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(54) **ULTRASONOGRAPH, ULTRASONIC IMAGE PROCESSING DEVICE, AND ULTRASONIC IMAGE PROCESSING METHOD**

ULTRASCHALLGERÄT, ULTRASCHALLBILD-VERARBEITENDE VORRICHTUNG UND ULTRASCHALLBILD-VERARBEITUNGSVERFAHREN

ULTRASONOGRAPHE, DISPOSITIF DE TRAITEMENT D'IMAGE ULTRASON ET MÉTHODE DE TRAITEMENT D'IMAGE ULTRASON

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EP 1 652 477 B1

Description

Technical Field

[0001] The present invention relates to an ultrasonic diagnostic system and a system and a method for ultrasonic imaging wherein the velocity of biological tissue such as cardiac muscle is estimated, and the estimated velocity information is processed to output local motion information of the tissue, thereby providing information useful in medical diagnosis, and in particular, it relates to a method for reducing the time and labor for operation by automatically detecting an end systole phase.

Background Art

[0002] Objective and quantitative evaluation of functions of biological tissue is generally very important for diagnosis of biological tissue such as cardiac muscle. Diagnostic imaging using an ultrasonic imaging system also tries various quantitative evaluations principally for hearts as an example. A typical example is tissue tracking imaging (TTI) method. The TTI method allows quantitative evaluation by local-wall-motion indices such as distortion and displacement using tissue velocity.

[0003] To find distortion or displacement using tissue velocity, time quadrature is required. Since the result of time quadrature depends on an integration interval (time), the importance of the setting of the interval will easily be understood.

[0004] Of particular importance is a start phase. When integration start phase is, for example, in an end diastole phase, systolic distortion and displacement can be analyzed. Paying attention to distortion, normal cardiac muscle is thickened in the wall thickness direction (the minor axis), and shortened along the major axis during systole. In contrast, when the integration start phase is in end systole phase, diastolic distortion and displacement can be analyzed. Also paying attention to distortion, normal cardiac muscle is thinned in the wall thickness direction (the minor axis), and stretched along the major axis during systole.

[0005] Furthermore, integration end time is important second to the start time phase as a time phase that reflects the final state of distortion and displacement in specified intervals such as systole and diastole. Specifically, the most common way will be that the state of the whole motion by time quadrature for systole is analyzed in an end systole phase, and the state of the whole motion by time quadrature for diastole is analyzed in an end diastole phase.

[0006] To determine the integration interval for systole or diastole for a variety of applications, the end diastole phase and the end systole phase must be provided as accurately as possible. To enhance simplicity of the analyzing process, it is desirable that the two time phases of end diastole phase and end systole phase be set automatically. Furthermore, a technique of monopolar display of distortion is disclosed in JP-A-2003-175041, for example, as another unique application setting other than the setting of an integration interval in each phase interval of systole and diastole. To realize accurate and simple time phase setting is also very useful for the distortion monopolar display.

[0007] Of the end diastole phase and the end systole phase, the end diastole phase can be detected automatically as an R-wave phase in an electrocardiogram. On the other hand, the end systole phase cannot easily be detected from an electrocardiogram; however, the following automatic setting technique is known.

[0008] With stress echo packages, which are recently becoming widespread, only systoles are often cut out from a series of moving images, and are analyzed. In this case, a specified interval (duration time DT[sec]) from R wave can be set. Specifically speaking, a DT phase corresponds to an end systole phase. It is known that DTs vary depending on heart rates (HR)[bpm] (DTs decrease generally as HRs increase). Accordingly, DTs can often be set by users as a table for each HR.

[0009] Despite such devised stress echo packages, the accuracy required for an end systole phase being set is so low to be determined uniquely by a predetermined time in advance. Thus, since it has not a structure determined to the motion of a signal source, e.g., it is not necessarily a high-accuracy setting method for an end systole phase. Accordingly, this has the disadvantage of low time accuracy in view of automatically setting intervals of time quadrature for finding distortion or displacement.

[0010] Furthermore, a technique of automatically recognizing an end systole phase using a cardiac-cavity volume/area or cardiac sound graph by automated contour tracking (ACT) method is recently disclosed. It is generally known that "an end systole phase in clinical term is the time when the second sound on a phonocardiogram is generated". However, it is difficult to stably detect only the second sound from a phonocardiogram waveform having many abrupt changes, and there can be also some cases in which a phonocardiogram cannot always be provided at examinations (because many cardiac ultrasonic examinations use only phonocardiograms as reference signals). The technique by the ACT method discloses "finding an end systole phase as a time phase in which the area or volume of a cardiac cavity is minimized" by estimating the area or volume of a cardiac cavity from positional information on endocardium that is automatically detected.

[0011] US 2001/0024516 A1 discloses an ultrasound diagnostic imaging system comprising a storage unit which is adapted to store time-series velocity information on a heart that repeats contraction and relaxation cyclically. This information is stored in the form of a moving picture of the heart. US 2001/0024516 A1 further discloses an estimation unit which is adapted to estimate a terminal diastole or a terminal systole for one cycle of the heart on the basis of the area of the inside contour of the heart.

Disclosure of Invention

[0012] However, the ACT method cannot be applied to cross sections such as a longitudinal image of a left ventricle in which a cardiac cavity is not clearly drawn. To increase the accuracy of time for finding an end systole phase, it is preferable to obtain a cardiac-cavity volume with high accuracy. However, only one cross section allows definition of only an area, so that it is difficult to ensure an accurate volume. Multiple reference cross sections are generally required to obtain a high-accuracy volume. This is complicated technically, thus decreasing simplicity. Consequently, the ACT method cannot increase the accuracy and lacks in operability in setting cross sections because of its limitation to available cross sections.

[0013] The invention has been made in view of the above-described circumstances. Accordingly, it is an object of the invention to provide an ultrasonic diagnostic system and a system and a method for ultrasonic imaging capable of simple and high-accuracy automatic detection of end systole phases for all cross section images used in general cardiac ultrasonography. This is achieved by the system of claim 1 and the method of claim 8. Further developments are given in the dependent claims.

Brief Description of Drawings

[0014]

FIG. 1 is a block diagram of an ultrasonic diagnostic system 10 according to a first embodiment.

FIG. 2 is an explanatory diagram of the function of estimating end systole phase ES, showing a graph indicating the temporal changes of a myocardial velocity.

FIG. 3 is a diagram of an example of an ROI set in an ultrasonic image used for calculating a myocardial velocity.

FIG. 4 is an example of a table showing the relationship among heart rates, estimation-object-period start phases (start phases), and the widths of the estimation object period from the start phase.

FIG. 5 is a graph of an example of the relationship between the end systole phase ES, indicated by ES-phase line, and an electrocardiographic complex.

FIG. 6 is a diagram of an example in which the latest systole 2 is automatically set as an integration interval by TTI method.

FIG. 7 is a diagram of an example in which the latest diastole 2 is automatically set as an integration interval by TTI method.

FIG. 8 is a diagram of an example in which the latest cardiac cycle is automatically set as an integration interval by TTI method.

FIG. 9 is a flowchart for the procedure of a series of processes of TTI including automatic time-phase estimation.

Best Mode for Carrying Out the Invention

[0015] Embodiments of the invention will be described wither reference to the drawings. In the following description, components having the same function and structure will be given the same reference numerals and a duplicated description will be given as required.

[0016] FIG. 1 is a block diagram of an ultrasonic diagnostic system 10 according to a first embodiment. The ultrasonic diagnostic system 10 includes an ultrasonic probe 11, a transmitting unit 12, a receiving unit 13, a B-mode processing unit 14, a tissue Doppler processing unit 15, a motion-information processing unit 16, a display control unit 17, a display unit 18, an input unit 19, a storage unit 20, a control unit 21, and an input unit 22.

[0017] The ultrasonic probe 11 includes a plurality of piezoelectric vibrators that generates ultrasonic waves in response to a drive signal from the transmitting unit 12, and converts reflected waves from a subject to electric signals; a matching layer provided to the piezoelectric vibrators; and a backing material for preventing propagation of the ultrasonic waves from the piezoelectric vibrators to the back. When ultrasonic waves are transmitted from the ultrasonic probe 11 to the subject, various harmonic components are generated with the propagation of the ultrasonic waves owing to the nonlinearity of biological tissue. The fundamental waves and harmonic components that constitute transmission ultrasonic waves are scattered backward by the boundary of acoustic impedance of in vivo tissue, microscattering etc., and are received by the ultrasonic probe 11 as reflected waves (echo). Since this embodiment and the following-described embodiments explain a case of a heart being an imaged object as an example, a sector probe is used as the ultrasonic probe 1.

[0018] The transmitting unit 12 includes a delay circuit and a pulser circuit (not shown). The pulser circuit repeatedly generates a rate pulse for forming transmission ultrasonic waves at a predetermined rate frequency fr Hz (cycle: 1/fr sec). The delay circuit provides each rate pulse with a delay time necessary for converging ultrasonic waves into a beam for each channel and determining transmission directivity. The transmitting unit 12 applies driving pulses to each vibrator at timing based on the rate pulses so that the ultrasonic beams are formed in the direction of a specified scan line.

[0019] The receiving unit 13 includes an amplifier circuit, an A/D converter, an adder and the like (not shown). The amplifier circuit amplifies the echo signal taken via the probe 11 channel by channel. The A/D converter provides a delay time necessary for determining reception directivity to the amplified echo signal, and thereafter, the adder performs adding process. The addition generates an ultrasonic echo signal corresponding to a specified scan line.

[0020] The B-mode processing unit 14 applies an envelope detection process to the ultrasonic echo signal received from the receiving unit 13 to thereby generate a B-mode signal corresponding to the amplitude intensity of the ultrasonic echo signal.

[0021] The tissue Doppler processing unit 15 applies an orthogonal detection process, an autocorrelation process, and so on to the echo signal received from the receiving unit 13 to obtain a tissue Doppler signal corresponding to the velocity, dispersion, and power of the tissue moving in the subject on the basis of the Doppler displacement component of the ultrasonic echo signal subjected to the delay and addition process.

[0022] The motion-information processing unit 16 executes various processes for obtaining a motion-information image on the basis of the B-mode signal output from the B-mode processing unit 14 and the Doppler signal output from the tissue Doppler processing unit 16.

[0023] The motion-information processing unit 16 also executes the process of estimating a desired time phase and the process of automatically setting an integration interval by TTI method, which will be described later, using velocity-distribution images stored in the storage unit 20.

[0024] The display control unit 17 generates a B-mode ultrasonic image indicative of the dimensional distribution of a B-mode signal on a specified cross section. The display control unit 17 also generates a tissue Doppler ultrasonic image indicative of a two-dimensional distribution of the velocity, dispersion, and power values on a specified cross section on the basis on the tissue Doppler signal. The display control unit 17 also generates a superimposed image of a B-mode ultrasonic image and a tissue Doppler ultrasonic image, a superimposed image of a B-mode ultrasonic image and a two-dimensional distribution image of displacement or distortion, and so on as needed.

[0025] The display unit 18 displays in-vivo morphological information and blood-flow information according to a video signal from the display control unit 17 as an image. When a contrast medium is used, the motion-information processing unit 16 displays a luminance image or a color image according to quantitative information on the spatial distribution of the contrast medium, that is, the area of blood flow or blood.

[0026] The input unit 19 is connected to the system main body, and includes a mouse, a track ball, a mode switch, a keyboard, and so on for bringing various instructions from the operator, such as an instruction to set a region of interest (ROI) and an instruction to set various image-quality conditions to the system main body.

[0027] The storage unit 20 stores ultrasonic image data (ultrasonic reception data) corresponding to each phase, a velocity-distribution image corresponding to time phases generated by the motion-information processing unit 16, and so on. The ultrasonic image data assumes tissue-image data taken in a tissue Doppler mode and tissue-image data taken in other than the tissue Doppler mode. The tissue image data may be so-called raw image data before scan conversion.

[0028] The control unit 21 has the function of an information processor (computer), and controls the operation of the ultrasonic diagnostic system body statically or dynamically.

[0029] The input unit 22 is connected to the system 10, and includes various switch buttons, a track ball, a mouse, a keyboard, and so on for bringing in various instructions from the operator, such as an instruction to set and change various parameters and conditions and an instruction to set a region of interest (ROI) to the system main body.

(Tissue Tracking Imaging)

[0030] Tissue tracking imaging method (TTI) that is the prerequisite technique of the embodiment will be briefly described. The tissue tracking imaging images the parameters of local displacement and distortion obtained by integrating a signal based on velocity information, as tissue-motion information, while tracking the position of tissue which changes with motion. The technique allows the image of the distortion and displacement of local cardiac muscle to be produced and displayed using, e.g., a minor-axis image, thus supporting the analysis of temporal changes in image output values for a local region. In the case of using the minor-axis image, the main object function of cardiac analysis is thickening (change in thickness). The tissue tracking imaging method adopts the concept of a contraction motion field directed to a contraction center and setting therefor to detect a component relating to the thickening by angular compensation and to image it. The tissue tracking imaging method is also applicable to a temporally variable motion field by temporally shifting the contraction center position in consideration of the effects of the translational motion (also referred to as "translation") of the entire heart. This consequently allows tracking to the variations of the contract center position due to translational motion. Further details of the tissue tracking imaging method is described in JP-A-2003-175041, for example.

[0031] The tissue tracking imaging method requires a space-time distribution image of tissue velocities for multiple phases (an image indicative of the velocities of the positions of tissue to be diagnosed. The space-time distribution image of the tissue velocities (hereinafter, simply referred to as "a velocity-distribution image") can be generated from two-dimensional or three-dimensional ultrasonic image data on multiple time phases collected by tissue Doppler imaging, or alternatively, can be obtained by giving pattern-matching to multiple two-dimensional or three-dimensional tissue images on multiple time phases collected by the B-mode processing unit or the like.

[0032] The embodiment uses a two-dimensional velocity distribution image produced by the tissue Doppler imaging (TDI) to provide a concrete description. However, the invention is not limited to that, but may use a three-dimensional velocity distribution image produced by tissue Doppler imaging, for example, or a two-dimensional or three-dimensional velocity distribution image produced by pattern matching. The embodiment uses a heart as an diagnostic object by way of example. Accordingly, most of tissue velocities obtained by tissue tracking imaging can be regarded as myocardial velocity.

(Time-Phase Estimating Function)

[0033] The time-phase estimating function of the ultrasonic diagnostic system 10 will be described. The time-phase estimation is for analytically estimating, for example, various time phases, which are clinically important, using phase-to-phase velocity distribution images stored in the storage unit 20. Although estimation of an end systole phase will be described below to simplify the description as an example, in addition to that, the ultrasonic diagnostic system 10 can estimate an S-wave generation phase, an E-wave generation phase, a time phase in which the velocity reaches a specified velocity on the rising edge from E-wave, an A-wave generation phase, and any other phases specified by clinical characteristics.

[0034] The embodiment defines the end systole phase as the boundary phase between an S wave during a systole and an E wave during a diastole, and automatically estimates end systole phase ES from the idea of "end systole phase ES = time phase in which the motion of the heart stops = time phase in which myocardial velocity comes to zero or closest to zero".

[0035] FIG. 2 is an explanatory diagram of the function of estimating end systole phase ES, showing a graph indicating the temporal changes of a myocardial velocity. As shown in FIG. 2, it is preferable that the end systole phase ES be estimated by specifying a time phase in which |myocardial velocity | comes to the minimum in a predetermined period t0 to t0+tg that is set between an S-wave phase and an E-wave phase (hereinafter, referred to as "an estimation object period").

[0036] Here, as the myocardial velocity, for example the sum of the velocities at the positions of the cardiac muscle in the ROI set in the ultrasonic image (TDI image), as shown in FIG. 3, or the sum of the absolute values of the velocities at the positions of the cardiac muscle in the ROI (that is, |velocity|) is used.

[0037] When the myocardial velocity is defined as the sum of the velocities at the positions of the cardiac muscle in the ROI, the tissue velocity of the components toward beams can be found by the tissue Doppler imaging, so that the motion of tissue may be not always small if the sum is small. However, since the velocity in this estimation is high, a time phase in which the motion of cardiac tissue stands still can be detected approximately.

[0038] On the other hand, when the myocardial velocity is defined as the sum of the |velocities| at the positions of the cardiac muscle in the ROI, the component of motion is added as the absolute value in all cases, so that, although complicated, a time phase in which the motion of cardiac tissue stands still can be detected more accurately.

[0039] It is preferable that the estimation object period be controlled depending on the heart rate HR because the time per one heartbeat varies among individuals. As a specific method of controlling, it is preferable that an estimation-object-period start phase (start phase) and the width of the estimation object period from the start phase be stored in the storage unit 20 in advance as a table for heart rates, as shown in FIG. 4, and the motion-information processing unit 16 automatically determine the estimation object period on the basis of the heart rate obtained from an electrocardiogram (ECG) or input from the input unit 19 and the table. Alternatively, an integration-interval start phase by the TTI and the width of the estimation object period may be set by a predetermined function using a heart rate as a variable.

[0040] The end systole phase ES thus estimated is displayed in a specified form.

[0041] FIG. 5 is a graph of an example of the relationship between the end systole phase ES, indicated by ES-phase line L, and an electrocardiographic complex. This allows the user to easily grasp the position of the end systole phase ES throughout the heartbeat.

(Automatic Setting of Cardiac Phase Interval as Integration Interval)

[0042] Automatic setting of a cardiac phase interval as an integration interval of the ultrasonic diagnostic system 10 will next be described. The automatic setting is for automatically setting a cardiac phase interval, which can be an integration interval when a systole, a diastole, a cardiac cycle, and other motion information are calculated by the TTI method, based on the estimated end systole phase ES and an R-wave phase found by an ECG. This allows the motion information defined by time quadrature in TTI method to be analyzed and acquired easily.

[0043] FIG. 6 is a diagram of an example in which the latest systole 2 is automatically set as an integration interval by TTI method. As shown in FIG. 6, the motion-information processing unit 16 first regards the R-wave phase in each heartbeat detected by an ECG as an end diastole, and estimates the R-ES phase interval as a systole using the end diastole and the end systole phase ES obtained by the estimation, estimates the ES-R phase interval as a diastole, and estimates the R-R phase interval as one heart cycle. The motion-information processing unit 16 automatically sets the R2-wave phase that is the start phase of the latest systole 2 among the estimated phase intervals as the lower limit t0 of the integration interval, and sets the end systole phase ES2 that is the end time of the latest systole 2 as the upper limit tend of the integration interval.

[0044] FIG. 7 is a diagram of an example in which the latest diastole 2 is automatically set as an integration interval by TTI method. As in FIG. 6, the motion-information processing unit 16 automatically sets the end systole phase ES2 that is the start phase of the latest diastole 2 among the estimated phase intervals as the lower limit t0 of the integration interval, and sets the R3-wave phase that is the end time of the latest diastole 2 as the upper limit tend of the integration interval.

[0045] FIG. 8 is a diagram of an example in which the latest cardiac cycle is automatically set as an integration interval by TTI method. As in FIG. 6, the motion-information processing unit 16 automatically sets the R2-wave phase that is the start phase of the latest cardiac cycle 2 among the estimated phase intervals as the lower limit t0 of the integration interval, and sets the R3-wave phase that is the end time of the latest cardiac cycle 2 as the upper limit tend of the integration interval. The one cardiac cycle may not necessarily use the R-wave generating phase as the reference, and may use the end systole phase ES or the like, for example.

[0046] The selection of the integration interval among the systole, the diastole, and the one cardiac cycle described above is executed in such a manner that the user checks one of the items "one cardiac cycle (R-R)", "systole", and "diastole", as shown in FIG. 5. Another unique application setting other than the setting of an integration interval in each selected phase interval is then automatic switching of distortion monopolar display, for example. This allows automatic optimization of not only the setting of the object interval but also other accompanying settings, depending on the object cardiac phase interval, saving the user from controlling various settings manually to increase the simplicity of the operation.

[0047] The various object cardiac phase intervals estimated by the object cardiac-phase-interval estimation process agree with actual end systole phases with high accuracy. However, if the estimated end systole phase ES has an error, the integration interval may be fine-tuned manually, e.g., with reference to the ES-phase line L on the graph shown in FIG. 5, or may be set manually to applications.

(Operation)

[0048] A series of the processes of TTI including the automatic phase estimation and the automatic integration-interval setting will be described hereinbelow.

[0049] FIG. 9 is a flowchart for the procedure of a series of processes of the TTI including automatic time-phase estimation. As shown in FIG. 9, imaging by tissue Doppler echo cardiography is executed to generate a velocity distribution image for each time phase according to obtained echo signals (step S1).

[0050] The motion-information processing unit 16 next sets an estimation object period on the basis of a heart rate HR obtained from, e.g., an electrocardiogram. Also, a region of interest for finding a myocardial velocity is set on an TDI image by the manual operation of an operator. (step S2).

[0051] The motion-information processing unit 16 then calculates the absolute value of the myocardial velocity (|myocardial velocity| for each time phase in the set estimation object period (step S3), and estimates an end systole phase (step S4).

[0052] The motion-information processing unit 16 then estimates a systole, a diastole, and one cardiac cycle from an R-wave generation phase obtained from an electrocardiogram and the estimated end systole phase (step S5), and automatically sets an integration interval on the basis of the obtained estimation result (step S6).

[0053] The motion-information processing unit 16 then executes time quadrature in the automatically set integration interval to thereby calculate cardiac motion information including a distortion, a distortion factor, and a displacement (step S7), and for example generates a distortion image in each time phase based on the result and displays it on the display unit 18 (step S8).

[0054] The foregoing structure offers the following advantages.

[0055] The ultrasonic diagnostic system allows automatic estimation of, e.g., a desired time phase, which is important clinically, using phase-to-phase velocity-distribution images. The automatic estimation can be executed in an appropriate manner using velocity information. The operator can therefore set a desired time phase necessary for examination with high accuracy and easily. This system can also achieve highly objective phase setting without variation in information due to the difference of the operator as compared with the conventional manual phase setting, thus improving the quality of diagnostic information.

[0056] The ultrasonic diagnostic system determines the integration interval of motion information defined by time quadrature in TTI method using an automatically set desired time phase. This can provide highly objective motion information in TTI method, and reduce the work of the operator in setting integration intervals. Particularly, the ultrasonic diagnostic system can automatically separate a systole and a diastole from each other using an automatically detected end systole phase and an end diastole phase that is automatically detected from an electrocardiogram. Accordingly, highly objective quantitative evaluation method by local-wall-motion indices such as distortion and displacement using a tissue velocity can be quickly achieved by a simpler operation.

[0057] The invention is not limited to the foregoing embodiment and can be embodied in an actual step by modification of the components without deviating from the gist.

(1) For example, the desired-phase estimation process and the automatic integration-interval setting process which are aforementioned can also be achieved in such a manner that programs for executing each of the processes are installed in computers (including those built in workstations, image processors, or ultrasonic diagnostic systems), and are expanded on a memory. The programs for com-

puters to execute the technique may be distributed in the form of recording media such as magnetic disks (floppy(TM) disks, hard disks, and so on), optical disks (CD-ROMs, DVDs, and so on), and semiconductor memories.

(2) In the foregoing embodiment, the time phases including a systole are estimated in response to the values on the basis of myocardial velocities and velocity changes. However, the indices for phase estimation are not limited to the myocardial velocities and velocity changes, for example a structure may be adopted in which the timing at which the velocity reaches a specified velocity during a specified period in one cardiac cycle, and the rate of velocity change (the differential coefficient of velocity waveform) are used.

(3) The foregoing embodiment has been described using a heart as an diagnostic object by way of example. However, it is to be understood that the invention is not limited to that, the desired-phase estimation function of the ultrasonic diagnostic system can be applied to the diagnosis of moving regions that cyclically repeat contraction and relaxation of carotid artery, etc.

[0058] In addition, other various inventions may be made in appropriate combination of the components disclosed in the embodiment. For example, some of the components of the embodiment may be eliminated, or some of the components of different embodiments may be combined as appropriate.

Industrial Applicability

[0059] According to the embodiment, an ultrasonic diagnostic system and a system and a method for ultrasonic imaging capable of simple and high-accuracy automatic detection of end systole phases for all cross-section images used in general cardiac ultrasonic examinations as described above.

Claims

1. An ultrasonic diagnostic system or an ultrasonic imaging system, comprising:

a storage unit (20) adapted to store time-series velocity information on a plurality of positions of a moving region that repeats contraction and relaxation cyclically; and
an estimation unit (16) adapted to
calculate the velocity of the moving region or the velocity change rate of the moving region from the sum of the velocities of the plurality of positions present in a region of interest set in the moving region, the mean values, and other statistic calculated values; and to
estimate any desired time phase for one cycle including the contraction and relaxation of the moving region from the velocity of the moving region or the velocity change rate of the moving region.

2. The system according to claim 1, further comprising a calculation unit adapted to calculate any one of a distortion, a distortion factor, or a displacement, defined by time quadrature using the velocity information on at least two time phases, and to determine an integration interval for the time quadrature using the desired time phase estimated by the estimation unit.

3. The system according to claim 1 or 2, wherein
the estimated desired time phase is an end systole phase of the heart of a subject; and
the estimation unit (16) is adapted to estimate a time phase in which the motion of the moving region stands still as the end systole phase on the basis of at least the velocity of the moving region during a predetermined period set in the vicinity of the end systole phase.

4. The system according to claim 3, wherein the estimation unit (16) is adapted to
obtain as the velocity the sum of the velocities of the plurality of positions;
detect a time phase in which the absolute value of the sum comes to the minimum in the predetermined period set in the vicinity of the end systole phase; and to
estimate the time phase in which the detected absolute value of the sum comes to the minimum as the time phase in which the motion of the moving region stands still.

5. The system according to claim 4, further comprising:

an information obtaining unit adapted to obtain information on the heart rate of the subject; and
a setting unit adapted to control the predetermined period set in the vicinity of the end systole phase according to the obtained heart rate.

6. The system according to any of claims 1 to 5, further comprising a display unit adapted to display the desired time phase estimated by the estimation unit.

7. The system according to any of claims 1 to 6, wherein the time-series velocity information is generated on the basis of ultrasonic image data on a plurality of time phases obtained by tissue Doppler imaging or by applying pattern matching to tissue images for a plurality of time phases obtained by B-mode imaging.

8. A method for ultrasonic imaging, comprising:

obtaining time-series velocity information on a plurality of positions of a moving region that repeats contraction and relaxation cyclically;
calculating the velocity of the moving region or the velocity change rate of the moving region from the sum of the velocities of the plurality of positions present in a region of interest set in the moving region, the mean value, and other statistic calculated values; and
estimating any desired time phase for one cycle including the contraction and relaxation of the moving region from the velocity of the moving region or the velocity change rate of the moving region.

9. The method for ultrasonic imaging according to claim 8, further comprising: calculating any one of a distortion, a distortion factor, or a displacement, defined by time quadrature using the velocity information on at least two time phases, and calculating to determine an integration interval for the time quadrature using the desired time phase estimated by the estimation unit.

10. The method for ultrasonic imaging according to claim 8 or 9, wherein
the estimated desired time phase is an end systole phase of the heart of a subject; and
for the estimation, a time phase in which the motion of the moving region stands still is estimated as the end systole phase on the basis of at least the velocity of the moving region during a predetermined period set in the vicinity of the end systole phase.

11. The method for ultrasonic imaging according to claim 10, comprising:

the sum of the velocities of the plurality of positions is obtained as the velocity;
a time phase in which the absolute value of the sum comes to the minimum in the predetermined period set in the vicinity of the end systole phase is detected; and
the time phase in which the detected absolute value of the sum comes to the minimum is estimated as the time phase in which the motion of the moving region stands still.

12. The method for ultrasonic imaging according to claim 11, further comprising:

obtaining information on the heart rate of the subject; and
controlling the predetermined period set in the vicinity of the end systole phase according to the obtained heart rate.

13. The method for ultrasonic imaging according to claim 8, further comprising displaying the estimated desired time phase.

14. The method for ultrasonic imaging according to any of claims 8 to 13, wherein the time-series velocity information is generated on the basis of ultrasonic image data on a plurality of time phases obtained by tissue Doppler imaging or by applying pattern matching to tissue images for a plurality of time phases obtained by B-mode imaging.

Patentansprüche

1. Ultraschalldiagnosesystem oder Ultraschallbildgebungssystem, enthaltend:

eine Speichereinheit (20), die angepasst ist zum Speichern einer Geschwindigkeitsinformationszeitreihe über eine Mehrzahl von Positionen einer sich bewegenden Region, die eine Kontraktion und Entspannung zyklisch wiederholt; und
eine Schätzeinheit, die angepasst ist zum
Berechnen der Geschwindigkeit der sich bewegenden Region oder der Geschwindigkeitsänderungsrate der sich bewegenden Region aus der Summe der Geschwindigkeit der Mehrzahl von Positionen, die in einer Region, die von Interesse ist, vorhanden sind, die in der sich bewegenden Region gesetzt ist, den Mittelwerten und anderen statistisch berechneten Werten; und
zum Schätzen irgendeiner gewünschten Zeitphase für einen Zyklus, der die Kontraktion und die Entspannung der sich bewegenden Region enthält, aus der Geschwindigkeit der sich bewegenden Region oder der Geschwindigkeitsänderungsrate der sich bewegenden Region.

2. System nach Anspruch 1, ferner enthaltend eine Berechnungseinheit, die angepasst ist
zum Berechnen einer Verzerrung, eines Verzerrungsfaktors oder einer Versetzung, die definiert sind durch Zeitquadratur unter Verwendung der Geschwindigkeitsinformation über mindestens zwei Zeitphasen, und zum Bestimmen eines Integrationsintervalls für die Zeitquadratur unter Verwendung der gewünschten Zeitphase, die durch die Schätzungseinheit geschätzt wird.

3. System nach Anspruch 1 oder 2, bei dem
die geschätzte gewünschte Zeitphase eine endsystolische Phase des Herzens eines Subjekts ist, und die Schätzeinheit (16) angepasst ist zum Schätzen einer Zeitphase, in der die Bewegung der sich bewegenden Region ruht, als die endsystolische Phase basierend auf mindestens der Geschwindigkeit der sich bewegenden Region während einer vorbe-

stimmten Zeitperiode, die in der Nähe der endsystolische Phase gesetzt ist.

4. System nach Anspruch 3, bei dem die Schätzeinheit (16) angepasst ist zum
Erlangen der Summe von Geschwindigkeiten der Mehrzahl von Positionen als die Geschwindigkeit;
Detektieren einer Zeitphase, in der der absolute Wert der Summe eine Minimum wird in der vorbestimmten Periode, die in der Nähe der endsystolischen Phase gesetzt ist; und
zum Schätzen der Zeitphase, in der der detektierte absolute Wert der Summe das Minimum wird, als diejenige Zeitphase, in der die Bewegung der sich bewegenden Region ruht.

5. System nach Anspruch 4, ferner enthaltend:

eine Informationserlangungseinheit, die angepasst ist zum Erlangen von Information über die Herzfrequenz des Subjekts; und
eine Setzeinheit, die angepasst ist zum Steuern der vorbestimmten Periode, die in der Nähe der endsystolische Phase gesetzt ist, gemäß der erlangten Herzfrequenz.

6. System nach einem der Ansprüche 1 bis 5, ferner enthaltend
eine Anzeigeneinheit, die angepasst ist zum Anzeigen der gewünschten Zeitphase, die durch die Schätzeinheit geschätzt ist.

7. System nach einem der Ansprüche 1 bis 6, bei dem die Geschwindigkeitsinformationszeitreihe erzeugt wird basierend auf Ultraschallbilddaten über eine Mehrzahl von Zeitphasen, die durch Gewebedoppler-Bildgebung oder durch Anwenden eines Musterabgleichs auf Gewebebilder für eine Mehrzahl von Zeitphasen, die durch B-Modus Bildgebung erlangt werden, gewonnen werden.

8. Verfahren zur Ultraschallbildgebung, mit:

Erlangen einer Geschwindigkeitsinformationszeitreihe über eine Mehrzahl von Positionen einer sich bewegenden Region, die eine Kontraktion und eine Entspannung zyklisch wiederholt;
Berechnen der Geschwindigkeit der sich bewegenden Region oder der Geschwindigkeitsänderungsrate der sich bewegenden Region aus der Summe der Geschwindigkeiten der Mehrzahl von Positionen, die in einer Region, die von Interesse ist, vorhanden sind, die in der sich bewegenden Region gesetzt ist, dem Mittelwert und anderen statistisch berechneten Werten; und
Schätzen von irgendeiner gewünschten Zeitphase für einen Zyklus, der die Kontraktion und die Entspannung der sich bewegenden Region enthält, aus der Geschwindigkeit der sich bewegenden Region oder der Geschwindigkeitsänderungsrate der sich bewegenden Region.

9. Verfahren zur Ultraschallbildgebung nach Anspruch 8, ferner mit:

Berechnen einer Verzerrung, eines Verzerrungsfaktors oder einer Versetzung, die definiert sind durch die Zeitquadratur unter Verwendung der Geschwindigkeitsinformation über mindestens zwei Zeitphasen, und Berechnen zum Bestimmen eines Integrationsintervalls für die Zeitquadratur unter Verwendung der gewünschten Zeitphase, die von der Schätzeinheit geschätzt wird.

10. Verfahren zur Ultraschallbildgebung nach Anspruch 8 oder 9, bei dem
die geschätzte gewünschte Zeitphase eine endsystolische Phase des Herzens eines Subjekts ist; und
für die Schätzung eine Zeitphase, in der die Bewegung der sich bewegenden Region nicht vorliegt, als die endsystolische Phase geschätzt wird basierend auf mindestens der Geschwindigkeit der sich bewegenden Region während einer vorbestimmten Periode, die in der Nähe der endsystolischen Phase gesetzt ist.

11. Verfahren zur Ultraschallbildgebung nach Anspruch 10, bei dem
die Summe der Geschwindigkeiten der Mehrzahl von Positionen als die Geschwindigkeit erlangt wird;
eine Zeitphase, in der der Absolutwert der Summe das Minimum in der vorbestimmten Periode wird, die in der Nähe der endsystolischen Phase gesetzt ist, detektiert wird; und
die Zeitphase, in der der detektierte Absolutwert der Summe das Minimum wird, als die Zeitphase geschätzt wird, in der die Bewegung der sich bewegenden Region ruht.

12. Verfahren zur Ultraschallbildgebung nach Anspruch 11, ferner mit:

Erlangen von Information über die Herzfrequenz des Subjekts; und
Steuern der vorbestimmten Periode, die in der Nähe der endsystolischen Phase gesetzt ist, gemäß der erlangten Herzfrequenz.

13. Verfahren zur Ultraschallbildgebung nach Anspruch 8, ferner mit einem Anzeigen der geschätzten gewünschten Zeitphase.

14. Verfahren zur Ultraschallbildgebung nach einem der Ansprüche 8 bis 13, bei dem die Geschwindigkeitsinformationszeitreihe erzeugt wird, basierend auf Ultraschallbilddaten über eine Mehrzahl von Zeitphasen, die erlangt werden durch Gewebedoppler-Bildgebung oder durch Anwenden eines Musterabgleichs auf Gewebebilder für eine Mehrzahl von Zeitphasen, die durch B-Modus Bildgebung erlangt werden.

Revendications

1. Système de diagnostic ultrasonique ou système d'imagerie ultrasonique comprenant :

    une unité de stockage (20) qui est à même de stocker des informations de vitesse en séries chronologiques sur une pluralité de positions d'une région mobile qui répète la contraction et la relaxation de manière cyclique ; et
    une unité d'estimation (16) qui est à même :

        de calculer la vitesse de la région mobile ou le taux de changement de vitesse de la région mobile à partir de la somme des vitesses de la pluralité de positions présentes dans une région intéressante réglée dans la région mobile, des valeurs moyennes et d'autres valeurs statistiques calculées ; et
        d'estimer une phase temporelle souhaitée quelconque pour un cycle comprenant la contraction et la relaxation de la région mobile depuis la vitesse de la région mobile ou du taux de changement de vitesse de la région mobile.

2. Système selon la revendication 1, comprenant par ailleurs une unité de calcul qui est à même de calculer l'une quelconque de valeurs parmi une distorsion, un facteur de distorsion ou un déplacement, définies par quadrature temporelle en utilisant les informations de vitesse sur au moins deux phases temporelles et de déterminer un intervalle d'intégration pour la quadrature temporelle en utilisant la phase temporelle souhaitée estimée par l'unité d'estimation.

3. Système selon la revendication 1 ou la revendication 2, dans lequel :

    la phase temporelle estimée souhaitée est une phase systolique terminale du coeur d'un sujet ; et
    l'unité d'estimation (16) est à même d'estimer une phase temporelle dans laquelle le mouvement de la région mobile reste fixe comme phase systolique terminale sur la base d'au moins la vitesse de la région mobile au cours d'une période prédéterminée réglée au voisinage de la phase systolique terminale.

4. Système selon la revendication 3, dans laquelle l'unité d'estimation (16) est à même :

    d'obtenir comme vitesse la somme des vitesses de la pluralité de positions ;
    de détecter une phase temporelle dans laquelle la valeur absolue de la somme chute au minimum dans la période prédéterminée réglée au voisinage de la phase systolique terminale ; et
    d'estimer la phase temporelle dans laquelle la valeur absolue détectée de la somme chute au minimum comme phase temporelle dans laquelle le mouvement de la région mobile reste fixe.

5. Système selon la revendication 4, comprenant par ailleurs :

    une unité d'obtention d'informations qui est à même d'obtenir des informations sur le rythme cardiaque du sujet ; et
    une unité de réglage qui est à même de commander la période prédéterminée réglée au voisinage de la phase systolique terminale selon le rythme cardiaque obtenu.

6. Système selon l'une quelconque des revendications 1 à 5, comprenant par ailleurs une unité d'affichage qui est à même d'afficher la phase temporelle souhaitée estimée par l'unité d'estimation.

7. Système selon l'une quelconque des revendications 1 à 6, dans lequel les informations de vitesse en séries chronologiques sont générées sur la base de données d'images ultrasoniques sur une pluralité de phases temporelles obtenues par imagerie Doppler des tissus ou en appliquant un modèle concordant avec des images de tissus pendant une pluralité de phases temporelles obtenues par imagerie en mode B.

8. Procédé d'imagerie ultrasonique, comprenant les étapes consistant à :

    obtenir des informations de vitesse en séries chronologiques sur une pluralité de positions d'une région mobile qui répète la contraction et la relaxation de manière cyclique ;
    calculer la vitesse de la région mobile ou le taux de changement de vitesse de la région mobile à partir de la somme des vitesses de la pluralité de positions présentes dans une région intéressante réglée dans la région mobile, de la valeur moyenne et d'autres valeurs statistiques calculées ; et
    estimer une phase temporelle désirée quelconque pendant un cycle, comprenant la contrac-

tion et la relaxation de la région mobile à partir de la vitesse de la région mobile ou du taux de changement de vitesse de la région mobile.

9. Procédé d'imagerie ultrasonique selon la revendication 8, comprenant par ailleurs le calcul d'une valeur quelconque choisie parmi une distorsion, un facteur de distorsion ou un déplacement, définie par une quadrature temporelle en utilisant les informations de vitesse sur au moins deux phases temporelles, et le calcul pour déterminer un intervalle d'intégration pour la quadrature temporelle en utilisant la phase temporelle souhaitée estimée par l'unité d'estimation.

10. Procédé d'imagerie ultrasonique selon la revendication 8 ou la revendication 9, dans lequel :

la phase temporelle estimée souhaitée est une phase systolique terminale du coeur d'un sujet ; et
pour l'estimation, on estime une phase temporelle dans laquelle le mouvement de la région mobile reste fixe comme phase systolique terminale sur la base d'au moins la vitesse de la région mobile au cours d'une période prédéterminée réglée au voisinage de la phase systolique terminale.

11. Procédé d'imagerie ultrasonique selon la revendication 10, comprenant :

la somme des vitesses de la pluralité de positions qui est obtenue à titre de vitesse ;
une phase temporelle, dans laquelle la valeur absolue de la somme chute au minimum dans la période prédéterminée réglée au voisinage de la phase systolique terminale, qui est détectée ; et
la phase temporelle, dans laquelle la valeur absolue détectée de la somme chute au minimum, qui est estimée comme phase temporelle dans laquelle le mouvement de la région mobile reste fixe.

12. Procédé d'imagerie ultrasonique selon la revendication 11, comprenant par ailleurs les étapes consistant à :

obtenir des informations sur le rythme cardiaque du sujet ; et
commander la période prédéterminée réglée au voisinage de la phase systolique terminale selon le rythme cardiaque obtenu.

13. Procédé d'imagerie ultrasonique selon la revendication 8, comprenant par ailleurs l'affichage de la phase temporelle estimée souhaitée.

14. Procédé d'imagerie ultrasonique selon l'une quelconque des revendications 8 à 13, dans lequel les informations de vitesse en séries chronologiques sont générées sur la base de données d'images ultrasoniques sur une pluralité de phases temporelles obtenues par imagerie Doppler des tissus ou en appliquant un modèle qui concordant avec des images de tissus pendant une pluralité de phases temporelles obtenues par imagerie en mode B.

FIG. 1

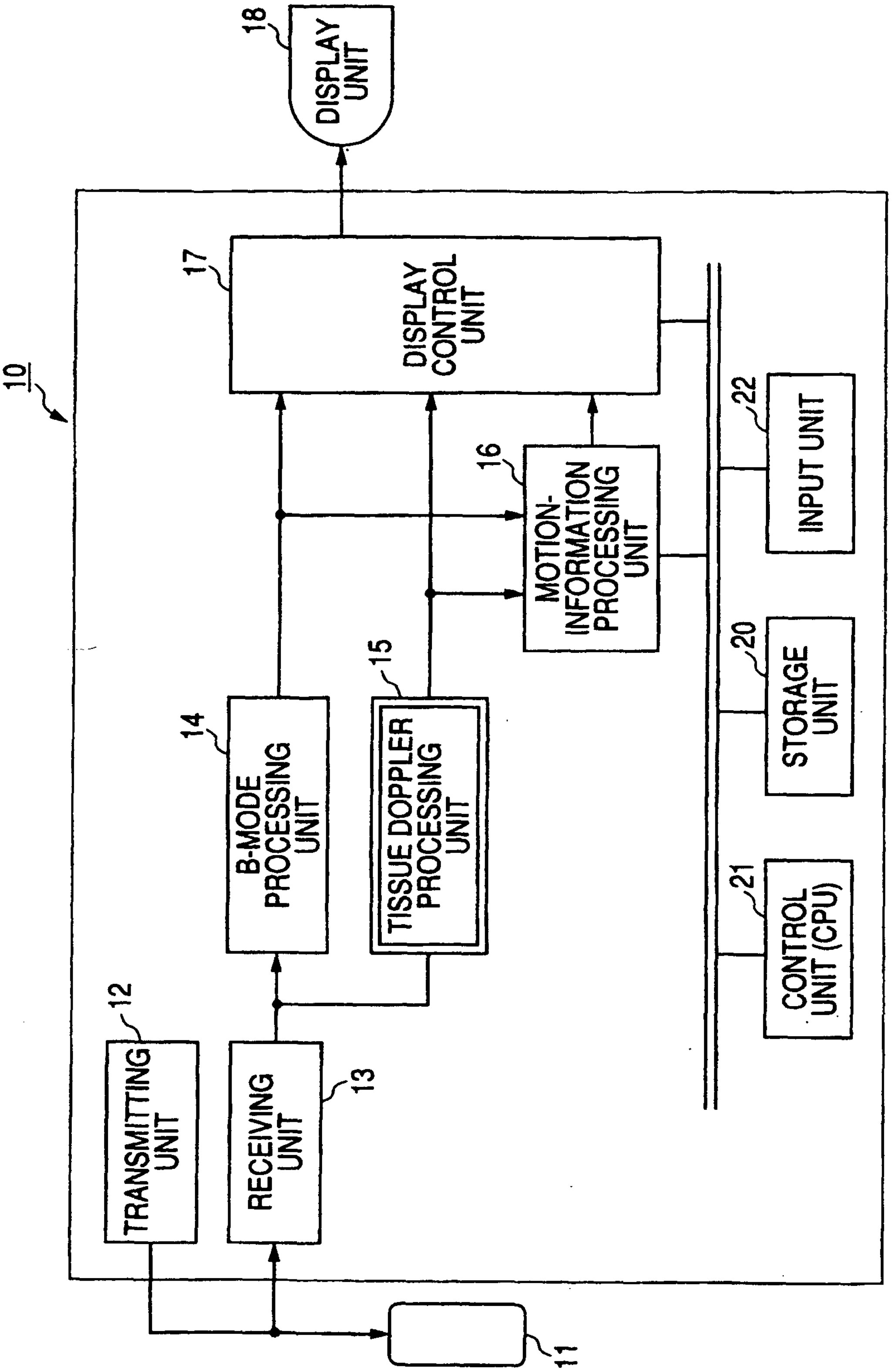

10
11
TRANSMITTING UNIT
12
RECEIVING UNIT
13
B-MODE PROCESSING UNIT
14
TISSUE DOPPLER PROCESSING UNIT
15
MOTION-INFORMATION PROCESSING UNIT
16
DISPLAY CONTROL UNIT
17
DISPLAY UNIT
18
STORAGE UNIT
20
CONTROL UNIT (CPU)
21
INPUT UNIT
22

FIG. 2

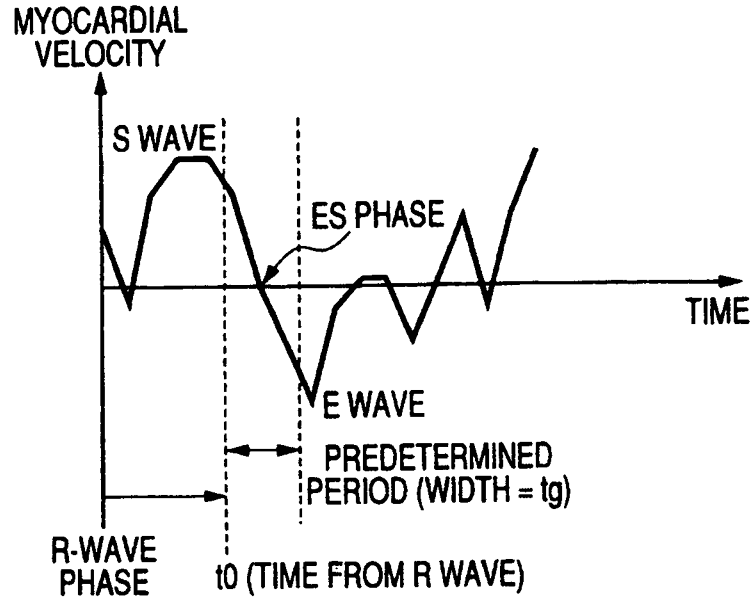

MYOCARDIAL
VELOCITY
S WAVE
ES PHASE
TIME
E WAVE
PREDETERMINED
PERIOD (WIDTH = tg)
R-WAVE
PHASE
t0 (TIME FROM R WAVE)

FIG. 3

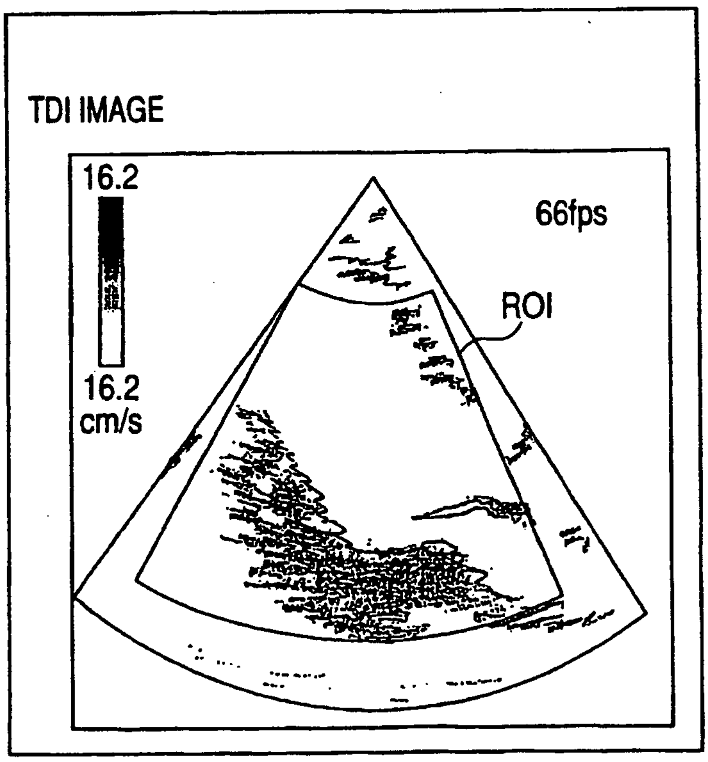

TDI IMAGE
16.2
66fps
ROI
16.2
cm/s

FIG. 4

HR [bpm]	t0 [msec]	tg [msec]
<50	300	100
50≤ <100	250	100
100≤ <200	200	100
200≤	150	100

FIG. 5

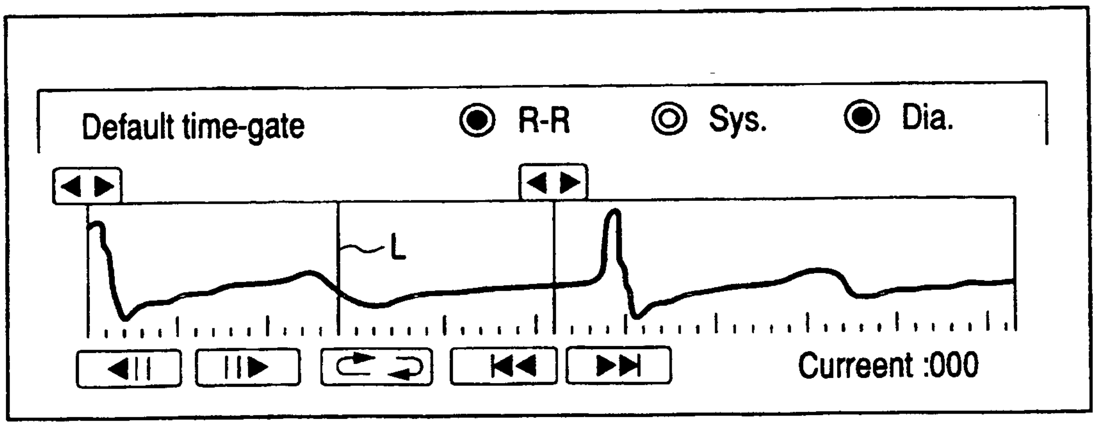


FIG. 6

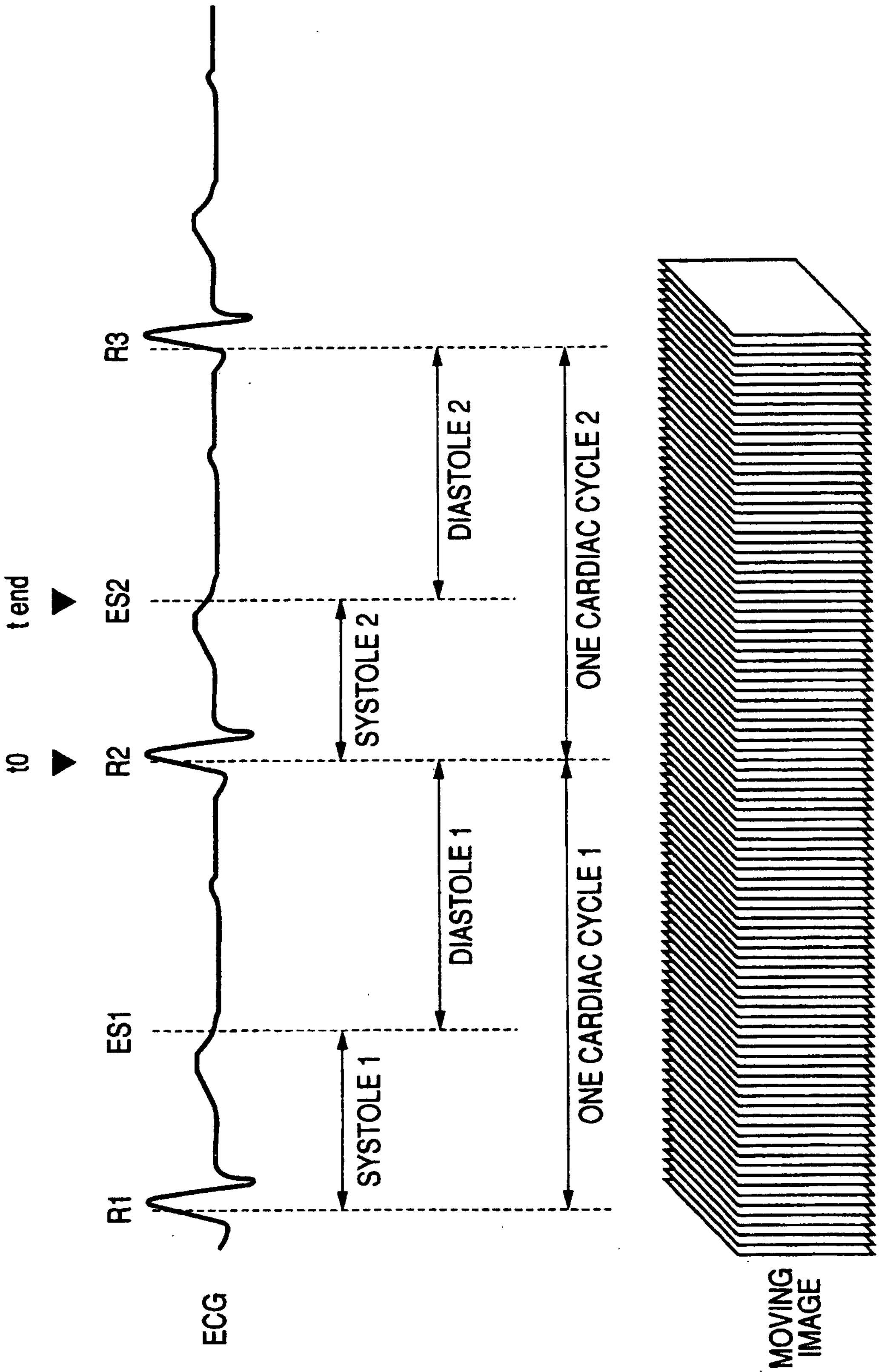

t0
t end
R1
ES1
R2
ES2
R3
ECG
SYSTOLE 1
DIASTOLE 1
SYSTOLE 2
DIASTOLE 2
ONE CARDIAC CYCLE 1
ONE CARDIAC CYCLE 2
MOVING IMAGE

FIG. 7

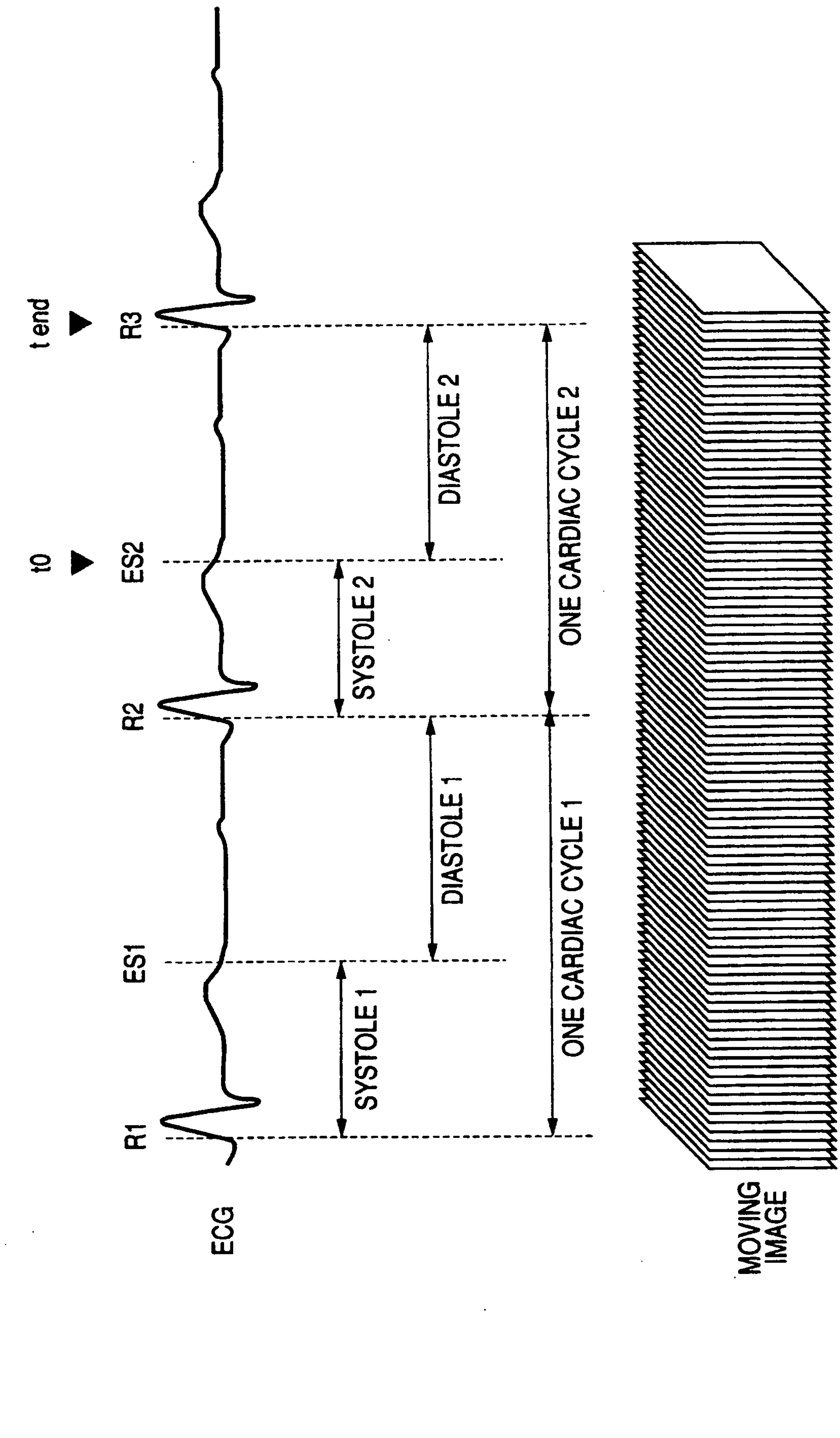

t0
t end
ECG
R1
ES1
R2
ES2
R3
SYSTOLE 1
DIASTOLE 1
SYSTOLE 2
DIASTOLE 2
ONE CARDIAC CYCLE 1
ONE CARDIAC CYCLE 2
MOVING IMAGE

FIG. 8

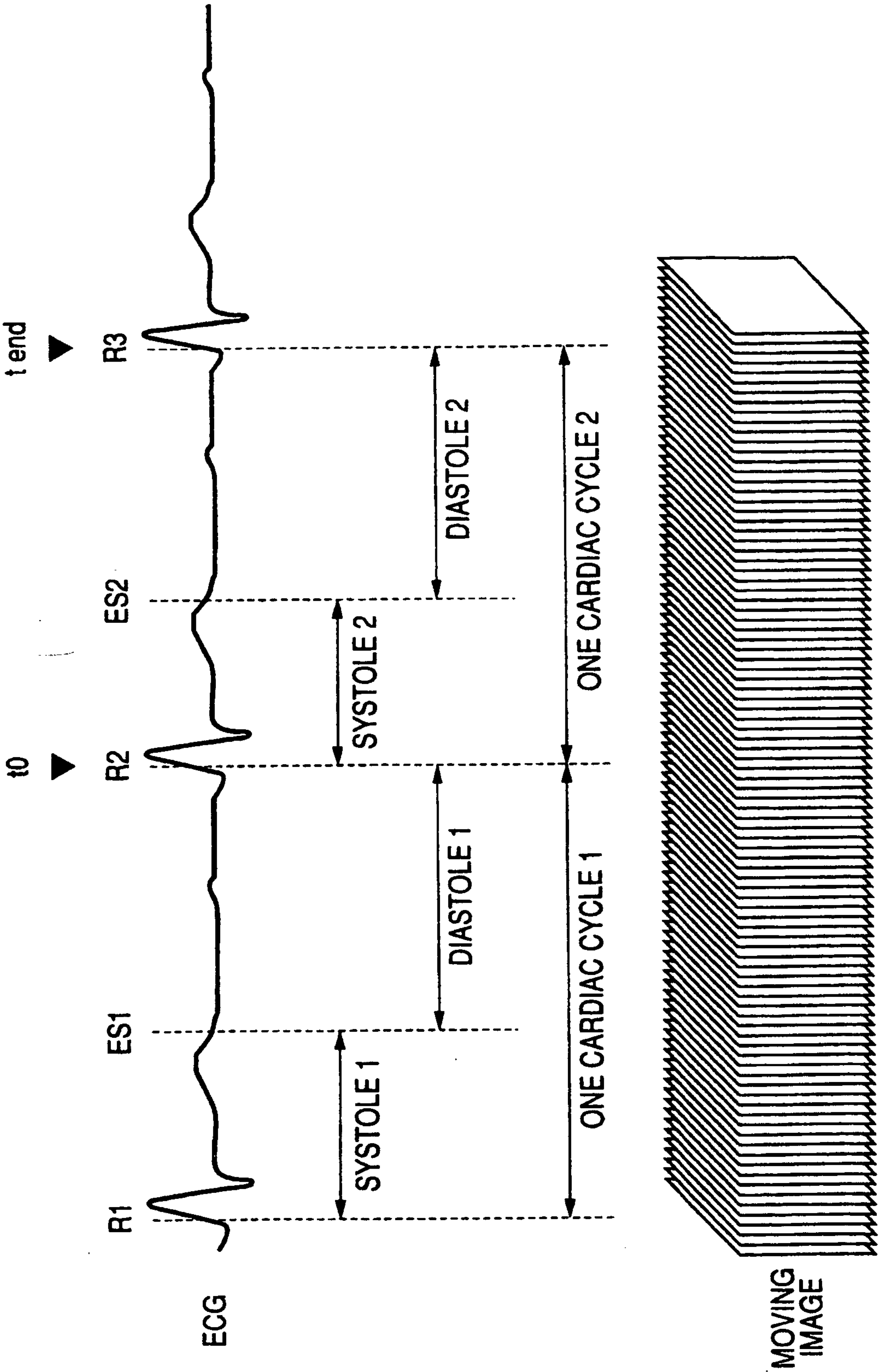
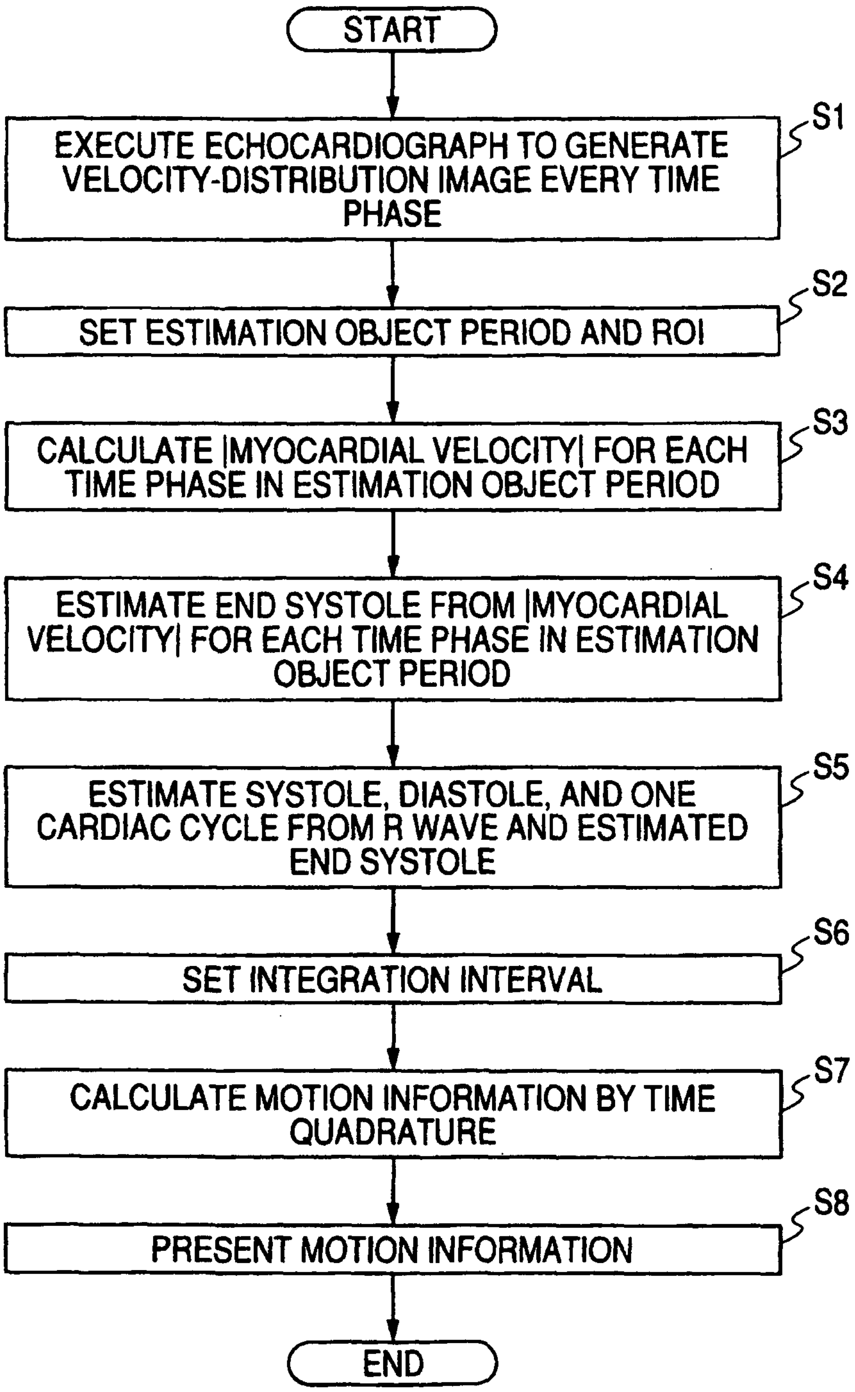

t0
t end
ECG
R1
ES1
R2
ES2
R3
SYSTOLE 1
DIASTOLE 1
SYSTOLE 2
DIASTOLE 2
ONE CARDIAC CYCLE 1
ONE CARDIAC CYCLE 2
MOVING IMAGE

FIG. 9


START
S1
EXECUTE ECHOCARDIOGRAPH TO GENERATE VELOCITY-DISTRIBUTION IMAGE EVERY TIME PHASE
S2
SET ESTIMATION OBJECT PERIOD AND ROI
S3
CALCULATE |MYOCARDIAL VELOCITY| FOR EACH TIME PHASE IN ESTIMATION OBJECT PERIOD
S4
ESTIMATE END SYSTOLE FROM |MYOCARDIAL VELOCITY| FOR EACH TIME PHASE IN ESTIMATION OBJECT PERIOD
S5
ESTIMATE SYSTOLE, DIASTOLE, AND ONE CARDIAC CYCLE FROM R WAVE AND ESTIMATED END SYSTOLE
S6
SET INTEGRATION INTERVAL
S7
CALCULATE MOTION INFORMATION BY TIME QUADRATURE
S8
PRESENT MOTION INFORMATION
END

REFERENCES CITED IN THE DESCRIPTION

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- JP 2003175041 A **[0006] [0030]**
- US 20010024516 A1 **[0011]**

专利名称(译)	超声波检查，超声波图像处理装置和超声波图像处理方法

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摘要(译)

超声诊断系统估计周期性地重复收缩和舒张的运动区域（例如，心脏）的期望时间相位或一个周期时段，其可以由心搏停止，收缩末期，预先收缩，舒张末期和基于针对每个时间阶段获得的关于移动区域的多个位置的速度信息，针对移动区域的一个周期的其他临床特征。更具体地，假设例如收缩末期相位=心肌速度变为零或接近零的时间相位，系统计算心率|对于预定时段中的每个时间阶段，并且估计该值最接近零的时间阶段作为收缩末期阶段。

FIG. 1