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(54) **MEDICAL IMAGE DIAGNOSIS APPARATUS AND PHASE DETERMINATION METHOD USING MEDICAL IMAGE DIAGNOSIS APPARATUS**

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(57) **ABSTRACT**

In order to provide a medical image diagnosis apparatus and a phase determination method using a medical image diagnosis apparatus that can determine an appropriate movement phase when obtaining a tomographic image corresponding to a specific movement phase, there are provided a storage unit that stores material distribution information, which is acquired from an object including a target organ that moves periodically, and movement information, which is measured together with the material distribution information, an image reconstruction unit that reconstructs a plurality of tomographic images of different movement phases using the material distribution information and the movement information, a superimposed image creation unit that creates a superimposed image by superimposing the plurality of tomographic images, a specific position calculation unit that calculates a specific position of the target organ based on the superimposed image, and a specific phase determination unit that determines a specific phase of the target organ based on the specific position.

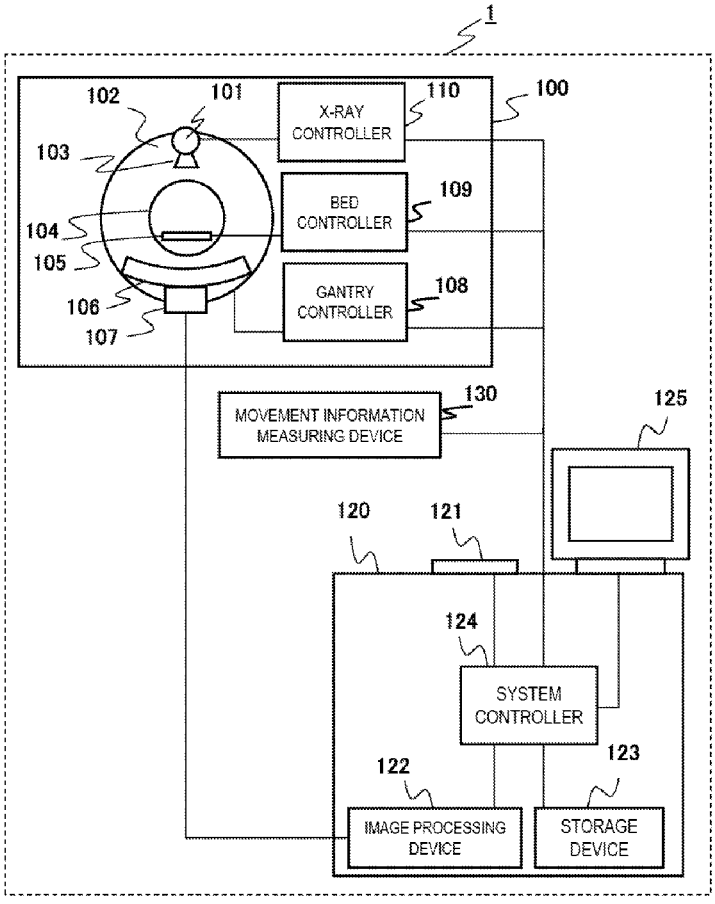


FIG. 1

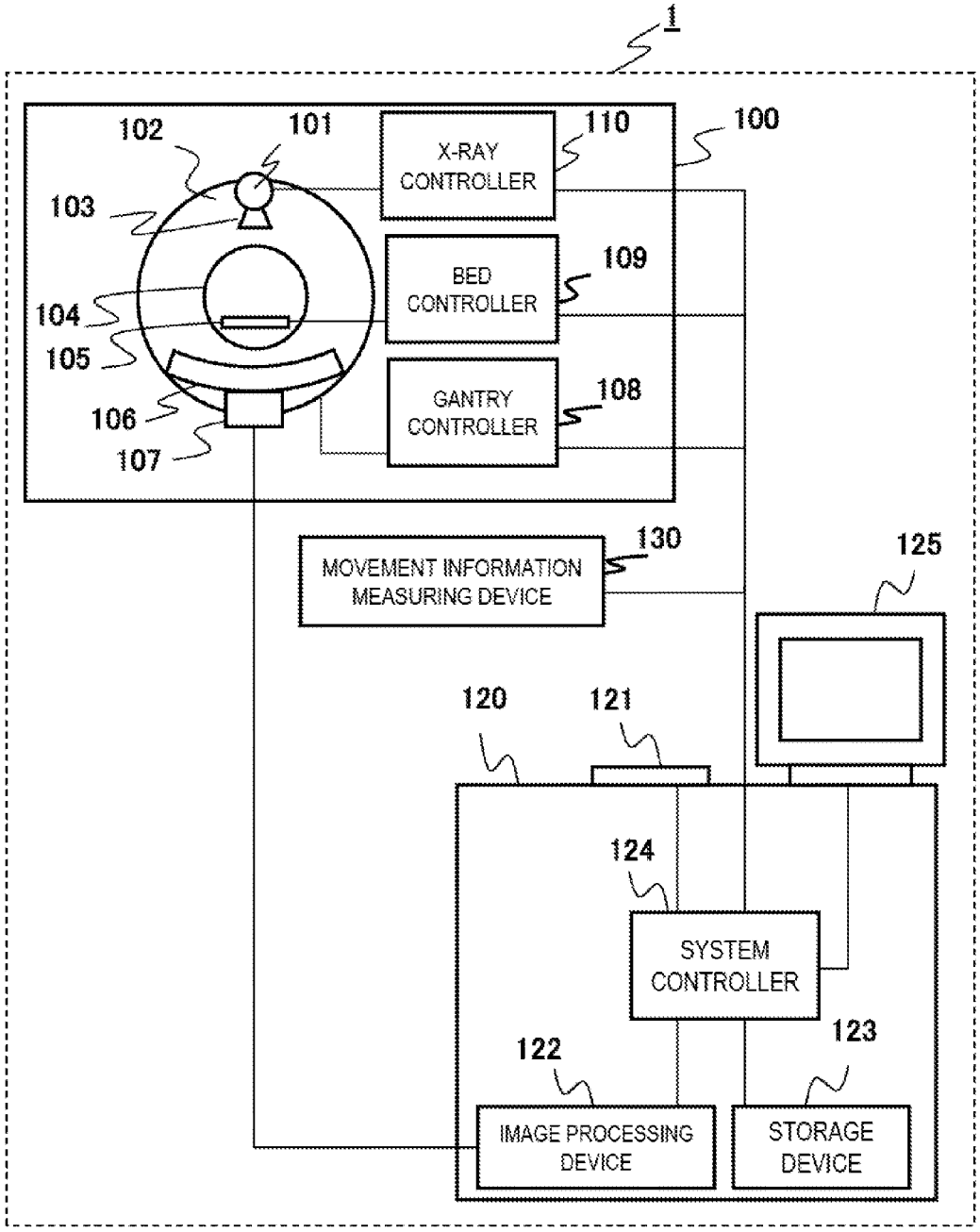

1
100
101
102
103
104
105
106
107
X-RAY CONTROLLER
110
BED CONTROLLER
109
GANTRY CONTROLLER
108
MOVEMENT INFORMATION MEASURING DEVICE
130
125
120
121
124
SYSTEM CONTROLLER
122
123
IMAGE PROCESSING DEVICE
STORAGE DEVICE

FIG. 2

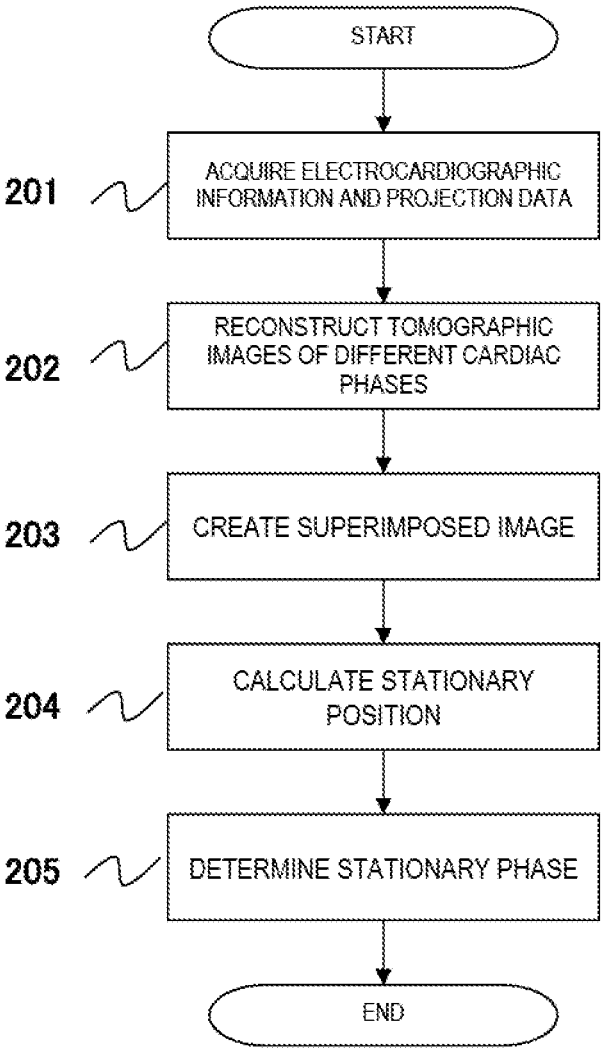

START
201
ACQUIRE ELECTROCARDIOGRAPHIC INFORMATION AND PROJECTION DATA
202
RECONSTRUCT TOMOGRAPHIC IMAGES OF DIFFERENT CARDIAC PHASES
203
CREATE SUPERIMPOSED IMAGE
204
CALCULATE STATIONARY POSITION
205
DETERMINE STATIONARY PHASE
END

FIG. 3

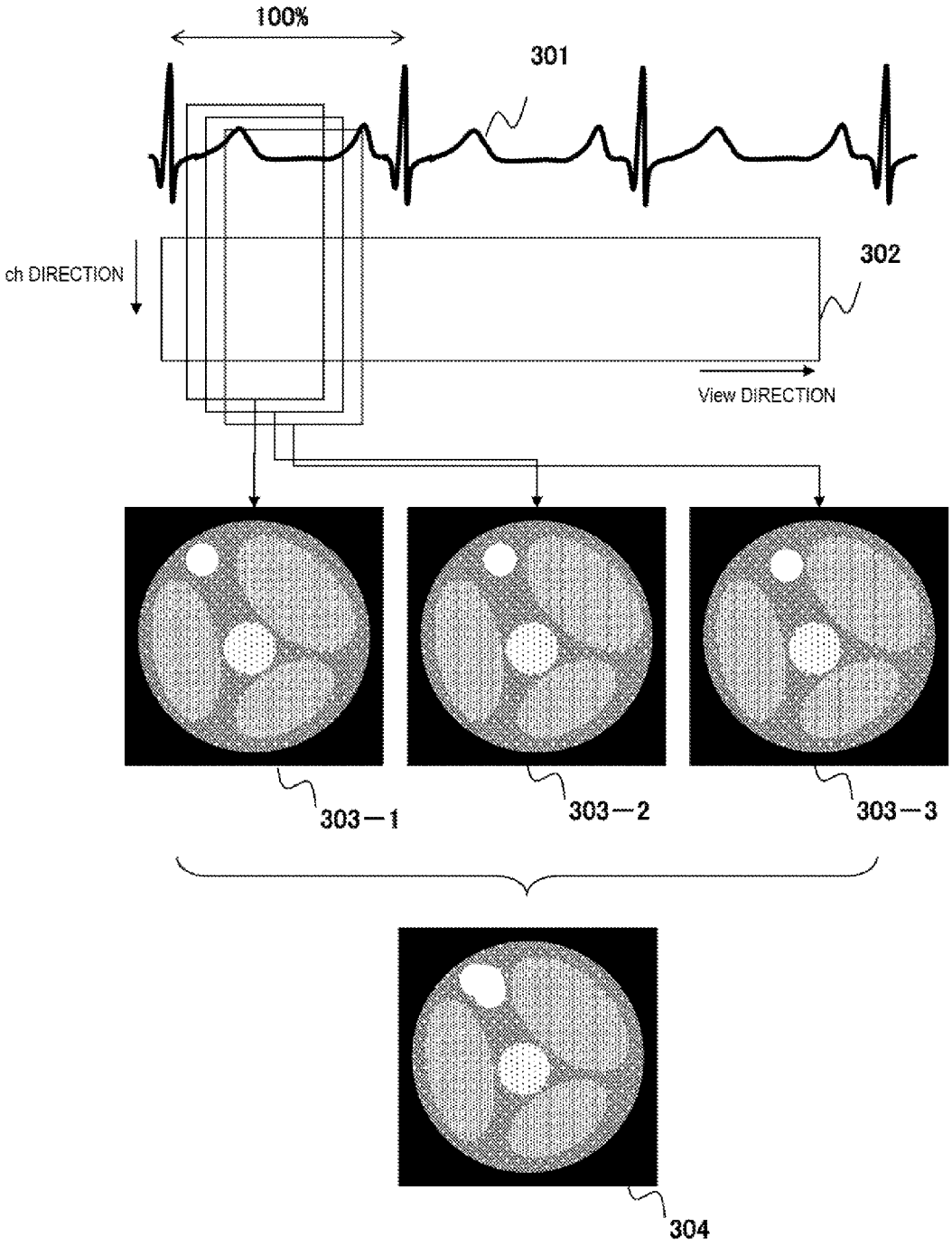


FIG. 4

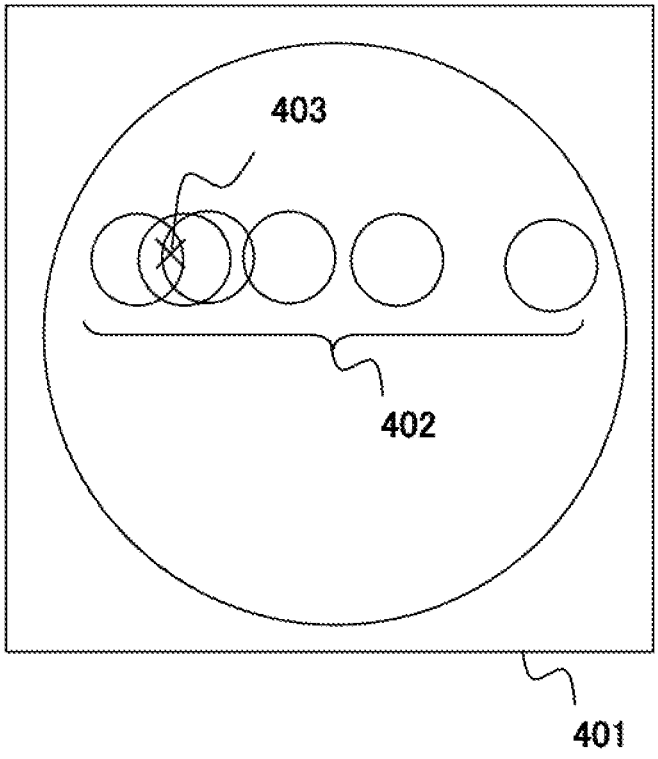


FIG. 5

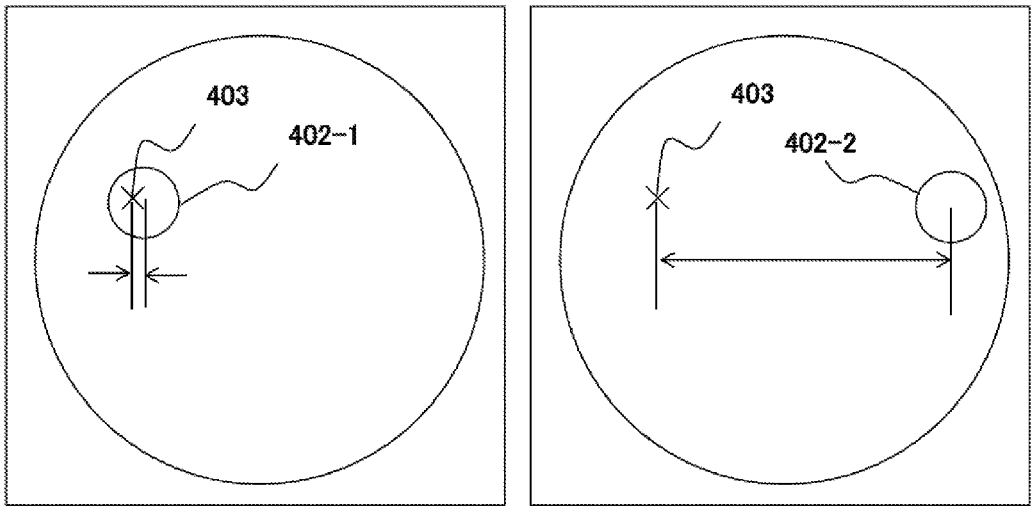


FIG. 6

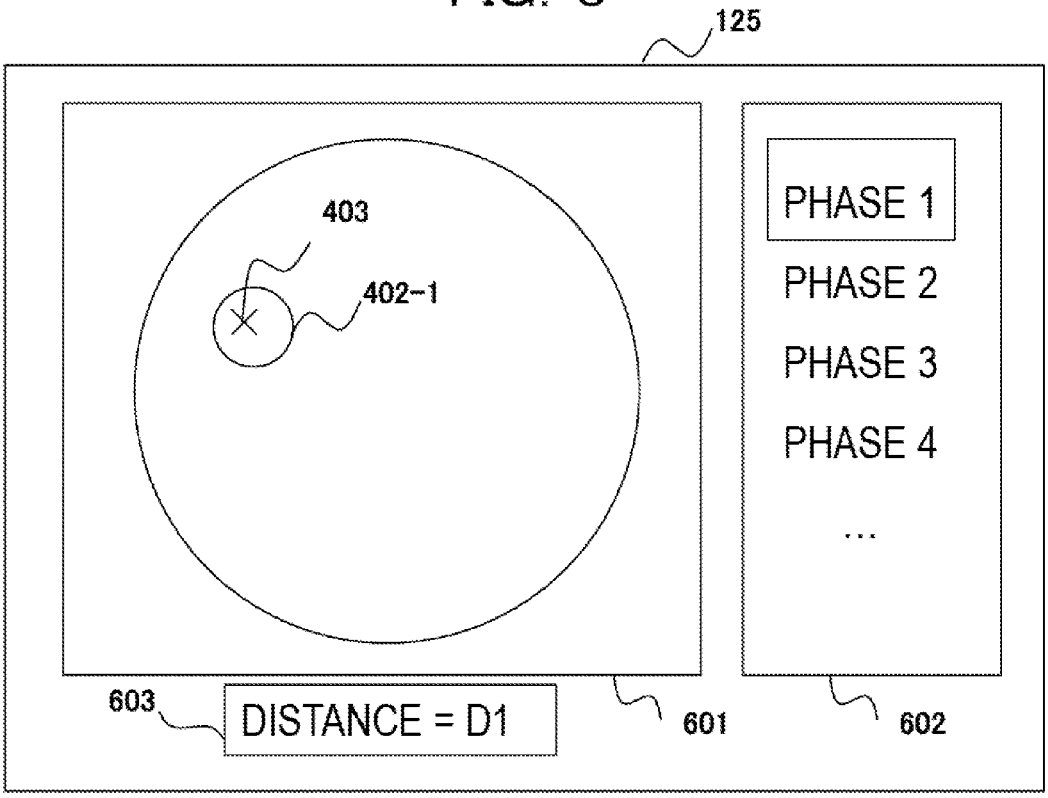

125
403
402-1
PHASE 1
PHASE 2
PHASE 3
PHASE 4
...
603
DISTANCE = D1
601
602

FIG. 7

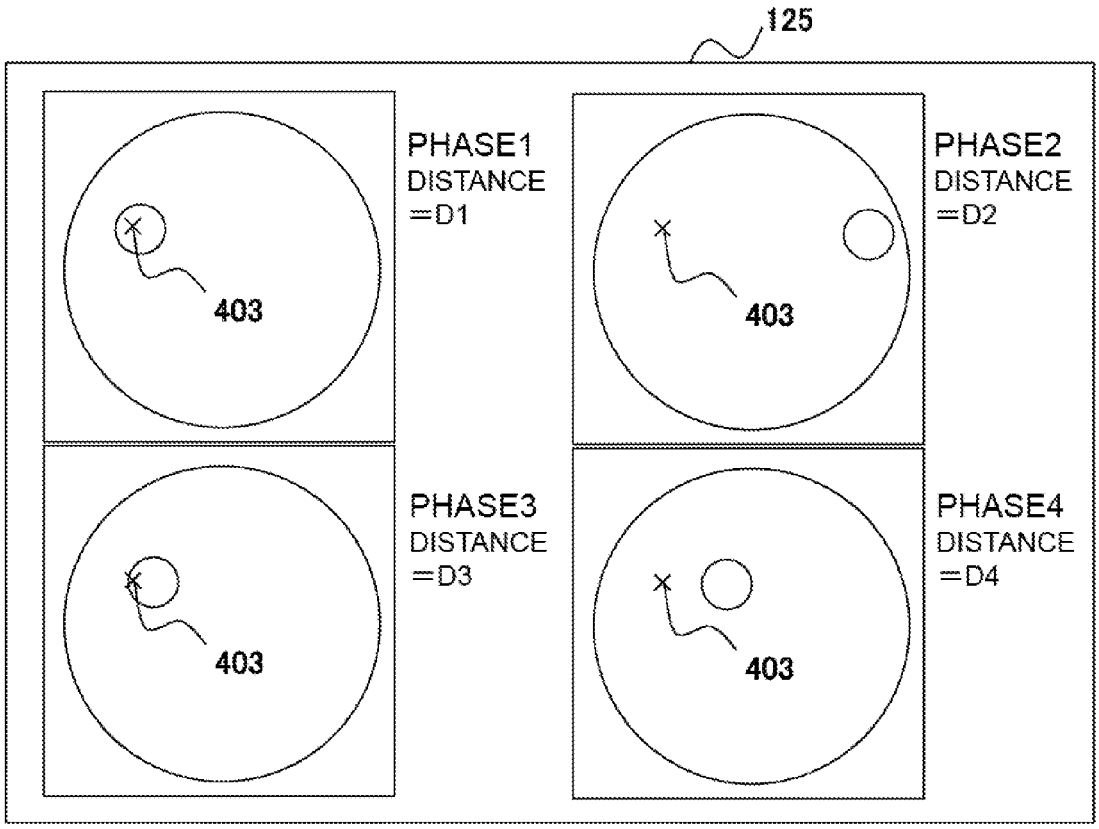

125
PHASE1
DISTANCE
=D1
403
PHASE2
DISTANCE
=D2
403
PHASE3
DISTANCE
=D3
403
PHASE4
DISTANCE
=D4
403

FIG. 8

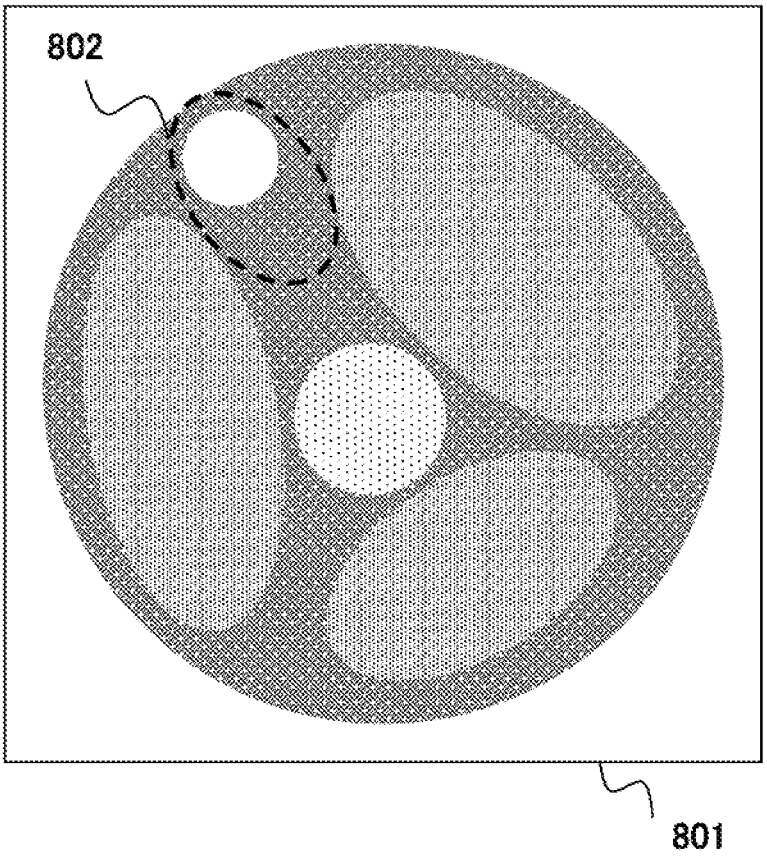


FIG. 9

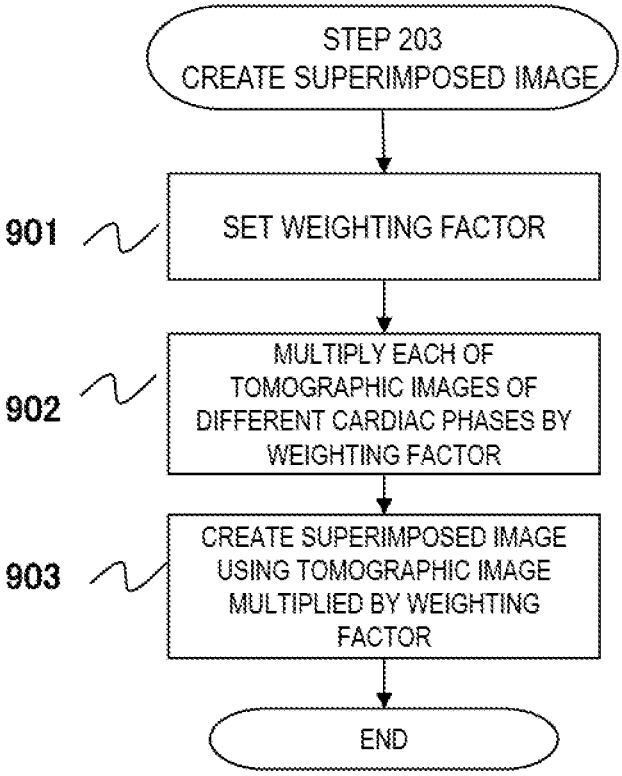

STEP 203
CREATE SUPERIMPOSED IMAGE
901
SET WEIGHTING FACTOR
902
MULTIPLY EACH OF TOMOGRAPHIC IMAGES OF DIFFERENT CARDIAC PHASES BY WEIGHTING FACTOR
903
CREATE SUPERIMPOSED IMAGE USING TOMOGRAPHIC IMAGE MULTIPLIED BY WEIGHTING FACTOR
END

FIG. 10

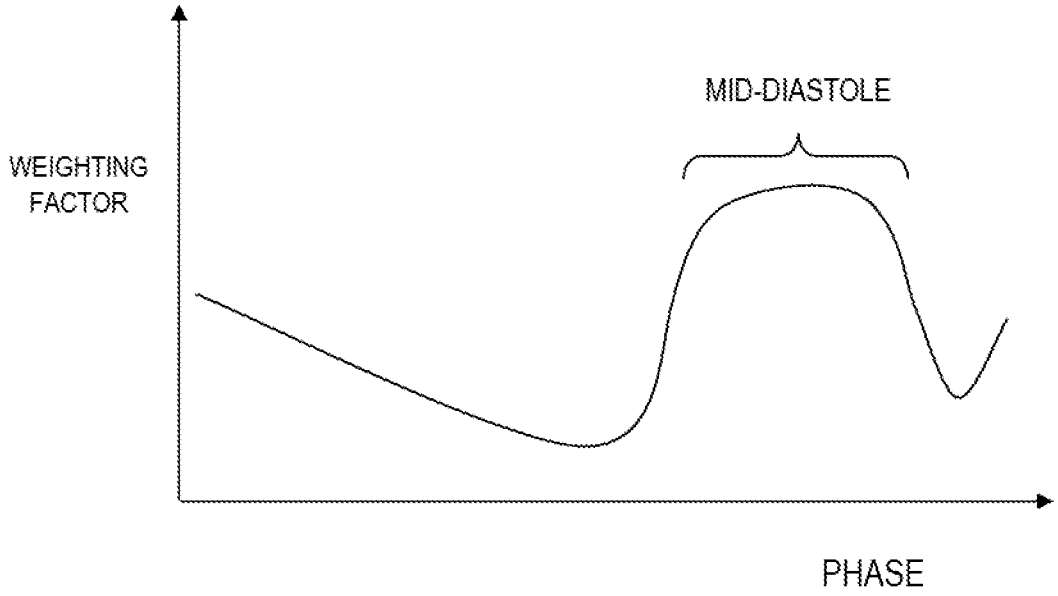


FIG. 11

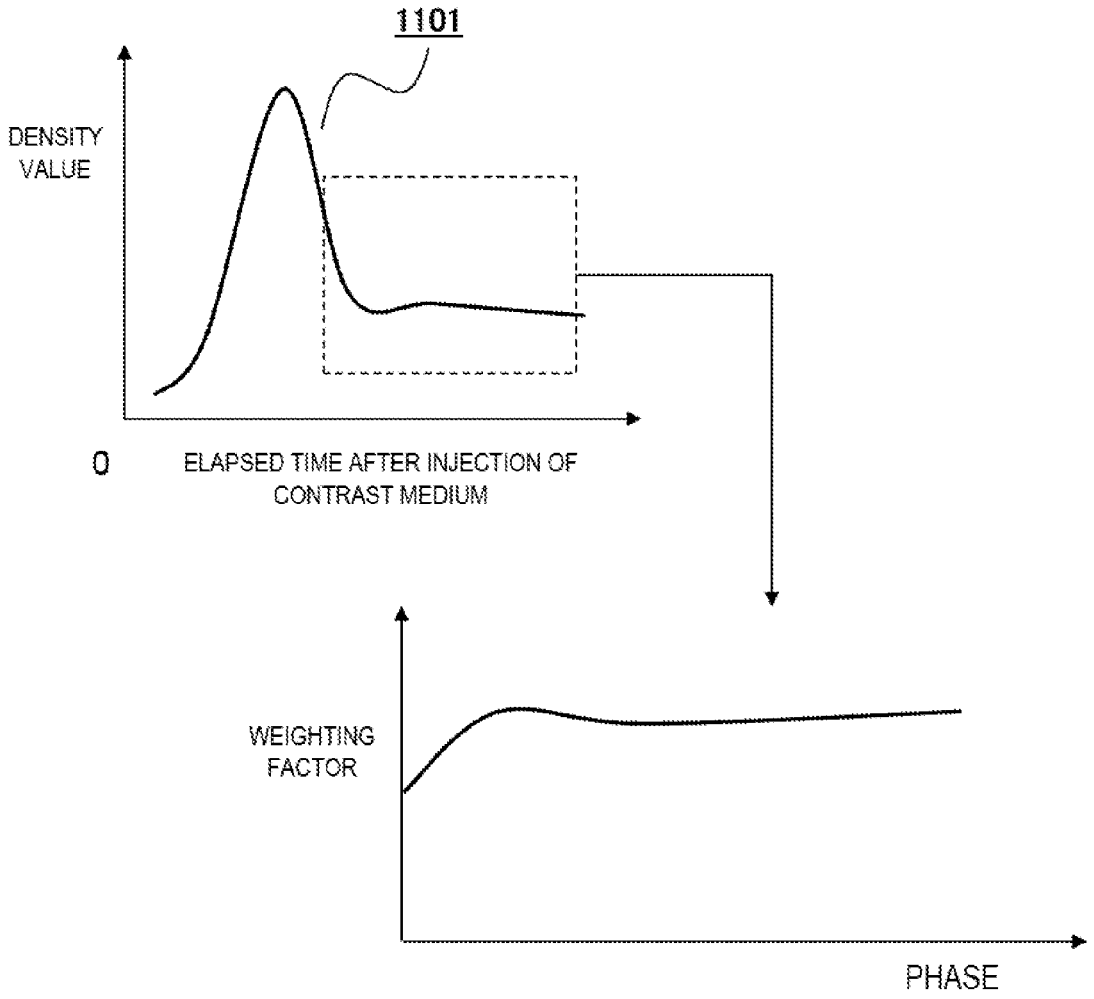

1101
DENSITY VALUE
0
ELAPSED TIME AFTER INJECTION OF CONTRAST MEDIUM
WEIGHTING FACTOR
PHASE

FIG. 12

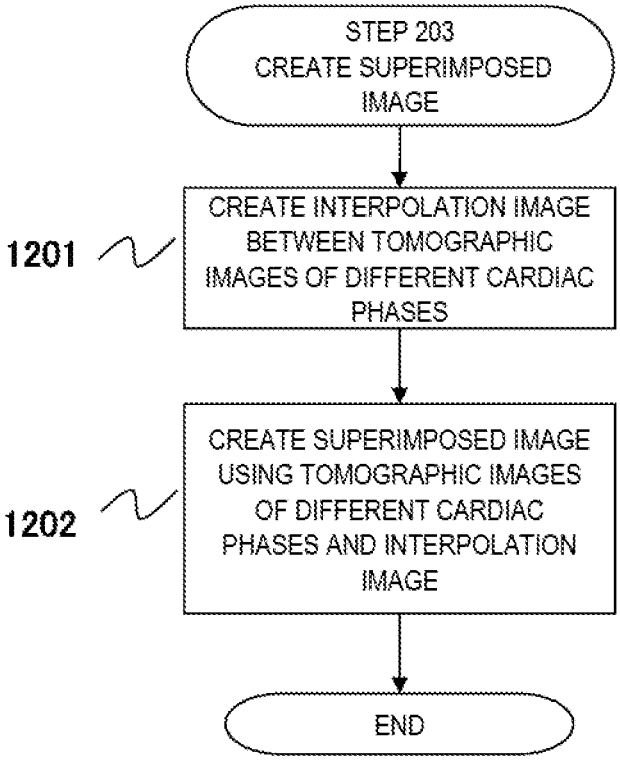

STEP 203
CREATE SUPERIMPOSED IMAGE
1201
CREATE INTERPOLATION IMAGE BETWEEN TOMOGRAPHIC IMAGES OF DIFFERENT CARDIAC PHASES
1202
CREATE SUPERIMPOSED IMAGE USING TOMOGRAPHIC IMAGES OF DIFFERENT CARDIAC PHASES AND INTERPOLATION IMAGE
END

FIG. 13

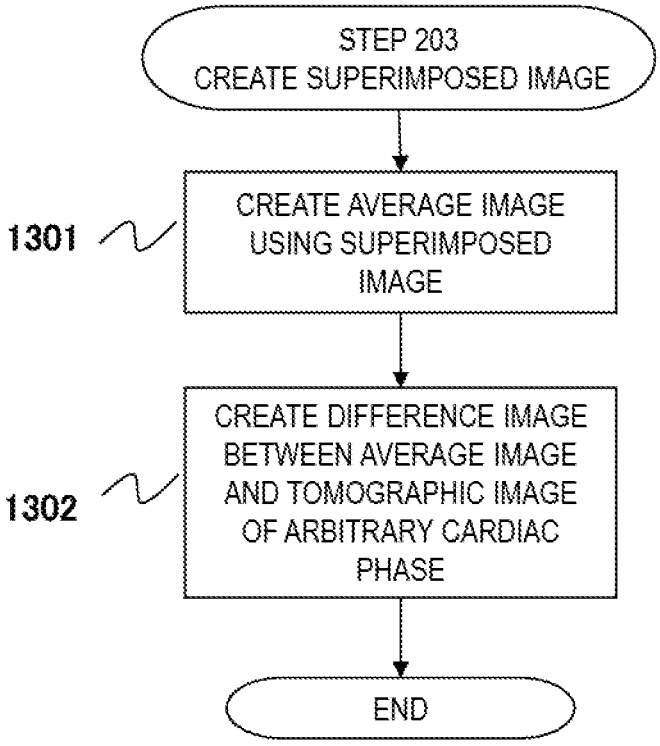
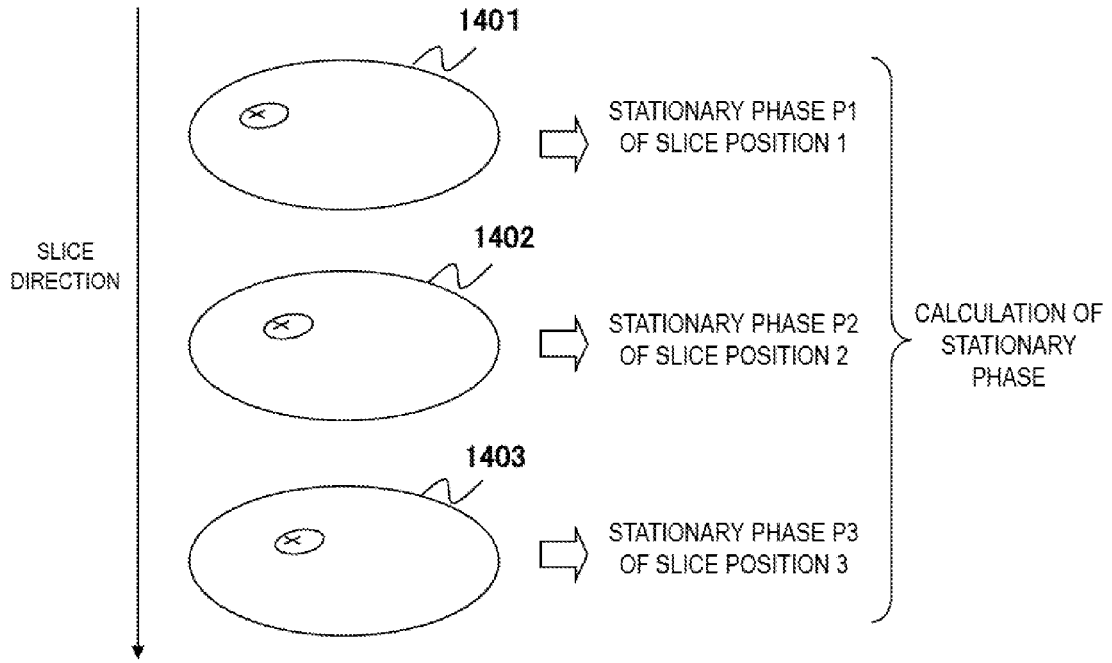

STEP 203
CREATE SUPERIMPOSED IMAGE
1301
CREATE AVERAGE IMAGE USING SUPERIMPOSED IMAGE
1302
CREATE DIFFERENCE IMAGE BETWEEN AVERAGE IMAGE AND TOMOGRAPHIC IMAGE OF ARBITRARY CARDIAC PHASE
END

FIG. 14


1401
1402
1403
SLICE DIRECTION
STATIONARY PHASE P1 OF SLICE POSITION 1
STATIONARY PHASE P2 OF SLICE POSITION 2
STATIONARY PHASE P3 OF SLICE POSITION 3
CALCULATION OF STATIONARY PHASE

MEDICAL IMAGE DIAGNOSIS APPARATUS AND PHASE DETERMINATION METHOD USING MEDICAL IMAGE DIAGNOSIS APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a medical image diagnosis apparatus including an X-ray computed tomography (CT) apparatus, and in particular, to a technique for performing scanning and image reconstruction of a moving organ, such as the heart.

BACKGROUND ART

[0002] When a moving organ is scanned by a medical image diagnosis apparatus represented by the X-ray CT apparatus, artifacts due to motion, so-called motion artifacts, are caused in the obtained tomographic image. As a method of reducing the motion artifacts, there is a method of controlling the acquisition timing of projection data or processing the acquired projection data based on electrocardiographic information or respiration information measured using a biometric sensor, such as an electrocardiograph or a respiratory sensor. With reference to the scanning of the heart as an example, there is a method in which electrocardiographic information measured using an electrocardiograph is collected together with projection data and projection data corresponding to an arbitrary cardiac phase is extracted from the collected projection data to perform image reconstruction and as a result, a tomographic image of the heart corresponding to the cardiac phase is obtained. This method is called an electrocardiographic synchronous reconstruction method.

[0003] In order to reduce the motion artifacts in the electrocardiographic synchronous reconstruction method, it is important to specify the cardiac phase corresponding to the projection data, which is used for image reconstruction, as an optimal phase, for example, as a cardiac phase in which the movement amount of the heart is smallest. PTL 1 discloses reconstructing a plurality of images of different cardiac phases, generating a plurality of difference images of different cardiac phases from the plurality of reconstructed images, and determining a specific cardiac phase based on the amount of movement corresponding to a plurality of cardiac phases calculated using the generated difference images. That is, a cardiac phase in which the sum of absolute values of the pixel values of the generated difference images is smallest is determined as a cardiac phase in which the amount of movement is small.

CITATION LIST

Patent Literature

[0004] PTL 1: JP-A-2007-37782

SUMMARY OF INVENTION

Technical Problem

[0005] In PTL 1, however, a specific cardiac phase is just determined based on the difference image generated between a plurality of images of different cardiac phases, and the influence of motion artifacts or noise, which is included in the respective images of different cardiac phases, on the determined cardiac phase is not taken into consideration. Since the amount of generation of motion artifacts or noise differs depending on an image, extra information, such as motion artifacts or noise, may be emphasized in the generated difference image. That is, a specific cardiac phase, which is determined based on the image in which motion artifacts or noise is emphasized, may not be an appropriate cardiac phase.

[0006] Therefore, it is an object of the present invention to provide a medical image diagnosis apparatus and a phase determination method using a medical age diagnosis apparatus that can determine an appropriate movement phase when obtaining a tomographic image corresponding to a specific movement phase.

Solution to Problem

[0007] In order to achieve the object described above, the present invention is a medical image diagnosis apparatus and a phase determination method using a medical image diagnosis apparatus for calculating a specific position based on a superimposed image, which is created using a plurality of tomographic images of different movement phases, and determining a specific movement phase based on the calculated specific position.

[0008] Specifically, there are provided: a storage unit that stores material distribution information, which is acquired from an object including a target organ that moves periodically, and movement information, which is measured together with the material distribution information; an image reconstruction unit that reconstructs a plurality of tomographic images of different movement phases using the material distribution information and the movement information; a superimposed image creation unit that creates a superimposed image by superimposing the plurality of tomographic images; a specific position calculation unit that calculates a specific position of the target organ based on the superimposed image; and a specific phase determination unit that determines a specific phase of the target organ based on the specific position.

[0009] In addition, a phase determination method using a medical image diagnosis apparatus includes: an image reconstruction step of reconstructing a plurality of tomographic images of different movement phases using material distribution information, which is acquired from an object including a target organ that moves periodically, and movement information, which is acquired together with the material distribution information; a superimposed image creation step of creating a superimposed image by superimposing the plurality of tomographic images; a specific position calculation step of calculating a specific position of the target organ based on the super imposed image; and a specific phase determination step of determining a specific phase of the target organ based on the specific position.

Advantageous Effects of Invention

[0010] According to the present invention, it is possible to provide a medical image diagnosis apparatus and a phase determination method using a medical image diagnosis apparatus that can determine an appropriate movement phase when obtaining a tomographic image corresponding to a specific movement phase.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a block diagram showing the entire configuration of an X-ray CT apparatus of the present invention.

[0012] FIG. **2** is a diagram showing the process flow in a first embodiment of the present invention.

[0013] FIG. **3** is a diagram explaining the reconstruction of tomographic images of different cardiac phases and the creation of a superimposed image.

[0014] FIG. **4** is a diagram explaining the calculation of a stationary position.

[0015] FIG. **5** is a diagram explaining the determination of a stationary phase.

[0016] FIG. **6** is a diagram showing an example of a display screen in the first embodiment.

[0017] FIG. **7** is a diagram showing another example of the display screen in the first embodiment.

[0018] FIG. **8** is a diagram showing an example of the setting of an area of interest.

[0019] FIG. **9** is a diagram showing the process flow of step **203** in a second embodiment of the present invention.

[0020] FIG. **10** is a diagram showing an example of a weighting factor.

[0021] FIG. **11** is a diagram showing another example of the weighting factor.

[0022] FIG. **12** is a diagram showing the process flow of step **203** in a third embodiment of the present invention.

[0023] FIG. **13** is a diagram showing the process flow of step **203** in a fourth embodiment of the present invention.

[0024] FIG. **14** is a diagram explaining a fifth embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0025] Hereinafter, preferred embodiments of an X-ray CT apparatus, which is one of a medical image diagnosis apparatus according to the present invention, will be described with reference to the accompanying diagrams. In the following explanation and the accompanying diagrams, the same reference numerals are given to components with the same functions, and repeated explanation thereof will be omitted.

[0026] FIG. **1** is a block diagram showing the entire configuration of an X-ray CT apparatus. As shown in FIG. **1**, an X-ray CT apparatus **1** includes a scanning gantry unit **100**, an operation unit **120**, and a movement information measuring device **130**.

[0027] The scanning gantry unit **100** includes an X-ray tube device **101**, a rotary disk **102**, a collimator **103**, an X-ray detector **106**, a data acquisition system **107**, a bed device **105**, a gantry controller **108**, a bed controller **109**, an X-ray controller **110**, an input/output device **111**, and an electrocardiographic data acquisition device **112**.

[0028] The X-ray tube device **101** is a device that irradiates an object placed on the bed device **105** with X-rays. The collimator **103** is a device for limiting the irradiation range of X-rays irradiated from the X-ray tube device **101**. The rotary disk **102** includes an opening **104** through which the object placed on the bed device **105** is inserted, and rotates around the object in a state where the X-ray tube device **101** and the X-ray detector **106** are mounted therein. The X-ray detector **105** is a device that disposed opposite the X-ray tube device **101** and measures the spatial distribution of transmitted X-rays by detecting X-rays transmitted through the object, and is formed by arraying a number of detection elements in a one-dimensional manner in the rotation direction of the rotary disk **102** or is formed by arraying a number of detection elements in a two-dimensional manner in the rotation direction and the rotation axis direction of the rotary disk **102**. The data acquisition system **107** is a device that collects the amount of X-rays detected by the X-ray detector **106** as digital data. The gantry controller **108** is a device that controls the rotation and inclination of the rotary disk **102**. The bed controller **109** is a device that controls up-and-down movement, back-and-forth movement, and left and right movement of the bed device **105**. The X-ray controller **110** is a device that controls electric power input to the X-ray tube device **101**.

[0029] The operation unit **120** includes an input device **121**, an image processing device **122**, a display device **125**, a storage device **123**, and a system controller **124**. The input device **121** is a device for inputting the name of the object, examination date anal time, scanning conditions, and the like. Specifically, the input device **121** is a keyboard, a pointing device, a touch panel, or the like. The image processing device **122** is a device that reconstructs a CT image by performing arithmetic processing on the measurement data transmitted from the data acquisition system **107**. The display device **125** is a device that displays the CT image created by the image processing device **122**. Specifically, the display device **125** is a cathode-ray tube (CRT), a liquid crystal display, or the like. The storage device **123** is a device that stores data collected by the data acquisition system **107** and image data of the CT image created by the image processing device **122**. Specifically, the storage device **123** is a hard disk drive (HDD) or the like. The system controller **124** is a device that controls these devices, the gantry controller **108**, the bed controller **109**, and the X-ray controller **110**. In addition, the system controller **124** may execute the flow of a process, which will be described later.

[0030] The movement information measuring device **130** is a device that measures the movement information of an organ, which moves periodically, of the object. For example, the movement information measuring device **130** is an electrocardiograph or a respiratory sensor. The measurement result of the movement information measuring device **130** is transmitted to the system controller **124** and is stored in the storage device **123**. When the movement information measuring device **130** is an electrocardiograph, electrocardiographic information is measured.

[0031] The X-ray controller **110** controls electric power input to the X-ray tube device **101** based on the scanning conditions input through the input device **121**, in particular, based on an X-ray tube voltage, an X-ray tube current, and the like, so that the X-ray tube device **101** irradiates the object with X-rays corresponding to the scanning conditions. The X-ray detector **106** detects X-rays, which are emitted from the X-ray tube device **101** and transmitted through the object, using a number of X-ray detection elements and measures the distribution of transmitted X-rays. The rotary disk **102** is controlled by the gantry controller **108**, and rotates based on the scanning conditions input through the input device **121**, in particular, based on rotation speed and the like. The bed device **105** is controlled by the bed controller **109**, and operates based on the scanning conditions input through the input device **121**, in particular, based on a helical pitch and the like.

[0032] X-ray emission from the X-ray tube device **101** and the measurement of the distribution of transmitted X-rays by the X-ray detector **106** are repeated with the rotation of the rotary disk **102**, and as a result, projection data from various angles is acquired. In the projection data, View showing each angle is matched with a channel (ch) number and a column number that are detection element numbers of the X-ray detector **106**. At the same time as the acquisition of projection

data, movement information is measured by the movement information measuring device **130**. The acquired projection data from various angles is transmitted to the image processing device **122**. The image processing device **122** reconstructs a CT image by performing back projection processing on the transmitted projection data from various angles. The CT image obtained by reconstruction is displayed on the display device **125**.

[0033] The X-ray CT apparatus **1** may be connected to a server in a hospital or a server outside a hospital through a network (not shown), and may read required data timely from each server.

First Embodiment

[0034] FIG. **2** is a diagram showing the flow of a process of a first embodiment of the present invention. Hereinafter, each step of FIG. **2** will be described in detail with reference to FIGS. **3** to **8**. In addition, although a case where the heart including the coronary artery is a target organ will be described below, the target organ is not limited to the heart. For example, the target object may be an organ around the heart that moves according to the heart beat or may be an organ that moves according to the act of breathing.

[0035] In the present embodiment, since the heart is a target organ, movement information is electrocardiographic information. However, in the case of an organ that moves according to the act of breathing, respiratory information may be used as the movement information. In the present embodiment, a stationary position with less movement is calculated as a specific position of the target organ, and a stationary phase is determined as a specific phase of the target organ. However, the present invention is not limited to this.

[0036] (Step **201**)

[0037] The system controller **124** reads electrocardiographic information **301** and projection data **302**, which has been acquired together with the electrocardiographic information **301**, from the storage device **123**. The electrocardiographic information and the projection data may be read from a server in a hospital or a server outside a hospital through a network. The electrocardiographic information is measured by an electrocardiograph, which is the movement information measuring device **130**, in parallel to the acquisition of the projection data **302**. That is, the acquisition of the projection data **302** and the measurement of electrocardiographic information are performed simultaneously. When observing a blood vessel, it is preferable that projection data be acquired by contrast imaging.

[0038] As shown in FIG. **3**, the electrocardiographic information **301** and the projection data **302** are associated with the cardiac phase of the electrocardiographic information **301** and the view of the projection data **302**. The cardiac phase is expressed by a relative value when the value between the adjacent P waves is assumed to be 100%.

[0039] (Step **202**)

[0040] The system controller **124** causes the image processing device **122** to create tomographic images of different cardiac phases using the projection data **302** acquired together with the electrocardiographic information **301**. For example, when a cardiac phase is set for each percentage, 100 tomographic images are created. It is preferable that tissue for comparison with the movement of the object be included in the tomographic images created in this step. For example, when observing the heart, it is preferable that coronary arteries be included in the tomographic images. In addition, since only the difference between the cardiac phases is compared, it is preferable that all parameters other than the cardiac phase be the same in the created tomographic images.

[0041] FIG. **3** shows three tomographic images **303-1** to **303-3** of different cardiac phases as a simulation diagram of the tomographic image of the heart. The tomographic images **303-1** to **303-3** shown in FIG. **3** are reconstructed using projection data acquired by contrast imaging, and the pixel value of the coronary artery displayed in the upper left part of each tomographic image is high compared with others.

[0042] (Step **203**)

[0043] The system controller **124** causes the image processing device **122** to create a superimposed image using the tomographic images of different cardiac phases created in step **202**. The superimposed image is an image created by integrating the pixel values of pixels of the same coordinates in a plurality of images. That is, the pixel value PVs (x, y) of the coordinates (x, y) in the superimposed image is calculated by the following expression.

$$PVs(x, y) = \sum_{k=1}^{n} PV_k(x, y) \quad \text{[Expression 1]}$$

[0044] Here, PV_k (x, y) indicates a pixel value of the coordinates (x, y) in a tomographic image corresponding to the k-th cardiac phase, and n is the number of images used to create the superimposed image. FIG. **3** shows that a superimposed image **304** is created using the three tomographic images **303-1** to **303-3**.

[0045] Motion artifacts or noise is included in the tomographic images of different cardiac phases, and the amount of occurrence changes with a tomographic image. However, the motion artifacts or noise included in each tomographic image is reduced by creating the superimposed image.

[0046] In the superimposed image, the trajectory of each organ in the tomographic image is displayed, and a portion with small movement is displayed brightly and a portion with large movement is displayed darkly. That is, the portion displayed brightly on the superimposed image is a position of small movement.

[0047] (Step **204**)

[0048] The system controller **124** calculates the stationary position of the target organ based on the superimposed image created in step **203**. The calculation of the stationary position will be described with reference to FIG. **4**. FIG. **4** shows a superimposed image **401** as a simulation diagram of the superimposed image created in step **203**. A trajectory **402** of the target organ is included in the superimposed image **401**. Since the portion displayed brightly on the superimposed image **401** is a position with small movement as described previously, the brightest pixel in the trajectory **402** of the target organ is calculated as a stationary position **403**. When there is a plurality of brightest pixels, the center-of-gravity coordinates of the plurality of pixels are calculated as the stationary position **403**. In FIG. **4**, a marker indicating the stationary position **403** is shown as X.

[0049] (Step **205**)

[0050] The system controller **124** determines the stationary phase of the target organ based on the stationary position calculated in step **204**. The determination of the stationary phase will be described with reference to FIG. **5**.

[0051] In this step, first, a region showing the target organ is extracted on respective tomographic images of different cardiac phases. For region extraction, for example, threshold value processing is used. If the target organ is a contrast blood vessel, extraction is simple since the pixel value is high compared with other regions. FIG. **5** shows tomographic images of phase 1 and phase 2 as an example of tomographic images of different cardiac phases, and regions **402-1** and **402-2** showing the target organ are shown on the respective tomographic images.

[0052] A distance between a region of the target organ extracted and the stationary position **403** calculated in step **204** is measured. Distance measurement is executed for each of the tomographic images of different cardiac phases. As a result, a distance is calculated for each cardiac phase. In FIG. **5**, a distance between the region **402-1** and the stationary position **403** and a distance between the region **402-2** and the stationary position **403** are shown on the tomographic images of the phase 1 and the phase 2, respectively.

[0053] Then, a stationary phase is determined based on the distance calculated for each cardiac phase. For example, a cardiac phase of the tomographic image with the shortest distance is determined as the stationary phase. In FIG. **5**, the distance in the phase 1 is shorter than that in the phase 2. Accordingly, the phase 1 is determined as a stationary phase. In addition, it may be possible to approximate the relationship between the cardiac phase and the distance with a polynomial curve and determine the value of the cardiac phase, in which the value of the distance is a minimum value, as a stationary phase.

[0054] By executing the flow of the process described above, a specific position is calculated based on the superimposed mage created using a plurality of tomographic images of different movement phases, and a specific movement phase is determined based on the calculated specific position. According to this method, even if motion artifacts or noise is included in a plurality of tomographic images of different movement phases, the influence of the motion artifacts or noise is reduced by creating the superimposed image. Therefore, it is possible to determine an appropriate movement phase.

[0055] A screen for the operator to check the stationary phase determined in step **205** may be displayed on the display device **125**. FIG. **6** shows an example of the display screen. The display screen shown in FIG. **6** includes an image display portion **601**, a phase display portion **602**, and a distance display portion **603**.

[0056] One of a plurality of tomographic images of different cardiac phases is displayed on the image display portion **601** together with a marker indicating the stationary position **403** calculated in step **204**. In FIG. **6**, a tomographic image when the cardiac phase is the phase 1 is displayed, and the extracted target organ **402-1** and the marker indicating the stationary position **403** are displayed on the tomographic image.

[0057] The tomographic image displayed in the image display portion **501** may be a cine display. That is, a plurality of tomographic images of different cardiac phases may be sequentially switched and displayed while always displaying the marker indicating the stationary position **403**. The display speed of the cine display does not necessarily need to be constant, and may be increased or decreased for an arbitrary cardiac phase. For example, the image update rate may be reduced before and after mid-diastole. In addition, the superimposed image **401** shown in FIG. **4** may be displayed in the image display portion **601** together with a marker.

[0058] Cardiac phases corresponding to respective tomographic images are displayed as a list in the phase display portion **602**. In the list, a cardiac phase corresponding to the tomographic image displayed in the image display portion **601** or the stationary phase determined in step **205** is highlighted. In FIG. **6**, since the cardiac phase of the tomographic image displayed on the image display portion **601** is the phase 1, the phase 1 is displayed so as to be enclosed in a box. As a form of highlighting, monochrome highlighting, colored highlighting, blinking display, and the like may be used. When a tomographic image is cine-displayed in the image display portion **601** or when a superimposed image is displayed, the stationary phase is preferably highlighted.

[0059] In the distance display portion **603**, a distance between the stationary position **403** and the target organ on the tomographic image displayed in the image display portion **601** is numerically displayed. In FIG. **6**, since the cardiac phase of the tomographic image displayed on the image display portion **601** is the phase 1, a distance between the target organ **402-1** and the stationary position **403** is displayed. In addition, when the tomographic image is cine-displayed in the image display portion **601**, the value of the distance may be updated whenever the tomographic image changes. When a superimposed image is displayed in the image display portion **601**, a distance at the time of stationary phase may be displayed.

[0060] When the operator selects one cardiac phase from the cardiac phase list displayed in the phase display portion **602** using the input device **121**, a tomographic image corresponding to the selected cardiac phase may be displayed in the image display portion **601**.

[0061] FIG. **7** shows another example of the display screen. In the display screen shown in FIG. **7**, as an example in which a plurality of tomographic images of different cardiac phases are displayed, tomographic images of four cardiac phases are displayed together with a marker indicating the stationary position **403**. A cardiac phase corresponding to each tomographic image and a distance between the stationary position **403** and the target organ on the tomographic image are displayed beside each tomographic image.

[0062] When creating a superimposed image in step **203**, the calculation region may be limited. That is, a superimposed image may be created only in a region of interest **802** that the operator sets on a tomographic image **801** shown in FIG. **8** using the input device **121**. Since the speed of processing can be increased by limiting the calculation region and there is no influence by regions outside the calculation region in subsequent steps, it is possible to improve the calculation accuracy in the calculation of the stationary position and the determination of the stationary phase. Even if the target organ moves to the outside of the region of interest **802** in some cardiac phases, the influence of the calculation accuracy on the stationary position is small since the movement can be considered to be large in the cardiac phases.

[0063] Prior to creating the superimposed image in step **203**, it may also be possible to create a binary image, which is obtained by extracting only the target organ in each of tomographic images of different cardiac phases, and create a superimposed image using the binary image. By using the binary image, it is possible to reduce the influence of those other than the target organ.

Second Embodiment

[0064] In the first embodiment, the case of creating a superimposed image using tomographic images of different cardiac phases as they are in step **203** has been described. In the present embodiment, a superimposed image that is different from that of the first embodiment is created. That is, a superimposed image is created after multiplying each of the tomographic images of different cardiac phases by the weighting factor. Since the process flow of the present embodiment is the same as in the first embodiment except for step **203**, step **203** of the present embodiment will be described below.

[0065] FIG. **9** is a diagram showing the process flow of step **203** of a second embodiment of the present invention. Hereinafter, each step in FIG. **9** will be described in detail.

[0066] (Step **901**)

[0067] The system controller **124** sets a weighting factor. The weighting factor is set for each cardiac phase, and the value between 0 and 1 is set in many cases.

[0068] FIG. **10** shows an example of the weighting factor. Generally, it is said that the movement of the organ according to the heart beat is small in the mid-diastole of the heart. Therefore, in FIG. **10**, the weighting factor is set to be large n the cardiac phase of the mid-diastole. More extremely, the weighting factor may be set to 1 only in the range of the mid-diastole, and the weighting factor may be set to 0 in the other range.

[0069] FIG. **11** shows another example of the weighting factor. In a tomographic image obtained by contrast imaging, a pixel value may be different, even for the same blood vessel, according to the elapsed time after injection of a contrast medium. That is, when the target organ is a blood vessel, it is preferable to reduce the influence of the change in the pixel value according to the elapsed time after injection of a contrast medium. Incidentally, in contrast imaging, in order to measure the flow rate of the contrast medium before main imaging, a prescan called a monitoring scan is performed, and a time density curve (TDC) shown by the reference numeral **1101** in FIG. **11** is acquired. Therefore, in FIG. **11**, a weighting factor is set based on the time density curve acquired by the monitoring scan. For example, if a curve in a range surrounded by the dotted line portion of the time density curve corresponds to the cardiac phase at the time of contrast imaging, a weighting factor is set using the curve of the dotted line portion. In the weighting curve shown in the lower right of FIG. **11**, the inverse of the density value of the curve of the dotted line portion is set as a weighting factor, and is assigned to each cardiac phase.

[0070] (Step **902**)

[0071] The system controller **124** causes the image processing device **122** to multiply each of the tomographic images of different cardiac phases by the weighting factor. In this step, the weighting factor set for each cardiac phase in step **901** is used.

[0072] (Step **903**)

[0073] The system controller **124** causes the image processing device **122** to create a superimposed image using the tomographic image multiplied by the weighting factor. The calculation performed in steps **902** and **903** is expressed by the following expression.

$$PVs(x, y) = \sum_{k=1}^{n} (w_k \cdot PV_k(x, y)) \quad \text{[Expression 2]}$$

[0074] Here, PVs (x, y) indicates a pixel value of the coordinates (x, y) in a superimposed image, w_k indicates a weighting factor by which a tomographic image corresponding to the k-th cardiac phase is multiplied, PV_k (x, y) indicates a pixel value of the coordinates (x, y) in the k-th image, and n is the number of images used to create the superimposed image.

[0075] By executing the process flow described above, superimposed image is created after multiplying each of the tomographic images of different cardiac phases by the weighting factor. By executing such processing, it is possible to create a superimposed image, in which the range of a specific cardiac phase is highlighted, or a superimposed image, in which a difference caused between cardiac phases is reduced. For example, when the weighting factor is set to 1 in the range of the mid-diastole and to 0 in the other range, only the tomographic image corresponding to the range of the mid-diastole is used to create the superimposed image. Therefore, it is possible to calculate a stationary position only in the range of the mid-diastole. In addition, when the weighting factor is set based on the time density curve shown in FIG. **11**, a tomographic image in which the change in the pixel value according to the elapsed time after injection of a contrast medium is suppressed is used to create a superimposed image. Therefore, it is possible to improve the calculation accuracy of the stationary position.

Third Embodiment

[0076] In the first embodiment, the case of creating a superimposed image using tomographic images of different cardiac phases as they are in step **203** has been described. In the present embodiment, a superimposed image that is different from that in the first embodiment is created. That is, an interpolation image is created between tomographic images of different cardiac phases, and a superimposed image is created using the tomographic images of different cardiac phases and the interpolation image. Since the process flow of the present embodiment is the same as in the first embodiment except for step **203**, step **203** of the present embodiment will be described below.

[0077] FIG. **12** is a diagram showing the process flow of step **203** of the third embodiment of the present invention. Hereinafter, each step in FIG. **12** will be described in detail.

[0078] (Step **1201**)

[0079] The system controller **124** causes the image processing device **122** to create an interpolation image between tomographic images of different cardiac phases. For example, an interpolation image corresponding to the cardiac phase in the middle of adjacent cardiac phases is created using the respective tomographic images corresponding to the adjacent cardiac phases. The number of interpolation images corresponding to the middle cardiac phase is smaller than the number of tomographic images of different cardiac phases by 1.

[0080] In addition, interpolation images created in this step are not limited to the interpolation image corresponding to the cardiac phase in the middle of adjacent cardiac phases. For example, it may also be possible to create interpolation images corresponding to cardiac phases that divide a region between the adjacent cardiac phases into three or more parts.

In addition, preferably, the interval between the cardiac phase, to which the tomographic image created in step **202** corresponds, and the cardiac phase, to which the interpolation image corresponds, is an equal interval. For example, when an interpolation image is created by dividing a region between adjacent cardiac phases into three parts, it is preferable that a tomographic image, an interpolation image, an interpolation e, a tomographic image, an interpolation image, an interpolation image, a tomographic image, . . . be arranged in this order n a direction of the cardiac phase and the cardiac phase width between the respective images be equal.

[0081] The number of tomographic images used to create an interpolation image not limited to two tomographic images corresponding to adjacent cardiac phases, and three or more tomographic images may be used.

[0082] (Step **1202**)

[0083] The system controller **124** causes the image processing device **122** to create a superimposed image using the tomographic images of different cardiac phases and the interpolation image created in step **1201**. That is, the superimposed image is created by integrating all of the tomographic images created in step **202** and the interpolation image created in step **1201**.

[0084] By executing the process flow described above, a superimposed image is created using the tomographic images of different cardiac phases and the interpolation image created between the tomographic images. By executing such processing, even if overlap does not occur in the target organ only with tomographic images of different cardiac phases, it is possible to accurately calculate the stationary position. That is, in the present invention, since a portion of the target organ where the overlap of the target organ is large is calculated as a stationary position, the stationary position may not be able to be accurately calculated unless overlap occurs in the target organ. Even in this case, it is possible to accurately calculate the stationary position by applying the present embodiment.

Fourth Embodiment

[0085] In the first embodiment, the case of creating a superimposed image using tomographic images of different cardiac phases as they are in step **203** has been described. In the present embodiment, a superimposed image that is different from that in the first embodiment is created. That is, an average image is created from a superimposed image that is created using tomographic images of different cardiac phases as they are, a difference image between the average image and the tomographic image of an arbitrary cardiac phase is created, and the difference image is replaced with the superimposed image. Since the process flow of the present embodiment is the same as in the first embodiment except for step **203**, step **203** of the present embodiment will be described below.

[0086] FIG. **13** is a diagram showing the process flow of step **203** of the fourth embodiment of the present invention. Hereinafter, each step in FIG. **13** will be described in detail.

[0087] (Step **1301**)

[0088] The system controller **124** causes the image processing device **122** to perform a process of creating an average image from a superimposed image that is created using tomographic images of different cardiac phases as they are. The pixel value PVa (x, y) of the coordinates (x, y) in the average image is calculated by the following expression.

$$PVa(x,\ y) = \frac{1}{n}\sum_{k=1}^{n} PV_k(x,\ y) \qquad \text{[Expression 3]}$$

[0089] Here, PV_k (x, y) indicates a pixel value of the coordinates (x, y) in a k-th image, and n is the number of images used to create the superimposed image.

[0090] (Step **1302**)

[0091] The system controller **124** causes the image processing device **122** to create a difference image using the average image created in step **1301** and the tomographic image of an arbitrary cardiac phase. The pixel value PVd (x, y) of the coordinates (x, y) in the difference image is calculated by the following expression.

$$PVd(x,y)=PVa(x,y)-PV_k(x,y) \qquad \text{[Expression 4]}$$

[0092] The difference image created in this step is replaced with the superimposed image created previously. That is, in step **204**, the stationary position of the target organ is calculated based on the difference image created in this step.

[0093] In addition, the difference image created in this step may be a difference between a superimposed image, which is created using tomographic images of different cardiac phases as they are, and an image, which is n times a tomographic image of an arbitrary cardiac phase. The pixel value calculated in this case is n times the pixel value calculated by Expression 4. However, when calculating the stationary position in step **204**, the relative comparison of the pixel values on the difference image is performed. Therefore, even if the pixel value becomes n times, there is no influence on the calculation accuracy of the stationary position.

[0094] By executing the process flow described above, a difference image between the average image, which is created from the superimposed image created using the tomographic images of different cardiac phases as they are, and the tomographic image of an arbitrary cardiac phase is created, and the difference image is replaced with the superimposed image. By executing such processing, even if the pixel value of the target organ is not sufficiently high compared with others, it is possible to accurately calculate the stationary position. That is, if the pixel value of the target organ is not sufficiently high compared with others, the stationary position may not be able to be accurately calculated due to the influence of organs with less movement over the entire cardiac phase. Even in this case, since the influence of organs with less movement over the entire cardiac phase is reduced by applying the present embodiment, it is possible to accurately calculate the stationary position.

Fifth Embodiment

[0095] In the first embodiment, the case of creating a superimposed image at the single slice position, calculating a stationary position based on the superimposed image, and determining a stationary phase based on the stationary position has been described. In the present embodiment, a superimposed image is created at a plurality of slice positions, a stationary position and a stationary phase are calculated at each slice position, and the stationary phase of the target organ is determined based on the stationary phase at each slice position. Hereinafter, detailed explanation will be given with reference to FIG. **14**.

[0096] FIG. **14** shows that tomographic images **1401** to **1403** are created for a plurality of slice positions. The tomo-

graphic images **1401** to **1403** are tomographic images at slice positions 1 to 3. In the present embodiment, steps **201** to **205** in the first embodiment are executed at each slice position. When executing steps **201** to **205**, it is preferable to treat the same organ at each slice position as a target organ. As a result, stationary phases P1 to P3 are calculated at the slice positions 1 to 3.

[0097] The system controller **124** determines the stationary phase of the target organ based on the stationary phase calculated for each slice position. For example, the average value of the stationary phases calculated at the respective slice positions is assumed to be the stationary phase of the target organ. In the case of FIG. **14**, the average value of the stationary phases calculated at the respective slice positions is the average value (P1+P2+P3)/3 of P1 to P3. Alternatively, a stationary phase at a specific slice position of a plurality of slice positions may be set as the stationary phase of the target organ. For example, a stationary phase at the central slice position of a plurality of slice positions may be set as the stationary phase of the target organ. In the case of FIG. **14**, the stationary phase P2 at the slice position **2** is the stationary phase of the target organ.

[0098] According to the present embodiment, the stationary phase of the target organ is determined based on the stationary phases at a plurality of slice positions. Therefore, it is possible to obtain a calculation result based on a wider range of information without being limited to the information at a single slice position.

[0099] While a plurality of embodiments of the present invention have been described above, the respective embodiments may be appropriately combined.

[0100] In addition, the present invention is not limited to the description of the embodiments. Although the system controller **124** causes the image processing device **122** to execute some processing steps of each embodiment in the above explanation, the system controller **124** may execute the processing step.

[0101] In addition, although the X-ray CT apparatus has been described as an example of the medical image diagnosis apparatus of the present invention, a magnetic resonance imaging (MRI) apparatus that acquires nuclear magnetic resonance data, which is generated by the nuclear spins in the object placed in a uniform magnetic field, and creates a tomographic image using the acquired nuclear magnetic resonance data is also included in the medical image diagnosis apparatus of the present invention. In the MRI apparatus, the nuclear magnetic resonance data are acquired as the distribution information of the nuclear spins. In addition, in the X-ray CT apparatus, projection data is acquired as the distribution information of the X-ray attenuation material. That is, in medical image diagnosis apparatuses including an MRI apparatus and an X-ray CT apparatus, nuclear magnetic resonance data or projection data is acquired as material distribution information, and the acquired material distribution information is used to create a tomographic image.

REFERENCE SIGNS LIST

[0102] **1**: X-ray CT apparatus
[0103] **100**: scanning gantry unit
[0104] **101**: X-ray tube
[0105] **102**: rotary disk
[0106] **103**: collimator
[0107] **104**: opening
[0108] **105**: bed
[0109] **106**: X-ray detector
[0110] **107**: data acquisition system
[0111] **108**: gantry controller
[0112] **109**: bed controller
[0113] **110**: X-ray controller
[0114] **120**: console
[0115] **121**: input device
[0116] **122**: image processing device
[0117] **123**: storage device
[0118] **124**: system controller
[0119] **125**: display device
[0120] **130**: movement information measuring device
[0121] **301**: electrocardiographic information
[0122] **302**: projection data
[0123] **303-1** to **303-3**: tomographic images of different cardiac phases
[0124] **304**: superimposed image
[0125] **401**: superimposed image
[0126] **402**: trajectory of target organ
[0127] **403**: stationary position
[0128] **601**: image display portion
[0129] **602**: phase display portion
[0130] **603**: distance display portion
[0131] **801**: tomographic image
[0132] **802**: region of interest
[0133] **1401**: tomographic image of slice position 1
[0134] **1402**: tomographic image of slice position 2
[0135] **1403**: tomographic image of slice position 3

1. A medical image diagnosis apparatus, comprising:
a storage unit that stores material distribution information, which is acquired from an object including a target organ that moves periodically, and movement information, which is measured together with the material distribution information;
an image reconstruction unit that reconstructs a plurality of tomographic images of different movement phases using the material distribution information and the movement information;
a superimposed image creation unit that creates a superimposed image by superimposing the plurality of tomographic images;
a specific position calculation unit that calculates a specific position of the target organ based on the superimposed image; and
a specific phase determination unit that determines a specific phase of the target organ based on the specific position.

2. The medical image diagnosis apparatus according to claim **1**, further comprising:
a display unit that displays a marker, which indicates the specific position calculated by the specific position calculation unit, together with any one of the plurality of tomographic images or the superimposed image.

3. The medical image diagnosis apparatus according to claim **2**,
wherein the display unit displays a plurality of tomographic images selected from the plurality of tomographic images together with the marker.

4. The medical image diagnosis apparatus according to claim **1**,
wherein the superimposed image creation unit includes a weighting factor setting section that sets a weighting factor corresponding to the movement phase and a weighted tomographic image creation section that cre-

ates a plurality of weighted tomographic images by multiplying each of the plurality of tomographic images by the weighting factor, and creates the superimposed image by superimposing the plurality of weighted tomographic images.

5. The medical image diagnosis apparatus according to claim **4**,

wherein the weighting factor setting section sets the weighting factor based on a time density curve acquired by a monitoring scan performed before contrast imaging.

6. The medical image diagnosis apparatus according to claim **1**,

wherein the superimposed image creation unit includes an interpolation image creation section that creates an interpolation image between adjacent tomographic images of the plurality of tomographic images, and creates the superimposed image using the plurality of tomographic images and the interpolation image.

7. The medical image diagnosis apparatus according to claim **1**,

wherein the superimposed image creation unit includes an average image creation section that creates an average image of the plurality of tomographic images using the superimposed image and a difference image creation section that creates a difference image between the average image and any one of the plurality of tomographic images, and

the specific position calculation unit calculates the specific position of the target organ using the difference image.

8. The medical image diagnosis apparatus according to claim **1**,

wherein the image reconstruction unit reconstructs a plurality of tomographic images of different movement phases for different slice positions,

the superimposed image creation unit creates a superimposed image for different slice positions,

the specific position calculation unit calculates the specific position of the target organ for different slice positions, and

the specific phase determination unit calculates a specific phase for different slice positions, and determines the specific phase of the target organ based on the specific phase calculated for different slice positions.

9. The medical image diagnosis apparatus according to claim **1**,

wherein the material distribution information is projection data or nuclear magnetic resonance data acquired from the object.

10. A phase determination method using a medical image diagnosis apparatus, comprising:

an image reconstruction step of reconstructing a plurality of tomographic images of different movement phases using material distribution information, which is acquired from an object including a target organ that moves periodically, and movement information, which is measured together with the material distribution information;

a superimposed image creation step of creating a superimposed image by superimposing the plurality of tomographic images;

a specific position calculation step of calculating a specific position of the target organ based on the superimposed image; and

a specific phase determination step of determining a specific phase of the target organ based on the specific position.

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