to form a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

2. The ultrasound system of claim **1**, wherein the processing unit is configured to:

compute the displacement in an axial direction based on the first ultrasound data and the second ultrasound data,

compensate for displacement in an axial direction in the second ultrasound data based on the computed displacements of the axial direction,

compute displacement in a lateral direction based on the first ultrasound data and the axial displacement compensated second ultrasound data, and

compensate for displacement in a lateral direction in the axial displacement compensated second ultrasound data based on the computed displacement in the lateral direction.

3. The ultrasound system of claim **2**, wherein the processing unit is configured to:

form a one-dimensional data sequence in a lateral direction from the first ultrasound data,

form a one-dimensional data sequence in a lateral direction from the axial displacement compensated second ultrasound data,

perform Hilbert transform upon the one-dimensional data sequence corresponding to the first ultrasound data and the one-dimensional data sequence corresponding to the axial displacement compensated second ultrasound data to form first analytic data corresponding to the first ultrasound data and second analytic data corresponding to the axial displacement compensated second ultrasound data, respectively, and

compute displacement in the lateral direction by using a phase between the first analytic data and the second analytic data.

4. The ultrasound system of claim **3**, wherein the first analytic data and the second analytic data include complex data.

5. The ultrasound system of claim **3**, wherein the processing unit is configured to determine two scan lines in the axial displacement compensated second ultrasound based on the displacement of the lateral direction, and interpolate ultrasound data corresponding to the determined two scan lines in the axial displacement compensated second ultrasound to form interpolation data.

6. The ultrasound system of claim **5**, wherein the processing unit is configured to perform auto-correlation upon the first ultrasound data and the interpolation data to compute the displacement of the axial direction, and form the strain image based on the computed displacement of the axial direction.

7. A method of forming a strain image in an ultrasound system, comprising:

a) acquiring first ultrasound data where compression is not applied to a target object;

b) acquiring second ultrasound data where compression is applied to the target object;

c) compensating for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data; and

d) forming a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

8. The method of claim **7**, wherein the step c) includes:

c1) computing the displacement in the axial direction based on the first ultrasound data and the second ultrasound data;

c2) compensating for displacement in an axial direction in the second ultrasound data based on the computed displacements of the axial direction;

c3) computing displacement in a lateral direction based on the first ultrasound data and the axial displacement compensated second ultrasound data, and

c4) compensating for displacement in a lateral direction in the axial displacement compensated second ultrasound data based on the computed displacement in the lateral direction.

9. The method of claim **8**, wherein the step c3) includes:

forming a one-dimensional data sequence in a lateral direction from the first ultrasound data;

performing Hilbert transform upon the one-dimensional data sequence corresponding to the first ultrasound data to form first analytic data corresponding to the first ultrasound data;

forming a one-dimensional data sequence in a lateral direction from the axial displacement compensated second ultrasound data;

performing Hilbert transform upon the one-dimensional data sequence corresponding to the axial displacement compensated second ultrasound data to form second analytic data corresponding to the axial displacement compensated second ultrasound data; and

computing the displacement in the lateral direction by using a phase between the first analytic data and the second analytic data.

10. The method of claim **9**, wherein the first analytic data and the second analytic data include complex data.

11. The method of claim **9**, wherein the step c4) includes:

determining two scan lines in the axial displacement compensated second ultrasound based on the displacements of the lateral direction; and

interpolating ultrasound data corresponding to the determined two scan lines in the axial displacement compensated second ultrasound to form interpolation data.

12. The method of claim **11**, wherein the step d) includes:

performing auto-correlation upon the first ultrasound data and the interpolation data to compute the displacement of the axial direction; and

forming the strain image based on the computed displacement of the axial direction.

13. A computer-readable storage medium storing instructions that, when executed by a computer, cause the computer to perform a method of forming a strain image, the method comprising:

a) acquiring first ultrasound data where compression is not applied to a target object;

b) acquiring second ultrasound data where compression is applied to the target object;

c) compensating for displacements in axial and lateral directions in the second ultrasound data based on the first ultrasound data and second ultrasound data; and

d) forming a strain image based on the first ultrasound data and the axial and lateral displacement compensated second ultrasound data.

* * * * *

专利名称(译)	基于横向位移补偿的超声应变成像		
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[标]申请(专利权)人(译)	三星麦迪森株式会社		
申请(专利权)人(译)	三星MEDISON CO.，LTD.		
当前申请(专利权)人(译)	三星MEDISON CO.，LTD.		
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发明人	JEONG, MOK KUN KWON, SUNG JAE SHIN, DONG KUK		
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摘要(译)

公开了通过在超声系统中补偿向后方向上的位移来形成应变图像的实施例。在一个实施例中，超声系统包括：超声数据获取单元，被配置为获取第一超声数据，其中压缩未被应用于目标对象;以及第二超声数据，其中压缩被应用于目标对象;处理单元，被配置为基于第一超声数据和第二超声数据补偿第二超声数据中的轴向和横向的位移，处理单元还被配置为基于第一超声数据和轴的形成应变图像横向位移补偿第二超声数据。