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PROCESSING IN AN ULTRASOUND SYSTEM****Publication Classification**(75) Inventors: **Chi Young AHN**, Seoul (KR); **Suk
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Oct. 30, 2008 (KR) 10-2008-0106811(57) **ABSTRACT**

Embodiments for ultrasound data processing in an ultrasound system are disclosed. In one embodiment, a mapping table, in which linear operation information is associated with a plurality of diagnostic modes, is stored in a storage unit. If there is an instruction to select at least one of the diagnostic modes, then an ultrasound data acquisition unit transmits/receives ultrasound signals to/from a target object to thereby acquire ultrasound data according to the selected diagnostic mode. A processing unit forms an ultrasound data matrix based on the ultrasound data and retrieves the linear operation information associated with the selected diagnostic mode from the mapping table to form linear operation matrices. Further, the processing unit performs a matrix operation of the ultrasound data matrix and the linear operation matrices.

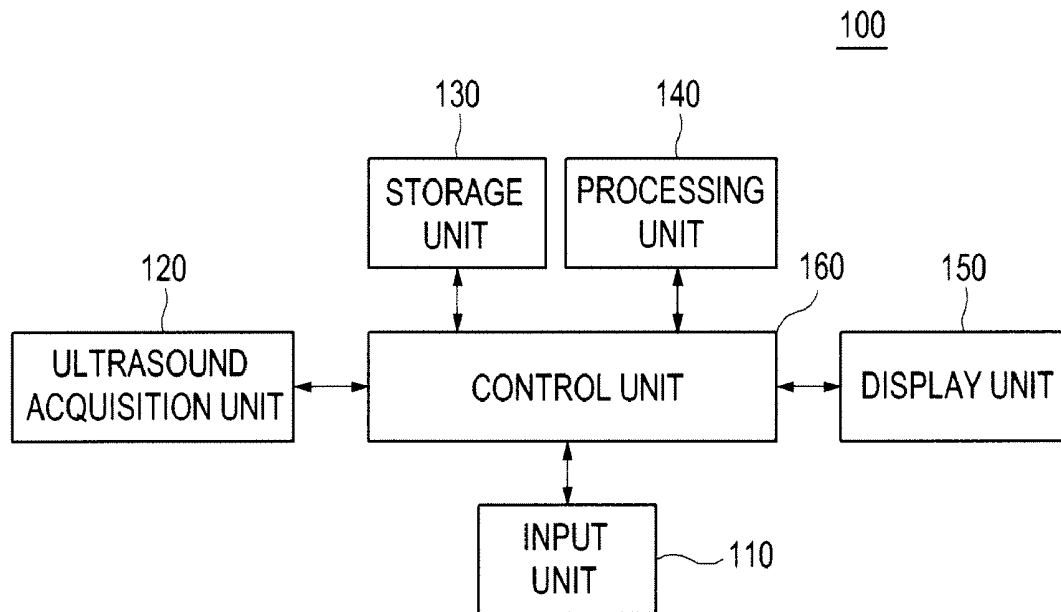


FIG. 1

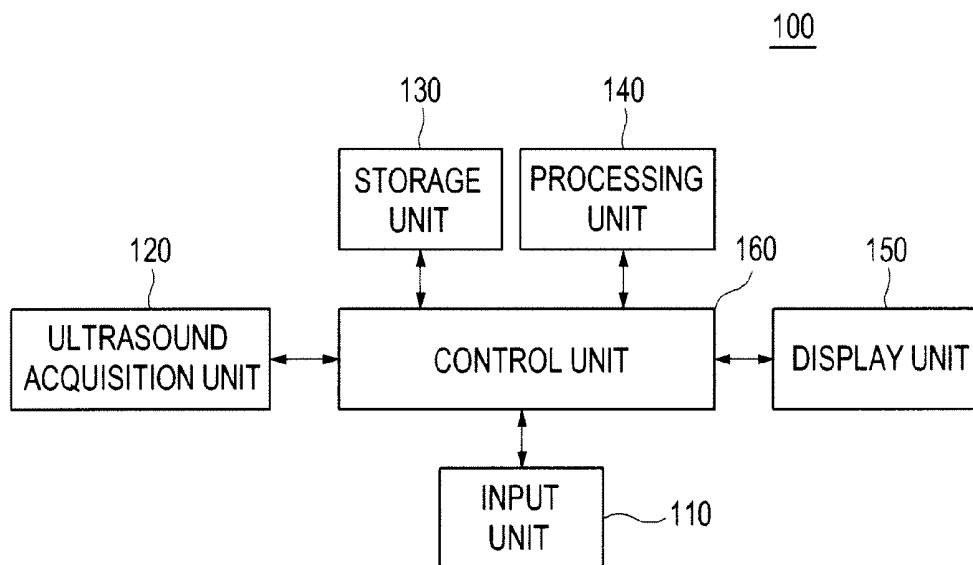


FIG. 2

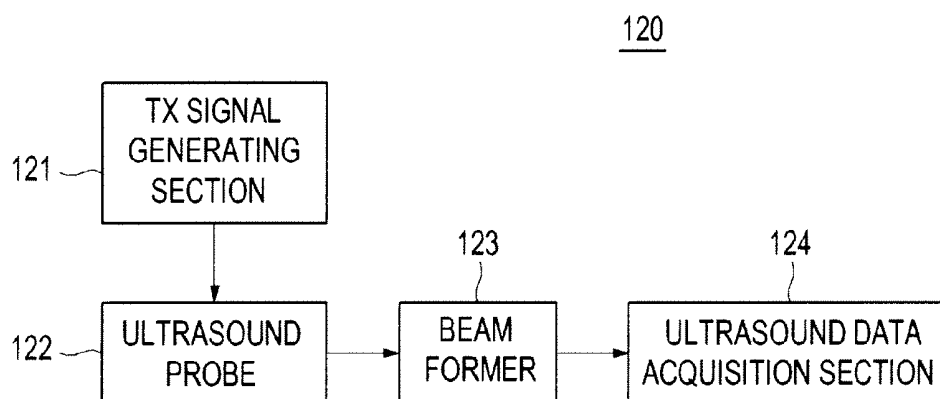


FIG. 3

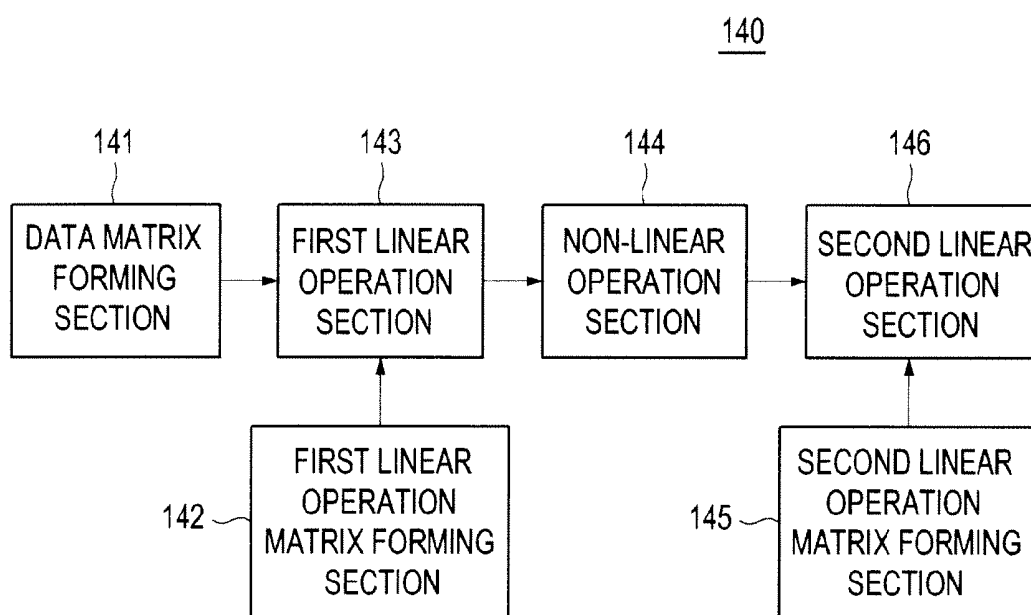


FIG. 4

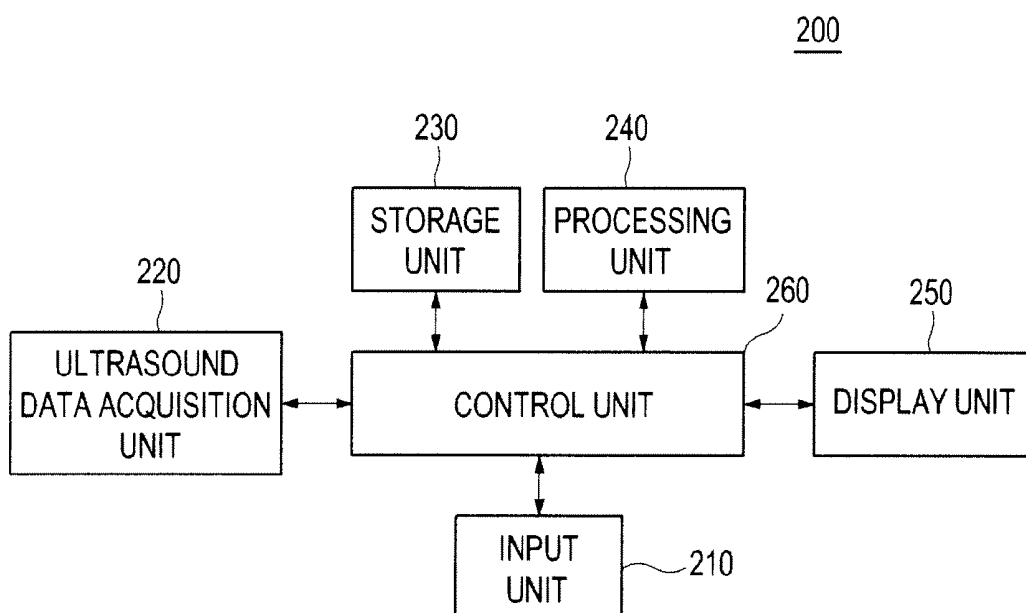


FIG. 5

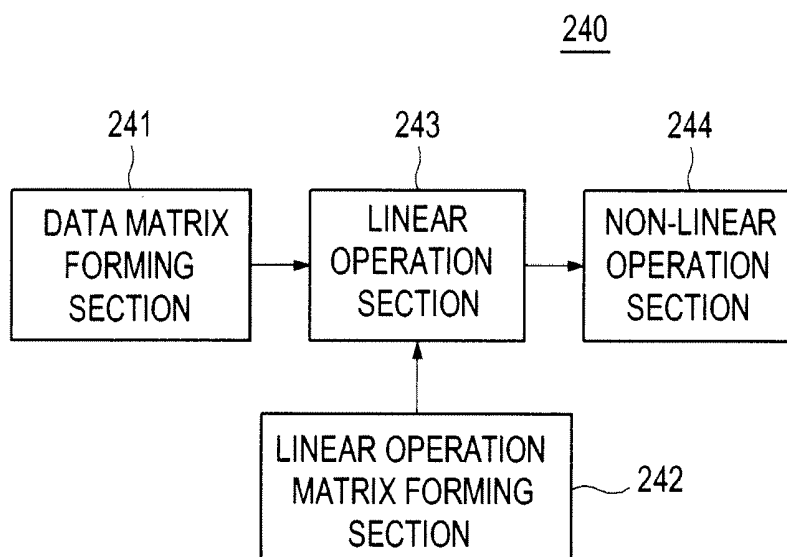


FIG. 6

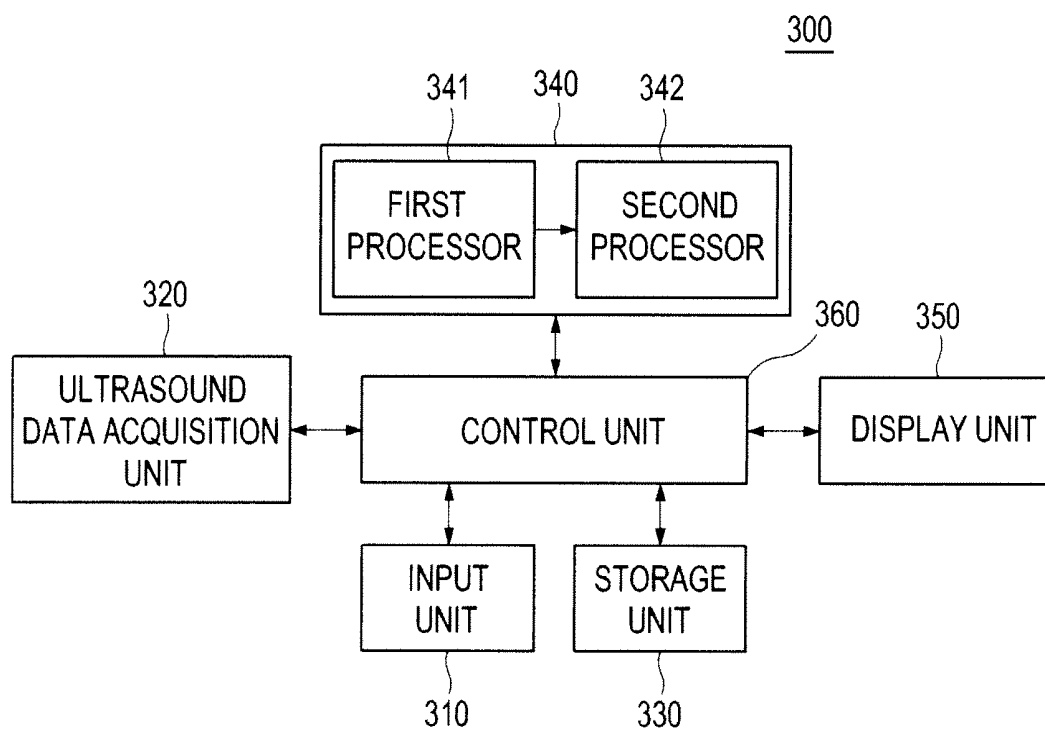


FIG. 7

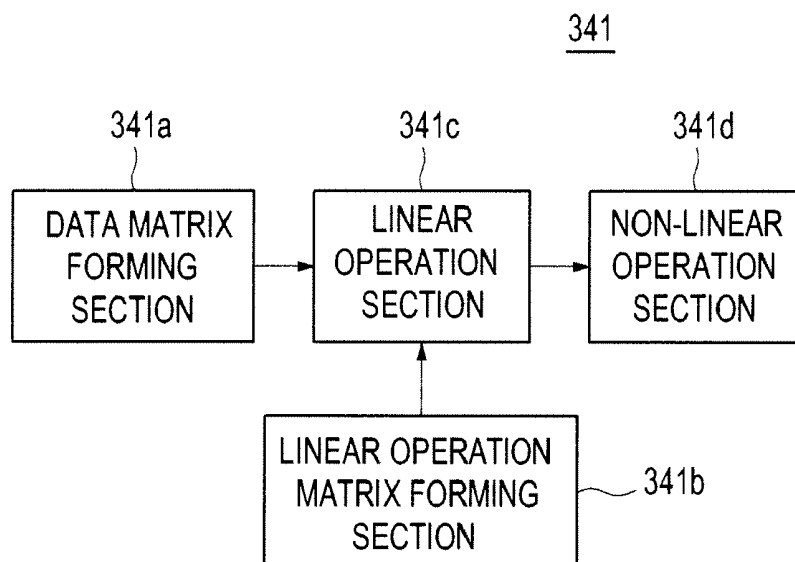


FIG. 8

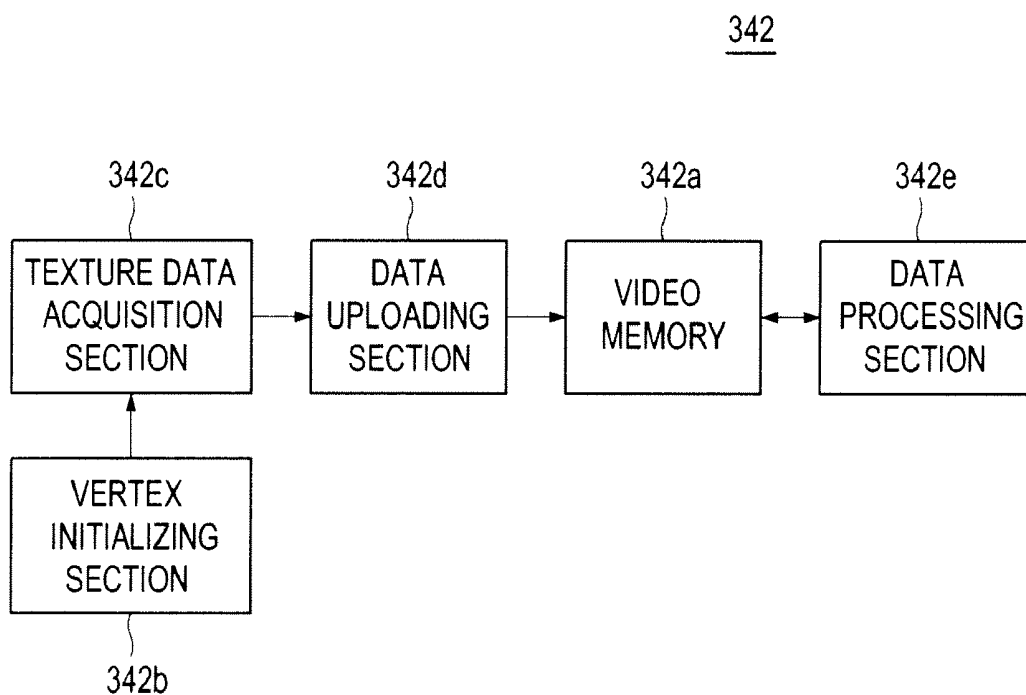


FIG. 9

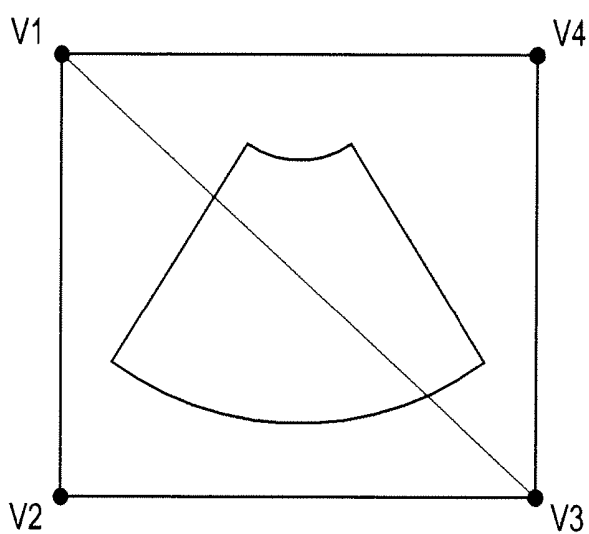


FIG. 10

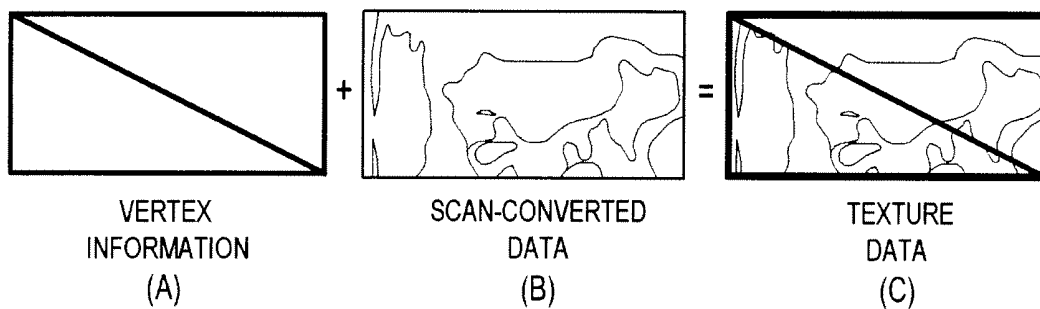


FIG. 11

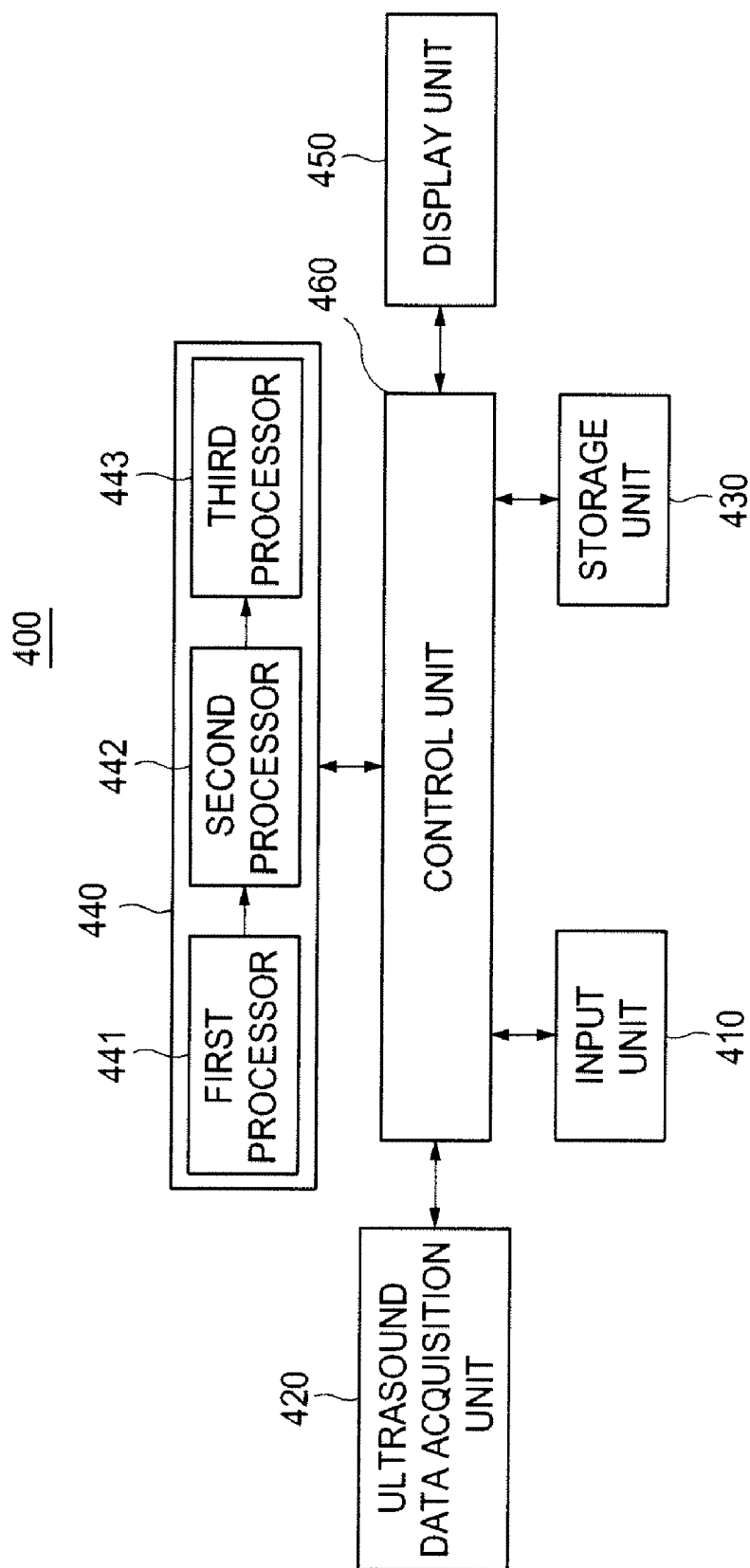


FIG. 12

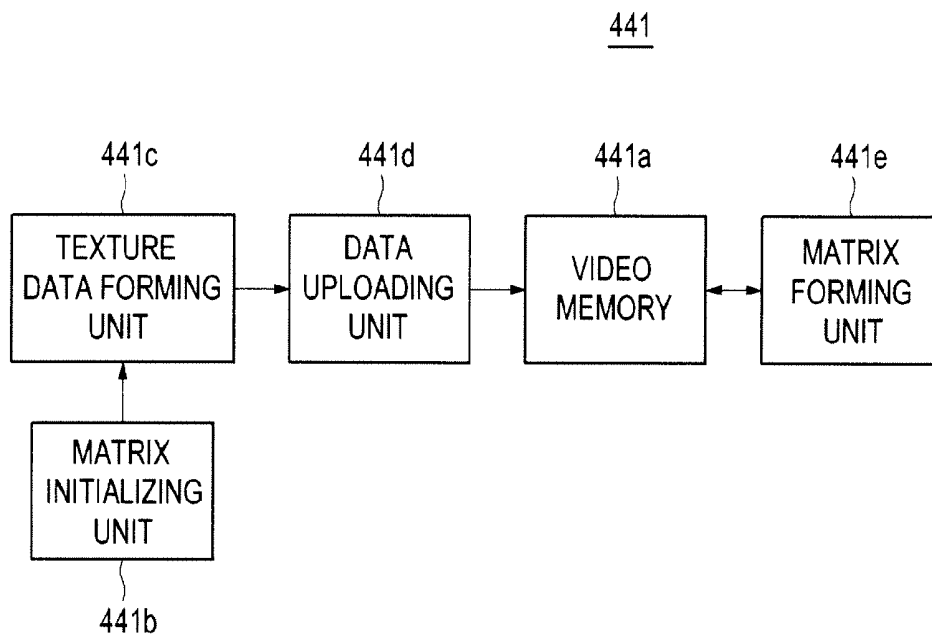


FIG. 13

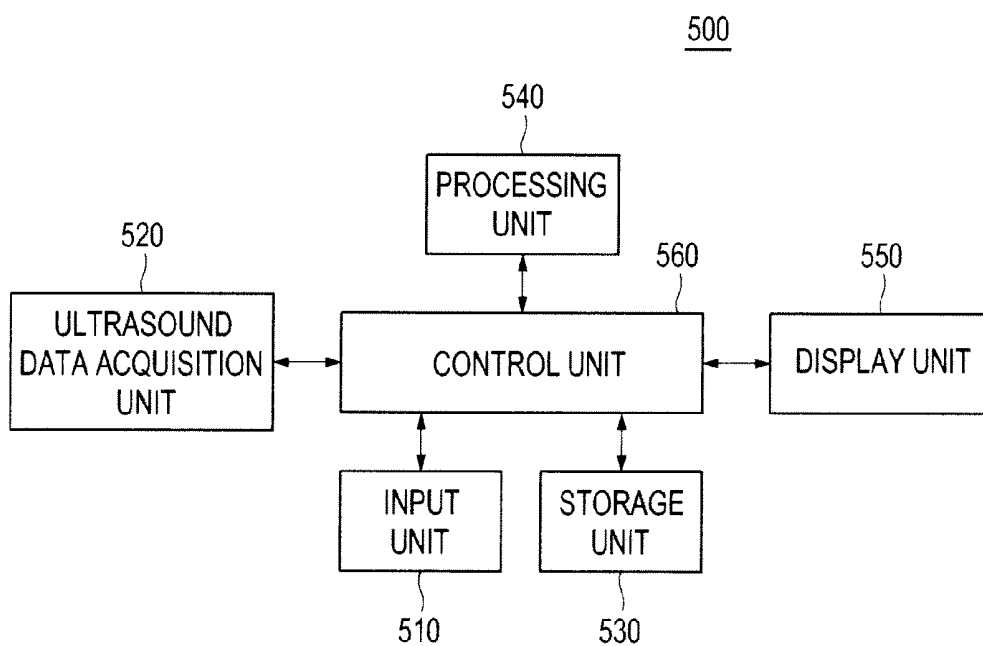
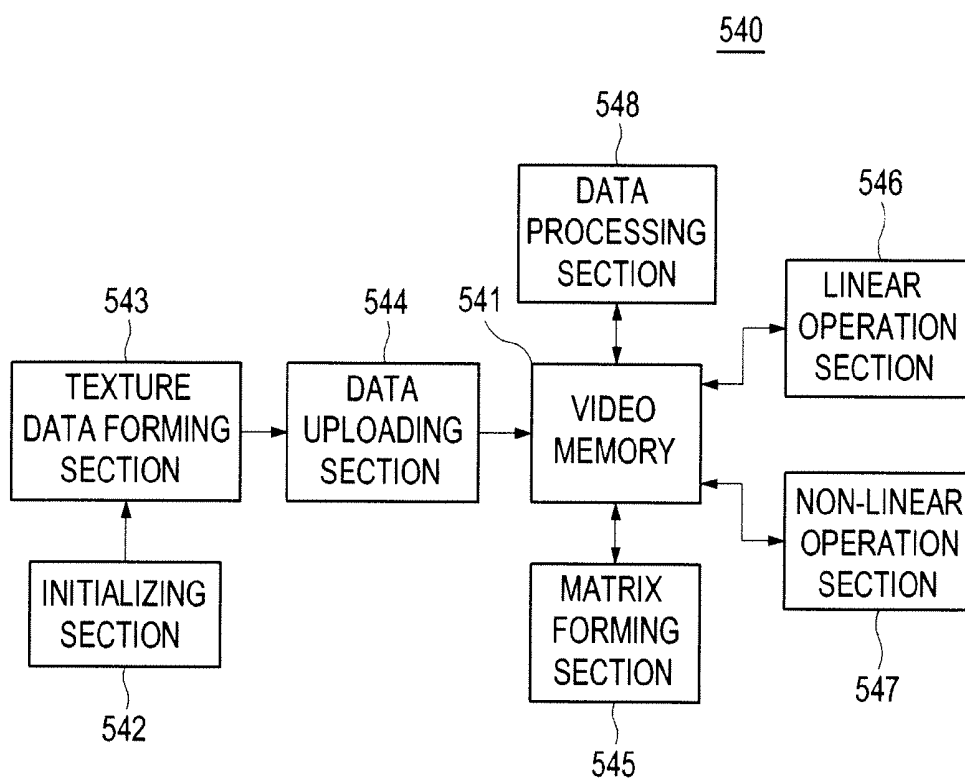


FIG. 14



ENHANCED ULTRASOUND DATA PROCESSING IN AN ULTRASOUND SYSTEM

[0001] The present application claims priority from Korean Patent Application Nos. 10-2008-66718 and 10-2008-106811 filed on Jul. 9, 2008 and Oct. 30, 2008, respectively, the entire subject matters of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to ultrasound systems, and more particularly to enhanced ultrasound data processing in an ultrasound system.

BACKGROUND

[0003] Recently, an ultrasound system has been extensively used in the medical field due to its non-invasive and non-destructive nature. Modern high-performance ultrasound imaging systems and techniques are commonly used to produce two dimensional ultrasound images and three-dimensional ultrasound images of internal features of patients.

[0004] Generally, to form the ultrasound images, time gain compensation, filtering (e.g., finite impulse response filtering), decimation, in-phase/quadrature-phase (I/Q) data formation, compression, scan conversion and the like should be sequentially performed. Thus, problems arise since it takes a long time to form the ultrasound image data, which makes it difficult to increase a frame rate.

SUMMARY

[0005] Embodiments for enhanced ultrasound data processing in an ultrasound system are disclosed herein. In one embodiment, by way of non-limiting example, an ultrasound system comprises: a storage unit for storing a mapping table having linear operation information associated with a plurality of diagnostic modes; an input unit for allowing a user to input an instruction to select at least one of the diagnostic modes; an ultrasound data acquisition unit operable to transmit/receive ultrasound signals to/from a target object according to the selected diagnostic mode to thereby acquire ultrasound data; and a processing unit operable to form an ultrasound data matrix based on the ultrasound data and retrieve the linear operation information associated with the selected diagnostic mode from the mapping table to form linear operation matrices, the processing unit being further operable to perform a linear operation upon the ultrasound data matrix and the linear operation matrices and perform at least one non-linear operation upon the ultrasound data.

[0006] In another embodiment, a method of processing ultrasound data in an ultrasound system, comprises: a) storing a mapping table associating linear operation information with a plurality of diagnostic modes; b) receiving an instruction to select at least one of the diagnostic mode; c) transmitting/receiving ultrasound signals to/from a target object to thereby acquire ultrasound data according to the selected diagnostic mode; and d) forming an ultrasound data matrix based on the ultrasound data, retrieving the linear operation information associated with the selected diagnostic mode from the mapping table to form linear operation matrices, and performing a linear operation upon the ultrasound data matrix and the linear operation matrices.

[0007] 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

[0008] FIG. 1 is a block diagram showing an ultrasound system in accordance with a first embodiment.

[0009] FIG. 2 is a block diagram showing an ultrasound data acquisition unit in accordance with a first embodiment.

[0010] FIG. 3 is a block diagram showing a processing unit in accordance with a first embodiment.

[0011] FIG. 4 is a block diagram showing an ultrasound system in accordance with a second embodiment.

[0012] FIG. 5 is a block diagram showing a processing unit in accordance with a second embodiment.

[0013] FIG. 6 is a block diagram showing an ultrasound system in accordance with a third embodiment.

[0014] FIG. 7 is a block diagram showing a first processing unit in accordance with a third embodiment.

[0015] FIG. 8 is a block diagram showing a second processing unit in accordance with a third embodiment.

[0016] FIG. 9 is a schematic diagram showing an example of vertex initialization in accordance with a third embodiment.

[0017] FIG. 10 is an exemplary diagram showing an example of forming texture data in accordance with a third embodiment.

[0018] FIG. 11 is a block diagram showing an ultrasound system in accordance with a fourth embodiment.

[0019] FIG. 12 is a block diagram showing a first processing unit in accordance with a fourth embodiment.

[0020] FIG. 13 is a block diagram showing an ultrasound system in accordance with a fifth embodiment.

[0021] FIG. 14 is a block diagram showing a processing unit in accordance with a fifth embodiment.

DETAILED DESCRIPTION

[0022] 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.

First embodiment

[0023] Referring to FIG. 1, an ultrasound system 100 may include an input unit 110 that may be operable to allow a user to input instructions. In one embodiment, the instructions may include an instruction for selecting one of diagnostic modes provided by the ultrasound system 100. The input unit 110 may include a control panel, a mouse, a keyboard, a track ball and the like. However, it is not limited thereto.

[0024] The ultrasound system 100 may further include an ultrasound data acquisition unit 120. The ultrasound data acquisition unit 120 may be operable to transmit/receive ultrasound signals to/from the target object, thereby outputting ultrasound data. The ultrasound data acquisition unit 120 may include a transmit (Tx) pulse signal generating section 121, as shown in FIG. 2. The Tx pulse signal generating section 121 may be operable to generate a plurality of Tx

pulse signals. The ultrasound data acquisition unit **120** may further include an ultrasound probe **122** containing a plurality of elements for reciprocally converting ultrasound signals and electrical signals. The ultrasound probe **122** may be operable to transmit ultrasound signals into a target object in response to the Tx pulse signals. The ultrasound probe **122** may be further operable to receive echo signals reflected from the target object to thereby output electrical receive signals, which may be analog signals. In one embodiment, the ultrasound probe **122** may be a convex probe, a linear probe, a 3-dimensional probe, a trapezoidal probe, an IVUS probe or the like. However, it is not limited thereto.

[0025] The ultrasound data acquisition unit **120** may further include a beam former **123**. The beam former may be operable to convert the electrical receive signals into digital signals. The beam former **123** may be further operable to apply delays to the digital signals in consideration of distances between the elements and focal points, thereby outputting digital receive-focused signals. In one embodiment, the beam former **123** may be configured with a field programmable gate array (FPGA) or an application specific integrated circuit (ASIC) to enhance a processing speed of the receive signals.

[0026] The ultrasound data acquisition unit **120** may further include an ultrasound data forming section **124** that may be operable to form the ultrasound data corresponding to at least one frame of an ultrasound image based on the digital receive-focused signals. In one embodiment, the ultrasound image may include a brightness mode (B-mode), a Doppler mode (D-mode) image, a color (C) mode image, an elastic (E) mode image and a 3-dimensional (3D) mode image. The B-mode image may be represented with gray scales based on reflectivity of the ultrasound signals in the target object. The D-mode image may represent velocities of a moving object (e.g., blood flow) with spectral Doppler by using Doppler effect. The C-mode image may represent velocities of a moving object with colors and the E mode image may be obtained by using displacements of the target object before and after applying a pressure thereto. The 3D-mode may 3-dimensionally display an ultrasound image based on the reflectivity of ultrasound signals in the target object. Although it is described that the diagnostic mode includes the B-mode, D-mode, 3D-mode, C-mode and E-mode, the diagnostic mode is not limited thereto.

[0027] Referring again to FIG. 1, the ultrasound system **100** may further include a storage unit **130**. The storage unit **130** may store the ultrasound data corresponding to at least one frame of an ultrasound image. The storage unit **130** may further store information upon linear operations (hereinafter, referred to as linear operation information) to be explained later. In one embodiment, the storage unit **130** may store a mapping table in which the linear operation information is associated with diagnostic modes as shown in Table 1.

TABLE 1

Diagnostic mode	Linear operation information
B-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, scan conversion parameters
D-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, clutter filter parameters, FFT parameters, scan conversion parameters

TABLE 1-continued

Diagnostic mode	Linear operation information
C-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, clutter filter parameters, scan conversion parameters
E-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, scan conversion parameters
3D mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, rendering parameters

[0028] In one embodiment, the storage unit **130** may include a first storage section (not shown) for storing the ultrasound data corresponding to at least one frame of an ultrasound image and a second storage section (not shown) for storing the mapping table.

[0029] The ultrasound system **100** may further include a processing unit **140**. The processing unit **140** may be operable to form a plurality of linear operation matrices to be used for performing linear operations (e.g., matrix multiplication) upon the ultrasound data. In one embodiment, the linear operations may include time gain compensation (TGC) for compensating for attenuation of the ultrasound signals in the target object, decimation for adjusting amount of the ultrasound data, quadrature mixing for forming in-phase/quadrature (I/Q) data, finite impulse response (FIR) filtering, clutter filtering, fast Fourier transform (FFT), scan conversion and interpolation, rendering and the like. However, they are not limited thereto. The linear operation information may be TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, clutter filter parameters, FFT parameters, scan conversion parameters, rendering parameters and the like. The linear operation matrices may be formed by searching the mapping table in response to an instruction for selecting a desired diagnostic mode, which is inputted through the input unit **110**. The processing unit **140** may be further operable to perform a plurality of linear operations corresponding to the selected diagnostic mode by using the linear operation matrices and perform non-linear operations upon the ultrasound data. In one embodiment, the non-linear operations may include envelope detection, compression, auto correlation, arctangent operation, a least mean square operation, a differential operation and the like, but are not limited thereto. The processing unit **140** may be configured with one of a central processing unit, FPGA, ASIC, a digital signal processing chip and the like.

[0030] FIG. 3 is a block diagram showing an illustrative embodiment of the processing unit **140**. As shown in FIG. 3, the processing unit **140** may include an ultrasound data matrix forming section **141**. The ultrasound data matrix forming section **141** may be operable to form a first ultrasound data matrix based on the ultrasound data provided from the ultrasound data acquisition unit **120** or stored in the storage unit **130**. In one embodiment, the ultrasound data may be obtained by scanning a plurality of scan lines and sampling electrical receive signals, which are outputted in response to echo signals reflected from the scan lines. That is, the ultrasound data may correspond to a plurality of sampling points on the scan lines. Thus, the first ultrasound data matrix may be formed to have a size of the number of sampling points on one scan line×the number of the scan lines.

[0031] The processing unit **140** may further include a first linear operation matrix forming section **142**. The first linear operation matrix forming section **142** may be operable to retrieve the linear operation information from the mapping

table in response to an instruction for selecting a desired diagnostic mode, which is inputted through the input unit 110. The first linear operation matrix forming section 142 may be further operable to form a first linear operation matrix by using the retrieved linear operation information.

[0032] In one embodiment, if the instruction for selecting the B-mode is inputted through the input unit 110, the first linear operation matrix forming section 142 may be operable to retrieve the linear operation information associated with the B-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the quadrature mixer parameters and the FIR filter parameters. The first linear operation matrix forming section 142 may be operable to form a TGC matrix, a decimation matrix, a FIR filtering matrix and a quadrature mixing matrix by using the retrieved parameters. Each of the matrices may be multiply formed according to the necessity thereof. The size of each of the matrices may be changed depending on the resolution of the display unit 150. In one embodiment, the TGC matrix may be represented by a diagonal matrix, as follows:

$$TGC \text{ matrix} = \begin{bmatrix} g_0 & 0 & 0 & 0 & \dots & 0 \\ 0 & g_1 & 0 & 0 & \dots & 0 \\ 0 & 0 & g_2 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \dots & g_{s-1} \end{bmatrix}$$

wherein g_i is a TGC parameter and s is the number of the sample points.

[0033] The decimation matrix may be determined by decimating rows from a unit matrix according to a decimation rate. The decimation matrix may have a size of the number of sampling points after the decimation $\times$ the number of sampling points before the decimation. For example, when the decimation rate is 2, the decimation matrix may be determined as follows:

$$\text{Decimation matrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & \dots & 0 \\ \vdots & & & \vdots & & & & \ddots & \vdots \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & \dots & 0 \\ & & & & & & & \ddots & \vdots \end{bmatrix}$$

[0034] Also, when the decimation rate is 3, the decimation matrix may be determined as follows:

$$\text{Decimation matrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & \dots & 0 \\ \vdots & & & \vdots & & & & \ddots & \vdots \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & \dots & 0 \\ & & & & & & & \ddots & \vdots \end{bmatrix}$$

[0035] The FIR filtering matrix may be represented by a square band matrix, which has a bandwidth corresponding to the number of taps, as follows:

$$FIR \text{ filter matrix} = \begin{bmatrix} f_7 & \dots & f_0 & 0 & \dots & \dots & 0 \\ \vdots & \vdots & \vdots & f_0 & & & \\ f_{14} & \vdots & \vdots & \vdots & \ddots & & \vdots \\ 0 & f_{14} & \vdots & \vdots & \ddots & & \\ \vdots & \vdots & \vdots & \vdots & \ddots & \ddots & 0 \\ & & & & \ddots & \ddots & f_0 \\ & & & & & \ddots & \vdots \\ 0 & \dots & \dots & 0 & f_{14} & \dots & f_7 \end{bmatrix}$$

wherein f_i is a FIR filter parameter.

[0036] The quadrature mixer matrix may be represented by a diagonal matrix, as follows:

$$\text{Quadrature mixer matrix} = \begin{bmatrix} q_0 & 0 & 0 & 0 & \dots & 0 \\ 0 & q_1 & 0 & 0 & \dots & 0 \\ 0 & 0 & q_2 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \dots & q_{s-1} \end{bmatrix}$$

wherein q_i is a quadrature mixer parameter and s is the number of the sampling points before or after the decimation.

[0037] The first linear operation matrix forming section 142 may be operable to perform a linear operation (e.g., matrix multiplication) of the TGC matrix, the decimation matrix, the FIR filter matrix and the quadrature matrix to thereby form the first linear operation matrix.

[0038] If the instruction for selecting the D-mode is inputted through the input unit 110, then the first linear operation matrix forming section 142 may be operable to retrieve the linear operation information associated with the D-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the quadrature mixer parameters, the FIR filter parameters, the clutter filter parameters and the FFT parameters. The first linear operation matrix forming section 142 may be operable to form a TGC matrix, a decimation matrix, a FIR filter matrix, a quadrature matrix, a clutter filter matrix and a FFT matrix by using the retrieved parameters. The size of each of the matrices may be changed depending on the resolution of the display unit 150. In one embodiment, the clutter filter matrix may be represented by a Teoplitz matrix, as follows:

$$\text{Clutter filter matrix} = \begin{bmatrix} k_1 & 0 & 0 & 0 & \dots & 0 \\ k_2 & k_1 & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ k_N & \dots & k_2 & k_1 \end{bmatrix}$$

wherein k_i is a clutter filter parameter. In one embodiment, although the clutter filter is represented by the Teoplitz matrix, the clutter filter is not limited thereto.

[0039] Also, the FFT matrix may be represented as follows.

$$FFT \text{ matrix} = \begin{bmatrix} 1 & 1 & \dots & 1 \\ 1 & e^{-j2\pi/N} & \dots & e^{-j2\pi(N-1)/N} \\ 1 & e^{-j2\pi 2/N} & \dots & e^{-j2\pi 2(N-1)/N} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & e^{-j2\pi(N-1)/N} & \dots & e^{-j2\pi(N-1)^2/N} \end{bmatrix}$$

[0040] The first linear operation matrix forming section 142 may be operable to perform linear operations (e.g., matrix multiplication) of the TGC matrix, the decimation matrix, the FIR filter matrix, the quadrature mixer matrix, the clutter filter matrix and the FFT matrix to thereby form the first linear operation matrix.

[0041] If the instruction for selecting the C-mode is inputted through the input unit 110, then the first linear operation matrix forming section 142 may be operable to retrieve the linear operation information associated with the C-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the FIR filter parameter, the quadrature mixer parameters and the clutter filter parameters. The first linear operation matrix forming section 142 may be operable to form a TGC matrix, a decimation matrix, an FIR filter matrix, a quadrature matrix and a clutter filter matrix by using the retrieved parameters. In one embodiment, the clutter filter matrix may be determined to have a size of the ensemble number (or packet number), as follows:

$$\text{Clutter filter matrix} = \begin{bmatrix} c_{0,0} & c_{0,1} & \dots & c_{0,n-1} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n-1,0} & c_{n-1,1} & \dots & c_{n-1,n-1} \end{bmatrix}$$

wherein $C_{i,j}$ represents a clutter filter parameter and n is the ensemble number.

[0042] Although it is described above that the B-mode, the D-mode and the C-mode are performed, the E-mode or the 3D-mode may be also performed in the same manner as the B-mode, the D-mode and the C-mode.

[0043] The processing unit 140 may further include a first linear operation section 143. The first linear operation section 143 may be operable to perform a linear operation (e.g., matrix multiplication) of the first ultrasound data matrix and the first linear operation matrix, thereby outputting a second ultrasound data matrix. For example, assuming that the first data matrix is A and the first linear operation matrix is B, the first linear operation section 143 may be operable to perform the matrix operation of $B \times A$.

[0044] The processing unit 140 may further include a non-linear operation section 144. The non-linear operation unit 144 may be operable to perform non-linear operations upon the ultrasound data contained in the second data matrix according to the selected diagnostic mode, thereby outputting a third ultrasound data matrix. In one embodiment, if the B-mode or the 3D-mode is selected, then the non-linear operation unit 144 may be operable to perform the non-linear operations (e.g., envelope detection and compression) upon the ultrasound data contained in the second data matrix, thereby outputting the third ultrasound data matrix. If the D-mode is selected, then the non-linear operation unit 144

may be operable to perform the non-linear operation (e.g., compression) upon the ultrasound data contained in the second data matrix, thereby outputting the third ultrasound data matrix. If the C-mode is selected, then the non-linear operation unit 144 may be operable to perform the non-linear operations (e.g., auto correlation and arctangent operation) upon the ultrasound data contained in the second data matrix, thereby outputting the third ultrasound data matrix. Further, if the E-mode is selected, then the non-linear operation unit 144 may be operable to perform the non-linear operations (e.g., auto correlation, least mean square operation and differential operation) upon the ultrasound data contained in the second data matrix, thereby outputting the third ultrasound data matrix.

[0045] The processing unit 140 may further include a second linear operation matrix forming section 145. The second linear operation matrix forming section 145 may be operable to perform linear operations upon the third ultrasound data matrix. The linear operations to be performed in the second linear operation matrix forming section 145 may include scan conversion and interpolation, rendering or the like. The second linear operation matrix forming section 145 may be operable to retrieve linear operation information associated with the selected diagnostic mode from the mapping table. The second linear operation matrix forming section 145 may be further operable to form a second linear operation matrix by using the retrieved linear operation information. In one embodiment, if one of the B-mode, D-mode, C-mode and E-mode is selected, then the second linear operation matrix forming section 145 may be operable to retrieve the scan conversion parameters from the mapping table. The second linear operation matrix forming section 145 may be further operable to form a second linear operation matrix for scan conversion and interpolation of the third ultrasound data matrix by using the retrieved scan conversion parameters. The second linear operation matrix may be represented in consideration of a geometry of the ultrasound probe 122, as follows:

Second linear operation matrix =

$$\begin{bmatrix} \alpha_{0,0} & \alpha_{0,1} & 0 & 0 & \dots & 0 & 0 \\ 0 & \alpha_{1,1} & \alpha_{1,2} & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & \alpha_{n-1,n-2} & \alpha_{n-1,n-1} \end{bmatrix}$$

[0046] Further, if the 3D-mode is selected in response to the instruction inputted through the input unit 110, then the second linear operation matrix forming section 145 may be operable to retrieve the rendering parameters from the mapping table. The second linear operation matrix forming section 145 may be further operable to form a second linear operation matrix for rendering upon the third data matrix by using the retrieved rendering parameters.

[0047] The processing unit 140 may further include a second linear operation section 146. The second linear operation section 146 may be operable to perform a linear operation (i.e., matrix multiplication) upon the third ultrasound data matrix and the second linear operation matrix. For example, assuming that the third ultrasound data matrix is C and the second linear operation matrix is D, the second linear operation section 146 may be operable to perform the matrix operation of $D \times C$.

[0048] Referring again to FIG. 1, the ultrasound system 100 may further include a display unit 150. The display unit 150 may receive the ultrasound data from the processing unit 140 and display an ultrasound image based thereon.

[0049] The ultrasound system 100 may further include a control unit 160. The control unit 160 may be operable to control the transmission/reception of the ultrasound signals and the formation of the ultrasound data in the ultrasound data acquisition unit 120. The control unit 160 may be further operable to control the processing unit 140 to effect the linear operation and the non-linear operation of the ultrasound data. The control unit 160 may be also operable to control the display of the ultrasound image.

[0050] Although it is described above that the processing unit 140 sequentially performs the first linear operation, the non-linear operation and the second linear operation upon the ultrasound data, the order of the operations is not limited thereto. In another embodiment, the processing unit 140 may sequentially perform the first linear operation, the second linear operation and the non-linear operation upon the ultrasound data. Also, in another embodiment, the processing unit 140 may be further configured to sequentially perform the non-linear operation, the first linear operation and the second linear operation of the ultrasound data.

[0051] Further, in one embodiment, the second linear operation matrix forming section 145 may be configured to form the second linear operation matrix for performing the scan conversion in a row direction of the ultrasound data matrix. The second linear operation section 146 may be operable to perform the scan conversion of the ultrasound data matrix in a row direction thereof.

[0052] In another embodiment, the second linear operation matrix forming section 145 may be operable to form the second linear operation matrix for performing scan conversion of the ultrasound data matrix in a column direction thereof. The second linear operation section 146 may be further configured to perform the scan conversion of the ultrasound data matrix in a column direction thereof. In this case, the second linear operation matrix may be represented as the following matrix.

Second linear operation matrix =

$$\begin{bmatrix} \beta_{1,0} & \beta_{1,1} & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & \beta_{n-2,n-2} & \beta_{n-2,n-1} \\ 0 & 0 & 0 & 0 & \dots & 0 & \beta_{n-1,n-1} \end{bmatrix}$$

Second Embodiment

[0053] FIG. 4 is a block diagram showing an illustrative embodiment of the ultrasound system 200. As shown in FIG. 4, the ultrasound system 200 may include an input unit 210 that may be operable to allow a user to input instructions. The configuration and the operation of the input unit 210 may be identical to those of the input unit 110 of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0054] The ultrasound system 200 may include an ultrasound data acquisition unit 220 configured to transmit/receive ultrasound signals to/from a target object, thereby acquiring ultrasound data. The configuration and the operation

of the ultrasound data acquisition unit 220 may be identical to those of the ultrasound data acquisition unit 120 of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0055] The ultrasound system 200 may further include a storage unit 230. The storage unit 230 may store the ultrasound data corresponding to at least one frame. The storage unit 230 may further store a mapping table in which information of linear operations is associated with diagnostic modes. The linear operations may be performed upon the ultrasound data to form an ultrasound image in each of the diagnostic modes. In one embodiment, the storage unit 230 may include a first storage section (not shown) for storing the ultrasound data and a second storage section (not shown) for storing the mapping table. The linear operation, the linear operation information and the mapping table may be identical to those described in the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0056] The ultrasound system 200 may include a processing unit 240. The processing unit 240 may be operable to form a linear operation matrix to be used for performing a linear operation (e.g., matrix multiplication) upon the ultrasound data in response to the inputted instruction for selecting a desired diagnostic mode. The processing unit 240 may be further configured to perform the linear operation by using the linear operation matrix and the non-linear operation upon the ultrasound data. The non-linear operation may be identical to that of the first embodiment. Thus, detailed descriptions thereof will be omitted herein. The processing unit 140 may be configured with one of central processing unit, FPAG, ASIC, digital signal processing chip and the like to enhance the performance thereof.

[0057] FIG. 5 is a block diagram showing an illustrative embodiment of the processing unit 240. Referring to FIG. 5, the processing unit 240 may include an ultrasound data matrix forming section 241, a linear operation matrix forming section 242, a linear operation section 243 and a non-linear operation section 244.

[0058] The ultrasound data matrix forming section 241 may be operable to form a first ultrasound data matrix by using the ultrasound data provided from the ultrasound data acquisition unit 220 or stored in the storage unit 230. Generally, the ultrasound data may be formed by scanning a plurality of scan lines and sampling electrical receive signals outputted in response to echo signals reflected from the scan lines. In one embodiment, since the ultrasound data may correspond to a plurality of sampling points on the scan lines, the first ultrasound data matrix may be formed to have a size of the number of the sampling points on one scan line $\times$ the number of the scan lines.

[0059] The linear operation matrix forming section 242 may be operable to retrieve linear operation information corresponding to the diagnostic mode selected in response to the instruction inputted through the input unit 210 from the mapping table. The linear operation matrix forming section 242 may be further operable to form linear operation matrices by using the retrieved linear operation information.

[0060] In one embodiment, if the B-mode is selected, then the linear operation matrix forming section 242 may be operable to retrieve the linear operation information associated with the B-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the quadrature mixer parameters, the FIR filter parameters and the scan conversion parameters. The linear operation matrix forming section 242

may be operable to form a TGC matrix, a decimation matrix, an FIR filter matrix, a quadrature mixer matrix and a scan conversion matrix by using the retrieved parameters. The TGC matrix, the decimation matrices, the FIR filter matrices, the quadrature mixer matrix and the scan conversion matrix may be identically configured to those of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0061] If the D-mode is selected, then the linear operation matrix forming section 242 may be operable to retrieve the linear operation information associated with the D-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the quadrature mixer parameters, the FIR filter parameters, the clutter filter parameters, the FFT parameters and the scan conversion parameters. The linear operation matrix forming section 242 may be operable to form the TGC matrix, the decimation matrices, the FIR filter matrices, the quadrature matrix, a clutter filter matrix, a FFT matrix and the scan conversion matrix by using the retrieved parameters. The matrices formed in the linear operation matrix forming section 242 may be identically configured to those of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0062] Although it is described as examples that the B-mode and the D-mode are selected above, the selection of the diagnostic mode is not limited thereto. The C-mode, the E-mode or the 3D-mode may be also selected. In this case, the linear operation matrix forming section 242 may also retrieve the linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form the linear operation matrices.

[0063] The linear operation section 243 may be operable to perform a linear operation, e.g., matrix multiplication of the first ultrasound data matrix and the linear operation matrix, thereby outputting a second ultrasound data matrix. For example, assuming that the first ultrasound data matrix is E and the first linear operation matrix is F, the linear operation section 243 may be operable to perform the linear operation of $F \times E$.

[0064] The non-linear operation unit 244 may be operable to perform the non-linear operation upon the ultrasound data contained in the second data matrix. In one embodiment, if the B-mode or the 3D-mode is selected, then the non-linear operation unit 244 may be operable to perform the non-linear operations (e.g., envelope detection and compression) upon the ultrasound data contained in the second data matrix. If the D-mode is selected, then the non-linear operation unit 244 may be operable to perform the non-linear operation (e.g., compression) upon the ultrasound data contained in the second data matrix. If the C-mode is selected, then the non-linear operation unit 244 may be operable to perform the non-linear operation (e.g., auto correlation and arctangent operation) upon the ultrasound data contained in the second data matrix. If the E-mode is selected, then the non-linear operation unit 244 may be operable to perform the non-linear operation (e.g., auto correlation, least mean square operation and differential operation) upon the ultrasound data contained in the second data matrix.

[0065] Referring again to FIG. 4, the ultrasound system 200 may further include a display unit 250. The display unit 250 may receive the ultrasound data with the linear and non-linear operations performed and display an ultrasound image based on the received ultrasound data.

[0066] The ultrasound system 200 may further include a control unit 260. The control unit 260 may be operable to control the transmission/reception of the ultrasound signals and the formation of the ultrasound data in the ultrasound data acquisition unit 220. The control unit 260 may be further operable to control the processing unit 240 to effect the linear operation and the non-linear operation upon the ultrasound data. The control unit 260 may also control the display of the ultrasound image.

[0067] Although it is described that the processing unit 240 may be sequentially operable to perform the linear operation and the non-linear operation upon the ultrasound data in other embodiment, the processing unit 240 may be further operable to perform operations upon the ultrasound data in an order of the non-linear operation and the linear operation.

Third Embodiment

[0068] FIG. 6 is a block diagram showing an illustrative embodiment of an ultrasound system 300. As depicted therein, the ultrasound system 300 may include an input unit 310 that may be operable to allow a user to input instructions. The configuration and the operation of the input unit 310 may be identical to those of the input unit 110 of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0069] The ultrasound system 300 may include an ultrasound data acquisition unit 320 that may be operable to transmit/receive ultrasound signals to/from a target object, thereby acquiring ultrasound data. The operation of the ultrasound data acquisition unit 320 may be identical to that of the ultrasound data acquisition unit 120 in the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0070] The ultrasound system 300 may further include a storage unit 330. The storage unit 330 may store the ultrasound data corresponding to at least one frame. The storage unit 330 may further store a mapping table in which information of linear operations is associated with the diagnostic modes. The linear operation information may include TGC parameters for the TGC, decimation parameters for the decimation, quadrature mixer parameters for the quadrature mixing, FIR filter parameters for the FIR filtering, clutter filter parameters for the clutter filtering, FFT parameters for the FFT and the like. However, the linear operation information may not be limited thereto. In one embodiment, the storage unit 330 may store the mapping table as shown in Table 2.

TABLE 2

Diagnostic mode	Linear operation information
B-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters
D-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, clutter filter parameters, FFT parameters
C-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters, clutter filter parameters
E-mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters
3D mode	TGC parameters, decimation parameters, quadrature mixer parameters, FIR filter parameters

[0071] In one embodiment, the storage unit **330** may include a first storage section (not shown) for storing the ultrasound data and a second storage section (not shown) for storing the mapping table.

[0072] The ultrasound system **300** may further include a processing unit **340**. The processing unit **340** may be operable to form a linear operation matrix for performing linear operation upon the ultrasound data. In one embodiment, the linear operations may include time gain compensation (TGC), decimation for adjusting amount of the ultrasound data, quadrature mixing for forming in-phase/quadrature (I/Q) data, finite impulse response (FIR) filtering, clutter filtering, fast Fourier transform (FFT) and the like. However, the linear operations may not be limited thereto. The linear operation matrix may be formed by using the mapping table in response to an inputted instruction for selecting a desired diagnostic through the input unit **310**. The processing unit **340** may be further configured to perform linear operations corresponding to the selected diagnostic mode by using the linear operation matrix and non-linear operation upon the ultrasound data. The non-linear operations may be identical to those described in the first embodiment. Thus, detailed descriptions thereof will be omitted herein. The processing unit **340** may be further operable to perform scan conversion or rendering upon the ultrasound data with the linear and non-linear operations performed. In one embodiment, the processing unit **340** may include a first processor **341** and a second processor **342**.

[0073] The first processor **341** may be operable to form an ultrasound data matrix by using the ultrasound data. The first processor **341** may be operable to perform the linear and non-linear operations upon the ultrasound data matrix.

[0074] FIG. 7 is a block diagram showing an illustrative embodiment of the first processor **341**. Referring to FIG. 7, the first processor **341** may include an ultrasound data matrix forming section **341a**, a linear operation matrix forming section **341b**, a linear operation section **341c** and a non-linear operation section **341d**.

[0075] The ultrasound data matrix forming section **341a** may be operable to form a first ultrasound data matrix by using the ultrasound data provided from the ultrasound data acquisition unit **320** or stored in the storage unit **330**. Generally, the ultrasound data may be formed by scanning a plurality of scan lines and sampling electrical receive signals outputted in response to echo signals reflected from the scan lines. In one embodiment, since the ultrasound data may correspond to a plurality of sampling points on the scan lines, the first ultrasound data matrix may be formed to have a size of the number of the sampling points on one scan line $\times$ the number of the scan lines.

[0076] The linear operation matrix forming section **341b** may be operable to retrieve linear operation information corresponding to the diagnostic mode selected in response to the instruction inputted through the input unit **210** from the mapping table stored in the storage unit **330**. The linear operation matrix forming section **341b** may be further operable to form a linear operation matrix by using the retrieved linear operation information.

[0077] In one embodiment, if the B-mode is selected, then the linear operation matrix forming section **341b** may be operable to retrieve the linear operation information associated with the B-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the FIR filter parameters and the quadrature mixer parameters. The linear operation matrix forming section **341b** may be operable to form a

TGC matrix, a decimation matrix, an FIR filter matrix and a quadrature mixer matrix by using the retrieved parameters. The TGC matrix, the decimation matrices, the FIR filter matrices and the quadrature mixer matrix may be identical to those of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0078] If the D-mode is selected, then the linear operation matrix forming section **341b** may be operable to retrieve the linear operation information associated with the D-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the FIR filter parameters, the quadrature mixer parameters, the clutter filter parameters and the FFT parameters. The linear operation matrix forming section **341b** may be operable to form a TGC matrix, a decimation matrix, a FIR filter matrix, a quadrature matrix, a clutter filter matrix and a FFT matrix by using the retrieved parameters. The matrices formed in the linear operation matrix forming section **341b** may be identical to those described in the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0079] Although it is described as examples that the B-mode and the D-mode are selected above, the selection of the diagnostic mode is not limited thereto. The C-mode, the E-mode or the 3D-mode may be also selected. In this case, the linear operation matrix forming section **341b** may also retrieve the linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form the linear operation matrix in the same manner as the B-mode or D-mode.

[0080] The linear operation section **341c** may be operable to perform a linear operation (i.e., matrix operation) upon the first ultrasound data matrix and the linear operation matrix, thereby outputting a second ultrasound data matrix. For example, assuming that the first ultrasound data matrix is G and the first linear operation matrix is H, the linear operation section **341c** may be operable to perform the matrix operation of $G \times H$.

[0081] The non-linear operation unit **341d** may be operable to perform the non-linear operation upon the ultrasound data contained in the second data matrix. In one embodiment, if the B-mode or the 3D-mode is selected, then the non-linear operation unit **341d** may be operable to perform the non-linear operations (e.g., envelope detection and compression) upon the ultrasound data contained in the second data matrix. If the D-mode is selected, then the non-linear operation unit **341d** may be operable to perform the non-linear operation (e.g., compression) upon the ultrasound data contained in the second data matrix. If the C-mode is selected, then the non-linear operation unit **341d** may be operable to perform the non-linear operations (e.g., auto correlation and arctangent operation) upon the ultrasound data contained in the second data matrix. If the E-mode is selected, then the non-linear operation unit **244** may be operable to perform the non-linear operations (e.g., auto correlation, least mean square operation and differential operation) upon the ultrasound data contained in the second data matrix.

[0082] Although it is described above that the non-linear operations are performed after performing the linear operations, the non-linear operations may be performed prior to the linear operations.

[0083] Referring to FIG. 6, the second processor **342** may be configured with a graphic processing unit (GPU) in one embodiment. The second processor **342** may be operable to

perform a non-linear operation upon the ultrasound data based on the selected diagnostic mode.

[0084] FIG. 8 is a block diagram showing an illustrative embodiment of the second processor 342. Referring to FIG. 8, the second processor 342 may include a video memory 342a, a vertex initializing section 342b, a texture data forming section 342c, a data upload section 342d and a data processing section 342e.

[0085] The video memory 342a may include a plurality of storage areas including a storage area for the pixel data corresponding to pixels consisting of a screen of the display unit 350. That is, the pixel data formed in the second processor 342 may be stored at the corresponding storage area of the video memory 342a and displayed on a screen of the display unit 350 at the same time. Thus, the necessary capacity of the video memory 342a may depend on the number of pixels and data format for each of the diagnostic modes. For example, in case of an ultrasound image of 640×480 pixels, a minimum capacity of the video memory may be 640×480×8 bits. The data format may be different according to the diagnostic modes. For example, the B-mode image may have an 8-bit data format and the C-mode image may have a 16-bit data format.

[0086] If the ultrasound data are inputted from the first processor 341, then the vertex initializing section 342b may be operable to form vertex information for initializing a position for displaying an ultrasound image on the screen of the display unit 350 by using a plurality of vertexes according to the selected diagnostic mode. The vertex initializing section 342b may be embodied with a 3-dimensional application programming interface (3D API). Referring to FIG. 9, when the B-mode image is formed, the vertex initializing section 342b may be operable to form vertex information for initialize positioning of the vertexes V1, V2, V3 and V4. Although it is described that the vertexes V1, V2, V3 and V4 are set, the vertexes are not limited thereto. Other vertexes may be additionally set according to the necessity.

[0087] Textures of a 3D graphic format should be used to upload an ultrasound image to the video memory 342a. The texture data forming section 342c may be operable to combine vertex information "A" formed at the vertex initializing unit 33 with the ultrasound data "B" with the linear and non-linear operations processed according to the selected diagnostic mode to thereby form texture data C, as shown in FIG. 10. For example, when the B-mode image having an 8-bit data format is formed by using DirectX, texture data having a "D3DFMT_L8" format, which is the format only for an 8-bits, are formed. Also, when the C-mode image of a 16-bit data format is formed, texture data of a "D3DFMT_R5G6B5" format, which is a 16-bit only format, are formed.

[0088] The data upload section 342d may be operable to allocate the storage areas of the video memory 342a according to the data format corresponding to the selected diagnostic mode. In this case, the storage areas may include a storage area for storing the texture data and a storage area for storing code data (e.g., shader code, field shader code and color palette data in case of the C-mode) necessary for forming functions of the GPU. Also, the data upload section 342d may be further operable to upload the texture data and the code data to the corresponding storage areas in the video memory 342a.

[0089] The data processing section 342e may be operable to perform data processing (e.g., scan conversion or rendering) upon the texture data by using the shader codes uploaded

to the video memory 342a according to the selected diagnostic mode. The data processing section 342e may be further operable to perform filtering, which applies the filter shader code to the scan-converted or rendered texture data, to thereby form the pixel data. The pixel data may be stored in a designated area in the video memory 342a.

[0090] Referring again to FIG. 6, the display unit 350 may display an ultrasound image based on the pixel data stored in the video memory 342a. The control unit 360 may be operable to control the transmission/reception of the ultrasound signals and the formation of the ultrasound data in the ultrasound data acquisition unit 320. The control unit 360 may be further operable to control the linear operation and the non-linear operation upon the ultrasound data in the processing unit 340. The control unit 360 may also control the display of the ultrasound image.

Fourth Embodiment

[0091] FIG. 11 is a block diagram showing an illustrative embodiment of an ultrasound system 400. The ultrasound system 400 may include an input unit 410, an ultrasound data acquisition unit 420, a storage unit 430, a processing unit 440, a display unit 450 and a control unit 460. The configurations and operations of the input unit 410 and the ultrasound data acquisition unit 420 may be identical to those of the input unit 110 and the ultrasound acquisition unit 120 of the first embodiment. As such, detailed descriptions thereof will be omitted herein. Also, the configuration of the storage unit 430 may be identical to that of the storage unit 330 of the third embodiment. Thus, the detailed description thereof will be omitted.

[0092] The processing unit 440 may be operable to form a linear operation matrix for performing linear operation upon the ultrasound data. The linear operation matrix may be formed by using the mapping table in response to an inputted instruction for selecting a desired diagnostic through the input unit 410. The processing unit 440 may be further configured to perform linear operations corresponding to the selected diagnostic mode by using the linear operation matrix and non-linear operation upon the ultrasound data. The non-linear operations may be identical to those described in the first embodiment. Thus, detailed descriptions thereof will be omitted herein. The processing unit 440 may be further operable to perform scan conversion or rendering upon the ultrasound data with the linear and non-linear operations performed. In one embodiment, the processing unit 440 may include a first processor 441, a second processor 442 and a third processor 443.

[0093] The first processor 441 may be embodied with a graphic processing unit (GPU) and be operable to form an ultrasound data matrix by using the ultrasound data. The first processor 441 may be operable to retrieve the linear operation information corresponding to the selected diagnostic mode in response to the instruction inputted through the input unit 410. The first processor 441 may be operable to form linear operation matrices perform linear operations upon the ultrasound data by using the retrieved linear operation information.

[0094] FIG. 12 is a block showing an illustrative embodiment of the first processor 441. Referring to FIG. 12, the first processor 441 may include a video memory 441a, a matrix initializing section 441b, a texture data forming section 441c, a data upload section 441d and a matrix forming section 441e. In one embodiment, the configuration of the video memory

441a may be identical to that of the video memory **342a** of the third embodiment. Thus, detailed description thereof will be omitted herein.

[0095] The matrix initializing section **441b** may be operable to compute a size and elements of an ultrasound data matrix to be formed by using the ultrasound data, thereby forming first matrix information including the computed size and elements. Generally, the ultrasound data may be formed by scanning a plurality of scan lines and sampling electrical receive signals outputted in response to echo signals reflected from the scan lines. In one embodiment, since the ultrasound data may correspond to a plurality of sampling points on the scan lines, the ultrasound data matrix may be formed to have a size of the number of the sampling points $\times$ the number of the scan lines.

[0096] The matrix initializing section **441b** may be operable to retrieve linear operation information corresponding to the diagnostic mode selected in response to the instruction inputted through the input unit **410** from the mapping table stored in the storage unit **430**. The matrix initializing section **441b** may be further operable to compute a size and elements of a linear operation matrix to be formed by using the retrieved linear operation information, thereby forming second matrix information containing the computed size and elements.

[0097] In one embodiment, if the B-mode is selected, then the matrix initializing section **441b** may be operable to retrieve the linear operation information associated with the B-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the FIR filter parameters and the quadrature mixer parameters. The matrix initializing section **441b** may be operable to calculate sizes and elements of a TGC matrix, a decimation matrix, an FIR filter matrix and a quadrature mixer matrix to be formed by using the retrieved parameters, thereby forming the second matrix information including the computed sizes and elements. The TGC matrix, the decimation matrices, the FIR filter matrices and the quadrature mixer matrix may be identically established with those of the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0098] If the D-mode is selected, then the matrix initializing section **441b** may be operable to retrieve the linear operation information associated with the D-mode from the mapping table, i.e., the TGC parameters, the decimation parameters, the FIR filter parameters, the quadrature mixer parameters, the clutter filter parameters and the FFT parameters. The matrix initializing section **441b** may be operable to compute sizes and elements of a TGC matrix, a decimation matrix, a FIR filter matrix, a quadrature matrix, a clutter filter matrix and a FFT matrix to be formed by using the retrieved parameters, thereby forming the second matrix information including the computed size and elements. The matrices formed in the matrix initializing section **441b** may be identically established with those described in the first embodiment. Thus, detailed descriptions thereof will be omitted herein.

[0099] Although it is described as examples that the B-mode and the D-mode are selected above, the selection of the diagnostic mode is not limited thereto. The C-mode, the E-mode or the 3D-mode may be also selected. In this case, the linear operation matrix forming section **441b** may also retrieve the linear operation information corresponding to the

selected diagnostic mode from the mapping table to thereby form the linear operation matrix in the same manner as the B-mode or D-mode.

[0100] The texture data forming unit **441c** may be operable to form first vertex data including the first matrix information provided from the matrix initializing section **441b** and second vertex data including the second matrix information provided from the matrix initializing section **441b**.

[0101] The data upload section **441d** may be operable to allocate the storage areas of the video memory **441a** according to the texture data corresponding to the selected diagnostic mode. In this case, the storage areas may include a storage area for storing the first texture data, a storage area for storing the second texture data and a storage area for storing the ultrasound data matrix. Also, the data upload section **441d** may be further operable to upload the first and second texture data to the corresponding storage areas in the video memory **441a**.

[0102] If the first and second texture data are uploaded to the video memory **441a**, then the matrix forming section **441e** may be operable to form the ultrasound data matrix based on the first texture data. The formed ultrasound data matrix may be stored to the corresponding storage area in the video memory **441a**. Also, the matrix forming section **441e** may be further operable to perform matrix operations between the linear operations based on the second texture data to thereby form a final linear operation matrix. For example, if the B-mode is selected, then the matrix forming unit **441e** may be operable to perform a matrix operation between a TGC matrix and a first FIR filter matrix, thereby obtaining a first matrix. The matrix forming unit **441e** may be further operable to perform a matrix operation between the first matrix and a decimation matrix to thereby obtain a second matrix. The matrix forming unit **441e** may be further operable to perform a matrix operation between the second matrix and a second FIR filter matrix to thereby obtain the final linear operation matrix. The first to final matrices may be stored in a temporal storage area in the video memory **441a**.

[0103] Although the formation of the linear operation matrix is described with reference to the selection of the B-mode, when the D-mode, the C-mode, the E-mode or the 3D-mode is selected, the linear operation matrices may be also formed in the same manner as the selection of the B-mode.

[0104] Referring again to FIG. 11, the second processor **442** may be configured with one of CPU, FPGA, ASIC and DSP. The second processor **442** may be operable to perform a matrix operation between the ultrasound data matrix and the final linear operation matrix to thereby obtain ultrasound data with the linear operation performed. Also, the second processor **442** may be operable to perform a non-linear operation upon the obtained ultrasound data. Although it is described above that the second processor **442** may be operable to perform the non-linear operation after the linear operation in one embodiment, the non-linear operation may be performed prior to the linear operation in another embodiment.

[0105] The third processor **443** may be configured with GPU and is operable to perform data processing upon the ultrasound data with the linear and non-linear operations performed. The data processing may include at least one of scan conversion and rendering. The configuration and operation of the third processor **443** may be identical to those of the second processor **342** of the third embodiment. Thus, the detailed descriptions thereof will be omitted herein.

[0106] In one embodiment, although it is described that the first to third processors are separately configured, the configuration thereof is not limited thereto. The first to third processors may be embodied to a single processor such as GPU.

[0107] The display unit 450 may display an ultrasound image based on pixel data formed in the third processor 443. The control unit 460 may be operable to control the transmission/reception of the ultrasound signals, the formation of the ultrasound data, the linear operation and the non-linear operation. The control unit 460 may also control the display of the ultrasound image.

Fifth Embodiment

[0108] FIG. 13 is a block diagram showing an illustrative embodiment of an ultrasound system 500. The ultrasound system 500 may include an input unit 510, an ultrasound data acquisition unit 520, a storage unit 530, a processing unit 540, a display unit 550 and a control unit 560. The configurations and operations of the input unit 510 and the ultrasound data acquisition unit 520 may be identical to those of the first embodiment. Thus, detailed descriptions thereof will be omitted herein. Also, the storage unit 530 may be identically configured with the storage unit 330 of the third embodiment. Accordingly, detailed descriptions will be omitted herein.

[0109] The processing unit 540 may be operable to form a linear operation matrix for performing linear operation upon the ultrasound data. The linear operation matrix may be formed by using the mapping table in response to an instruction for selecting a desired diagnostic mode, which is inputted through the input unit 510. The processing unit 540 may be further operable to perform linear operations corresponding to the selected diagnostic mode by using the linear operation matrix and non-linear operation upon the ultrasound data. In one embodiment, the non-linear operation may include envelope detection, compression, auto correlation, arc tangent operation, a least mean square operation, a differential operation and the like. However, it is not limited thereto. The processing unit 540 may be operable to perform scan conversion or rendering upon the ultrasound data with the linear and non-linear operations performed.

[0110] FIG. 14 is a block diagram showing an illustrative embodiment of the processing unit 540. The processing unit 540 may include a video memory 541 that may include a plurality of storage areas including a storage area for storing the pixel data corresponding to pixels consisting of a screen of the display unit 550. In one embodiment, the video memory 541 may be identically configured to the video memory 342a. Thus, detailed description thereof will be omitted herein.

[0111] The processing unit 540 may further include an initializing section 542. The initializing section 542 may be operable to form vertex information for initializing a position for displaying an ultrasound image on the screen of the display unit 550 by using a plurality of vertexes according to the selected diagnostic mode. In one embodiment, the vertex information may be identical to that of the third embodiment. Thus, detailed descriptions will be omitted herein.

[0112] The initializing section 542 may be operable to compute a size and elements of an ultrasound data matrix to be formed by using the ultrasound data, thereby forming first matrix information including the computed size and elements. Generally, the ultrasound data may be formed by scanning a plurality of scan lines and sampling electrical receive signals outputted in response to echo signals reflected

from the scan lines. In one embodiment, since the ultrasound data may correspond to a plurality of sampling points on the scan lines, the ultrasound data matrix may be formed to have a size of the number of the sampling points $\times$ the number of the scan lines.

[0113] The initializing section 542 may be operable to retrieve linear operation information corresponding to the diagnostic mode selected in response to the instruction inputted through the input unit 510 from the mapping table stored in the storage unit 530. The initializing section 542 may be further operable to compute a size and elements of a linear operation matrix to be formed by using the retrieved linear operation information, thereby forming second matrix information containing the computed size and elements.

[0114] The texture data forming section 543 may be operable to form first vertex data including the first matrix information provided from the initializing section 542 and second vertex data including the second matrix information provided from the initializing section 542. Further, the texture data forming section 543 may be operable to form third texture data including the vertex information provided from the initializing section 542.

[0115] The data upload section 544 may be operable to allocate the storage areas of the video memory 541 according to the first to third texture data corresponding to the selected diagnostic mode. In this case, the storage areas may include a storage area for storing the first texture data, a storage area for storing the second texture data, and a third storage area for storing the third texture data. The storage areas may further include a storage area for storing code data (e.g., shader code, field shader code and color palette data in case of the C-mode) necessary to perform functions of the GPU. Also, the data upload section 544 may be further operable to upload the first to third texture data to the corresponding storage areas in the video memory 541.

[0116] If the first to third texture data are uploaded to the video memory 541, then the matrix forming section 545 may be operable to form first ultrasound data matrix based on the first texture data. The formed first ultrasound data matrix may be stored to the corresponding storage area in the video memory 541. Also, the matrix forming section 545 may be further operable to perform matrix operations between the linear operations based on the second texture data to thereby form a final linear operation matrix. In one embodiment, the formation of the final linear operation may be identically performed to that of the final linear operation matrix in the matrix forming unit 441e of the fourth embodiment. Thus, detailed descriptions thereof will be omitted. The final matrices may be stored to a corresponding storage area in the video memory 541.

[0117] The linear operation section 546 may be operable to perform a matrix operation of the first ultrasound data matrix and the final linear operation matrix to thereby output second ultrasound data matrix. The outputted second ultrasound data matrix may be stored in a corresponding storage area in the video memory 541.

[0118] The non-linear operation section 547 may be operable to perform a matrix operation of the second ultrasound matrix and a non-linear operation matrix corresponding to the selected diagnostic mode to thereby output third ultrasound data matrix. The outputted third ultrasound data matrix may be stored to a corresponding storage area in the video memory 541.

[0119] Although it is described above that the linear operation is performed prior to the non-linear operation, the non-linear operation may be performed prior to the linear operation.

[0120] The data processing section 548 may be operable to perform data processing (e.g., scan conversion or rendering) upon the ultrasound data of the third ultrasound data matrix by using the shader codes uploaded to the video memory 541 according to the selected diagnostic mode. The data processing section 548 may be further operable to perform filtering, which applies the filter shader code to the data-processed ultrasound data, to thereby form the pixel data. The pixel data may be stored in a designated storage area in the video memory 342a.

[0121] Referring to FIG. 13, the display unit 550 may display an ultrasound image based on pixel data formed in the processing unit 540. The control unit 560 may be operable to control the transmission/reception of the ultrasound signals, the formation of the ultrasound data, the linear operation and the non-linear operation according to the selected diagnostic mode. The control unit 560 may also control the display of the ultrasound image.

[0122] As mentioned above, since the linear operations and the non-linear operations are separately performed to acquire an ultrasound image, an ultrasound data processing speed may be enhanced and the frame rate may be increased. Also, since the linear operations and the non-linear operations are performed in the GPU, the data processing speed may be also enhanced.

[0123] 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:

a storage unit for storing a mapping table having linear operation information associated with a plurality of diagnostic modes;

an input unit for allowing a user to input an instruction to select at least one of the diagnostic modes;

an ultrasound data acquisition unit configured to transmit/receive ultrasound signals to/from a target object according to the selected diagnostic mode to thereby acquire ultrasound data; and

a processing unit configured to form an ultrasound data matrix based on the ultrasound data and retrieve the linear operation information associated with the selected diagnostic mode from the mapping table to form linear operation matrices, the processing unit being further configured to perform a linear operation upon the ultrasound data matrix and the linear operation matrices and perform at least one non-linear operation upon the ultrasound data.

2. The system of claim 1, wherein the processing unit is configured with one of a central processing unit, a field pro-

grammable gate array, an application specific integrated circuit, and a digital signal processing chip.

3. The system of claim 2, wherein the linear operation information include time gain compensation (TGC) parameters, decimation parameters for adjusting an amount of the ultrasound data, quadrature mixer parameters for forming in-phase/quadrature-phase data, finite impulse response (FIR) filter parameters for FIR filtering, clutter filter parameters for clutter filtering, fast Fourier transform (FFT) parameters for FFT, scan conversion and interpolation parameters for scan conversion and interpolation, and rendering parameters for rendering.

4. The system of claim 3, wherein the processing unit includes:

an ultrasound data matrix forming section configured to form a first ultrasound data matrix based on the ultrasound data;

a first linear operation matrix forming section configured to retrieve first linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one first linear operation matrix;

a first linear operation section configured to perform at least one first linear operation upon the first ultrasound data matrix and the first linear operation matrix to thereby output a second ultrasound data matrix;

a non-linear operation section configured to perform at least one non-linear operation upon the second ultrasound data matrix to output a third ultrasound data matrix;

a second linear operation matrix forming section configured to retrieve second linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one second linear operation matrix; and

a second linear operation section configured to perform at least one second linear operation upon the third ultrasound data matrix and the second linear operation matrix.

5. The ultrasound system of claim 3, wherein the processing unit includes:

an ultrasound data matrix forming section configured to form a first ultrasound data matrix based on the ultrasound data;

a non-linear operation section configured to perform at least one non-linear operation upon the first ultrasound data matrix according to the selected diagnostic mode to thereby output a second ultrasound data matrix;

a first linear operation matrix forming section configured to retrieve first linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form a first linear operation matrix;

a first linear operation section configured to perform a matrix operation of the second ultrasound data matrix and the first linear operation matrix to thereby output third ultrasound data matrix;

a second linear operation matrix forming section configured to retrieve second linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form a second linear operation matrix; and

a second linear operation section configured to perform a matrix operation of the third ultrasound data matrix and the second linear operation matrix.

6. The system of claim 3, wherein the processing unit includes:

- an ultrasound data matrix forming section configured to form a first ultrasound data matrix based on the ultrasound data;
- a first linear operation matrix forming section configured to retrieve first linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one first linear operation matrix;
- a first linear operation section configured to perform at least one first linear operation upon the first ultrasound data matrix and the first linear operation matrix to thereby output second ultrasound data matrix;
- a second linear operation matrix forming section configured to retrieve second linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one second linear operation matrix;
- a second linear operation section configured to perform at least one second linear operation upon the second ultrasound data matrix and the second linear operation matrix to thereby output a third ultrasound data matrix; and
- a non-linear operation section configured to perform at least one non-linear operation upon the third ultrasound data matrix.

7. The system of claim 3, wherein the processing unit includes:

- a first processor configured to perform at least one linear operation upon the ultrasound data by retrieving the linear operation information from the mapping table and at least one non-linear operation upon the ultrasound data with at least one linear operation performed; and
- a second processor configured to perform scan conversion or rendering upon the ultrasound data with the linear and non-linear operations performed.

8. The system of claim 7, wherein the first processor includes:

- an ultrasound data matrix forming section configured to form a first ultrasound data matrix based on the ultrasound data;
- a linear operation matrix forming section configured to retrieve linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one linear operation matrix;
- a linear operation section configured to perform at least one linear operation upon the first ultrasound data matrix and the linear operation matrix to thereby output second ultrasound data matrix; and
- a non-linear operation section configured to perform at least one non-linear operation upon the second ultrasound data matrix according to the selected diagnostic mode.

9. The system of claim 8, wherein the second processor includes:

- a video memory containing a plurality of storage areas;
- a vertex initializing section configured to initialize positions for displaying an ultrasound image by using a plurality of vertexes according to the selected diagnostic mode to thereby form vertex information;
- a texture data forming section configured to combine the ultrasound data with the linear and non-linear operations performed with the vertex information to thereby form texture data;

- a data upload section configured to allocate the storage areas of the video memory according to a data format of the selected diagnostic mode and upload the texture data to a corresponding storage area; and

- a data processing section configured to perform scan conversion or rendering upon the texture data and perform filtering upon the scan converted or rendered texture data to thereby form pixel data corresponding to the ultrasound image.

10. The system of claim 3, wherein the processing unit includes:

- a first processor configured to form an ultrasound data matrix by using the ultrasound data and form at least one linear operation matrix based on linear operation information according to the selected diagnostic mode;
- a second processor configured to perform at least one linear operations by using said at least one linear operation matrix and at least one non-linear operation upon the ultrasound data matrix according to the selected diagnostic mode; and
- a third processor configured to perform scan conversion or rendering the ultrasound data matrix with the linear and non-linear operation performed.

11. The system of claim 10, wherein the first processor includes:

- a video memory containing a plurality of storage areas;
- a matrix initializing section configured to compute a size and elements of the ultrasound data matrix based on the ultrasound data to form first matrix information, the matrix initializing section being further configured to compute a size and elements of each of a plurality of linear operation matrices to be formed based on the linear operation information corresponding to the selected diagnostic mode to form second matrix information;
- a texture data forming section configured to form first texture data including the first matrix information and a plurality of second texture data including the second matrix information;
- a data upload section configured to analyze the first and second texture data to allocate storage areas of the video memory and upload the first texture data and the plurality of second texture data to the corresponding storage areas; and
- a matrix forming section configured to form an ultrasound data matrix based on the uploaded first texture data and a plurality of matrices based on the plurality of second texture data, the matrix forming section being further operable to perform a linear operation upon the plurality of matrices to thereby form the linear operation matrix.

12. The system of claim 10, wherein the third processor includes:

- a video memory containing a plurality of storage areas;
- a vertex initializing section configured to initialize positions for displaying an ultrasound image by using a plurality of vertexes according to the selected diagnostic mode to thereby form vertex information;
- a texture data forming section configured to combine the ultrasound data with the linear and non-linear operations performed with the vertex information to thereby form texture data;
- a data upload section configured to allocate the storage areas of the video memory according to a data format of

the selected diagnostic mode and upload the texture data to a corresponding storage area; and

a data processing section configured to perform scan conversion or rendering upon the texture data and perform filtering upon the scan converted or rendered texture data to thereby form pixel data corresponding to the ultrasound image.

13. A method of processing ultrasound data in an ultrasound system, comprising:

- a) storing a mapping table associating linear operation information with a plurality of diagnostic modes;
- b) receiving an instruction to select at least one of the diagnostic modes;
- c) transmitting/receiving ultrasound signals to/from a target object to thereby acquire ultrasound data according to the selected diagnostic mode; and
- d) forming an ultrasound data matrix based on the ultrasound data, retrieving the linear operation information associated with the selected diagnostic mode from the mapping table to form linear operation matrices, and performing a linear operation upon the ultrasound data matrix and the linear operation matrices.

14. The method of claim **13**, further comprising performing at least one non-linear operation upon the ultrasound data.

15. The method of claim **14**, wherein the linear operation information include time gain compensation (TGC) parameters, decimation parameters for adjusting an amount of the ultrasound data, quadrature mixer parameters for forming in-phase/quadrature-phase data, finite impulse response (FIR) filter parameters for FIR filtering, clutter filter parameters for clutter filtering, fast Fourier transform (FFT) parameters for FFT, scan conversion and interpolation parameters for scan conversion and interpolation, and rendering parameters for rendering.

16. The method of claim **15**, wherein the step d) includes: forming a first ultrasound data matrix based on the ultrasound data;

retrieving first linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one first linear operation matrix; performing at least one first linear operation upon the first ultrasound data matrix and the first linear operation matrix to thereby output second ultrasound data matrix; performing at least one non-linear operation upon the second ultrasound data matrix to output a third ultrasound data matrix;

retrieving second linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one second linear operation matrix; and

performing at least one second linear operation upon the third ultrasound data matrix and the second linear operation matrix.

17. The method of claim **15**, wherein the step d) includes: forming a first ultrasound data matrix based on the ultrasound data;

performing at least one non-linear operation upon the first ultrasound data matrix according to the selected diagnostic mode to thereby output a second ultrasound data matrix;

retrieving first linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form a first linear operation matrix;

performing a matrix operation of the second ultrasound data matrix and the first linear operation matrix to thereby output third ultrasound data matrix;

retrieving second linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form a second linear operation matrix; and

performing a matrix operation of the third ultrasound data matrix and the second linear operation matrix.

18. The method of claim **15**, wherein the step d) includes: forming a first ultrasound data matrix based on the ultrasound data;

retrieving first linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one first linear operation matrix; performing at least one first linear operation upon the first ultrasound data matrix and the first linear operation matrix to thereby output a second ultrasound data matrix;

retrieving second linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one second linear operation matrix;

performing at least one second linear operation upon the second ultrasound data matrix and the second linear operation matrix to thereby output a third ultrasound data matrix; and

performing at least one non-linear operation upon the third ultrasound data matrix.

19. The method of claim **15**, wherein the step d) includes: d1) performing at least one linear operation upon the ultrasound data by retrieving the linear operation information from the mapping table and at least one non-linear operation upon the ultrasound data with at least one linear operation performed; and

d2) performing scan conversion or rendering upon the ultrasound data with the linear and non-linear operations performed.

20. The method of claim **19**, wherein the step d1) includes: forming a first ultrasound data matrix based on the ultrasound data;

retrieving linear operation information corresponding to the selected diagnostic mode from the mapping table to thereby form at least one linear operation matrix;

performing at least one linear operation upon the first ultrasound data matrix and the linear operation matrix to thereby output a second ultrasound data matrix; and

performing at least one non-linear operation upon the second ultrasound data matrix according to the selected diagnostic mode.

21. The method of claim **19**, wherein the step d2) includes: initializing positions for displaying an ultrasound image by using a plurality of vertexes according to the selected diagnostic mode to thereby form vertex information;

combining the ultrasound data with the linear and non-linear operations performed with the vertex information to thereby form texture data;

allocating storage areas of a video memory according to a data format of the selected diagnostic mode and uploading the texture data to the corresponding storage area; and

performing scan conversion or rendering upon the texture data and performing filtering upon the scan converted or

rendered texture data to thereby form pixel data corresponding to the ultrasound image.

22. The method of claim 15, wherein the step d) includes:

d1) forming an ultrasound data matrix by using the ultrasound data and form at least one linear operation matrix based on linear operation information according to the selected diagnostic mode;

d2) performing at least one linear operation by using said at least one linear operation matrix and at least one non-linear operation upon the ultrasound data matrix according to the selected diagnostic mode; and

d3) performing scan conversion or rendering the ultrasound data matrix with the linear and non-linear operation performed.

23. The method of claim 22, wherein the step d1) includes: computing a size and elements of the ultrasound data matrix based on the ultrasound data to form first matrix information, and computing a size and elements of each of a plurality of linear operation matrices to be formed based on the linear operation information corresponding to the selected diagnostic mode to form second matrix information;

forming first texture data including the first matrix information and a plurality of second texture data including the second matrix information;

analyzing the first and second texture data to allocate storage areas of the video memory and uploading the first texture data and the plurality of second texture data to the corresponding storage areas; and

forming an ultrasound data matrix based on the uploaded first texture data and a plurality of matrices based on the plurality of second texture data, and performing a linear operation upon the plurality of matrices to thereby form the linear operation matrix.

24. The method of claim 22, wherein the step d3) includes: initializing positions for displaying an ultrasound image by using a plurality vertexes according to the selected diagnostic mode to thereby form vertex information;

combining the ultrasound data with the linear and non-linear operations performed with the vertex information to thereby form texture data;

allocating the storage areas of the video memory according to a data format of the selected diagnostic mode and uploading the texture data to a corresponding storage area; and

performing scan conversion or rendering upon the texture data and performing filtering upon the scan converted or rendered texture data to thereby form pixel data corresponding to the ultrasound image.

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专利名称(译)	超声系统中增强的超声数据处理		
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当前申请(专利权)人(译)	三星MEDISON CO. , LTD.		
[标]发明人	AHN CHI YOUNG LEE SUK JIN KIM YUNG GIL		
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摘要(译)

公开了用于超声系统中的超声数据处理的实施例。在一个实施例中，将线性操作信息与多个诊断模式相关联的映射表存储在存储单元中。如果存在选择至少一个诊断模式的指令，则超声数据获取单元向/从目标对象发送/接收超声信号，从而根据所选择的诊断模式获取超声数据。处理单元基于超声数据形成超声数据矩阵，并从映射表中检索与所选诊断模式相关联的线性操作信息，以形成线性操作矩阵。此外，处理单元执行超声数据矩阵和线性运算矩阵的矩阵运算。

