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### X-ray CT apparatus, X-ray CT apparatus control method, and storage medium

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#### Abstract

An X-ray CT apparatus of an embodiment acquires projection data of a subject based on X-ray detection data according to biometric information synchronous scanning and generates a CT image of the subject based on the projection data. The X-ray CT apparatus includes a first acquisition unit, a determination unit, and a second acquisition unit. The first acquisition unit acquires biometric information of the subject at a timing when the biometric information synchronous scanning has been performed. The determination unit determines, as priority data, detection data that is a target for which data transfer will be preferentially performed among X-ray detection data acquired in the biometric information synchronous scanning based on the biometric information. The second acquisition unit acquires the priority data from a storage device that holds the detection data.

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## Background/Summary

### CROSS-REFERENCE TO RELATED APPLICATION

(1) The present application claims priority based on Japanese Patent Application No. 2021-107643 filed Jun. 29, 2021, the content of which is incorporated herein by reference.

### BACKGROUND

#### Field

(2) Embodiments disclosed herein relate generally to an X-ray CT apparatus, an X-ray CT apparatus control method, and a storage medium.

(3) Conventionally, there is an X-ray computed tomography (CT) apparatus that generates a cross-sectional image of a subject using X-rays. As X-ray CT apparatuses, one that collects and transfers projection data in parallel and one that acquires projection data and then transfers the acquired projection data are known. Although the latter method (hereinafter referred to as “two-stage transfer method”) was devised because real-time data transfer became difficult with the former method due to increases in capacity of projection data, it takes more time to complete data transfer than the former method. In recent years, an X-ray CT apparatus capable of generating a cross-sectional image that is less affected by movement of a subject according to electrocardiographic synchronous scanning for acquiring projection data at a timing when movement of the subject is small based on electrocardiographic waveforms of the subject has also been developed.

(4) However, a long time is required for the two-stage transfer type X-ray CT apparatus. Furthermore, when helical scanning is performed as electrocardiographic synchronous scanning, a helical pitch needs to be shorter than that of normal helical scanning in order to guarantee reconstruction at all phases, which increases the amount of data to be acquired and requires more time for data transfer. For this reason, when electrocardiographic synchronous scanning in a two-stage transfer type X-ray CT apparatus is performed, a time required for acquisition and transfer of projection data increases, and reconstruction processing at a target phase cannot be performed immediately after examination is completed and thus there is a possibility that it will take a long time to determine success or failure of examination.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a diagram showing a configuration example of an X-ray CT apparatus according to a first embodiment.

(2) FIG. 2 is a diagram showing an example of an electrocardiogram.

(3) FIG. 3 is a diagram showing an example of a method of determining priority data based on phase information.

(4) FIG. 4 is an image diagram showing a method of transferring X-ray CT apparatus priority data of the first embodiment from a gantry device to a console device.

(5) FIG. 5 is a flowchart showing an example of a flow of processing in which the X-ray CT apparatus determines priority data.

(6) FIG. 6 is a diagram showing a configuration example of an X-ray CT apparatus according to a second embodiment.

(7) FIG. 7 is a flowchart showing an example of a flow of processing in which the X-ray CT apparatus determines priority data.

- (8) FIG. **8** is an image diagram showing a method in which the X-ray CT apparatus of the second embodiment transfers priority data from the gantry device to the console device.
- (9) FIG. **9** is an image diagram showing a case where the transfer method of the first embodiment is applied to data transfer from a DAS **16** to a receiver **23**.
- (10) FIG. **10** is an image diagram showing a case where the transfer method of the second embodiment is applied to data transfer from the DAS **16** to the receiver **23**.

#### DETAILED DESCRIPTION

- (11) Hereinafter, an X-ray CT apparatus, an X-ray CT apparatus control method, and a storage medium of embodiments will be described with reference to the drawings.
- (12) An X-ray CT apparatus of an embodiment is an apparatus that acquires projection data of a subject based on X-ray detection data according to biometric information synchronous scanning and generates a CT image of the subject based on the projection data. The X-ray CT apparatus includes a processing circuitry. The processing circuitry acquires biometric information of the subject at a timing when the biometric information synchronous scanning has been performed. The processing circuitry determines, as priority data, detection data that is a target for which data transfer will be preferentially performed among X-ray detection data acquired in the biometric information synchronous scanning based on the biometric information. The processing circuitry acquires the priority data from a storage device that holds the detection data.
- (13) An X-ray CT apparatus of an embodiment is an apparatus that acquires projection data of a subject based on X-ray detection data according to biometric information synchronous scanning and generates a CT image of the subject based on the projection data. The X-ray CT apparatus includes a processing circuitry. The processing circuitry acquires exposure information indicating an X-ray exposure timing in the biometric information synchronous scanning. The processing circuitry determines, as priority data, detection data that is a target for which data transfer will be preferentially performed among X-ray detection data acquired in the biometric information synchronous scanning based on the exposure information. The processing circuitry acquires the priority data from a storage device that holds the detection data.

#### First Embodiment

- (14) FIG. **1** is a diagram showing a configuration example of an X-ray CT apparatus **1A** according to a first embodiment. The X-ray CT apparatus **1A** includes, for example, a gantry device **10**, a bed device **30**, and a console device **40**. In FIG. **1**, both a diagram of the gantry device **10** viewed in a Z-axis direction and a diagram viewed in an X-axis direction are shown for convenience of description, but in reality, there is one gantry device **10**. In the embodiment, the axis of rotation of a rotating frame **17** in a non-tilted state or the longitudinal direction of a top plate **33** of the bed device **30** is defined as the Z-axis direction, an axis orthogonal to the Z-axis direction and horizontal to the floor surface is defined as the X-axis direction, and a direction orthogonal to the Z-axis direction and perpendicular to the floor surface is defined as a Y-axis direction. The X-ray CT apparatus **1A** captures a contrast-enhanced CT image (hereinafter, simply referred to as a “CT image”) for performing image diagnosis according to electrocardiographic synchronous helical scanning. Electrocardiographic synchronous helical scanning is an example of “biometric information synchronous scanning.”
- (15) The gantry device **10** includes, for example, an X-ray tube **11**, a wedge **12**, a collimator **13**, an X-ray high voltage device **14**, an X-ray detector **15**, a data acquisition system (hereinafter, DAS) **16**, the rotating frame **17**, a control device **18**, and an electrocardiograph **21**.
- (16) The X-ray tube **11** generates X-rays by radiating thermoelectrons from a cathode (filament) toward an anode (target) according to application of a high voltage from the X-ray high voltage device **14**. The X-ray tube **11** includes a vacuum tube. For example, the X-ray tube **11** is a rotating anode type X-ray tube that generates X-rays by radiating thermoelectrons to a rotating anode.
- (17) The wedge **12** is a filter for adjusting an X-ray dose radiated from the X-ray tube **11** to a subject P that is an image diagnosis target. The wedge **12** attenuates X-rays passing through the

wedge **12** such that a distribution of the X-ray dose applied to the subject P from the X-ray tube **11** becomes a predetermined distribution. The wedge **12** is also called a wedge filter or a bow-tie filter. The wedge **12** is made by processing aluminum to have a predetermined target angle and a predetermined thickness, for example.

(18) The collimator **13** is a mechanism for narrowing a radiation range of X-rays that have passed through the wedge **12**. The collimator **13** narrows the X-ray radiation range by forming a slit, for example, by combining a plurality of lead plates. The collimator **13** may be called an X-ray diaphragm.

(19) The narrowing range of the collimator **13** may be mechanically driven.

(20) The X-ray high voltage device **14** includes, for example, a high voltage generation device and an X-ray control device. The high voltage generation device has an electric circuit including a transformer, a rectifier, and the like and generates a high voltage to be applied to the X-ray tube **11**. The X-ray control device controls the output voltage of the high voltage generation device according to X-ray dose to be generated in the X-ray tube **11**. The high voltage generation device may be one that boosts a voltage by the transformer described above or may be one that boosts a voltage by an inverter.

(21) The X-ray high voltage device **14** may be provided on the rotating frame **17** or may be provided on the side of a fixed frame (not shown) of the gantry device **10**.

(22) The X-ray detector **15** detects the intensity of X-rays that are generated by the X-ray tube **11**, and have passed through and are incident on the subject P. The X-ray detector **15** outputs an electric signal (which may be an optical signal or the like) depending on the detected intensity of X-rays to the DAS **16**. The X-ray detector **15** includes, for example, a plurality of X-ray detection element strings. Each of the plurality of X-ray detection element strings is an arrangement of a plurality of X-ray detection elements in a channel direction along an arc having a focal point of the X-ray tube **11** as a center. The plurality of X-ray detection element strings is arranged in a slice direction (column direction and row direction).

(23) The X-ray detector **15** is an indirect detector having, for example, a grid, a scintillator array, and an optical sensor array. The scintillator array has a plurality of scintillators. Each scintillator has a scintillator crystal. The scintillator crystal emits an amount of light corresponding to the intensity of incident X-rays. The grid is disposed on the surface of the scintillator array on which X-rays are incident and has an X-ray shielding plate having a function of absorbing scattered X-rays. The grid may also be called a collimator (one-dimensional collimator or two-dimensional collimator). The optical sensor array includes, for example, an optical sensor such as a photomultiplier tube (PMT). The optical sensor array outputs an electric signal depending on the amount of light emitted by the scintillator. The X-ray detector **15** may be a direct conversion type detector having a semiconductor element that converts incident X-rays into an electric signal.

(24) The DAS **16** includes, for example, an amplifier, an integrator, and an A/D converter. The amplifier performs amplification processing on the electric signal output by each X-ray detection element of the X-ray detector **15**. The integrator integrates the amplified electrical signal over a view period. The A/D converter converts an electric signal indicating the integration result into a digital signal. The DAS **16** outputs detection data of the X-ray detector **15** based on the digital signal to the console device **40**. Since X-rays are intermittently exposed in electrocardiographic synchronous helical scanning, the detection data output by the DAS **16** includes data indicating X-ray detection and data indicating X-ray non-detection (refer to FIG. 4).

(25) The rotating frame **17** supports the X-ray tube **11**, the wedge **12**, the collimator **13**, and the X-ray detector **15** in a facing manner. The rotating frame **17** is an annular member including both side surfaces of a circle having a circular opening formed at the center, an inner surface connecting the inner circles of both side surfaces, and an outer surface connecting the outer circles of both side surfaces. Both side surfaces of the rotating frame **17** are flat surfaces, and the inner and outer surfaces are curved surfaces.

(26) The rotating frame **17** is an annular member that supports the X-ray tube **11**, the wedge **12**, the collimator **13**, and the X-ray detector **15** in a facing manner. The rotating frame **17** is rotatably supported around the subject P introduced inside by a fixed frame (not shown). The rotating frame **17** further supports the DAS **16**. Detection data output by the DAS **16** is transmitted from a transmitter having a light emitting diode (LED) provided in the rotating frame **17** to a receiver **23** having a photodiode provided in a non-rotating part (for example, a fixed frame) of the gantry device **10** through optical communication and transferred to the console device **40** by the receiver **23**. The receiver **23** includes a memory that stores the detection data received from the transmitter at least until it is transferred to the console device **40**. The method of transmitting the detection data from the rotating frame **17** to the non-rotating part is not limited to the aforementioned method using optical communication, and any non-contact transmission method may be adopted. The rotating frame **17** is not limited to an annular member as long as it can support and rotate the X-ray tube **11** and the like and may be a member such as an arm.

(27) Although the X-ray CT apparatus **1A** is, for example, a rotate/rotate-type X-ray CT apparatus (third generation CT) in which both the X-ray tube **11** and the X-ray detector **15** are supported by the rotating frame **17** and rotate around the subject P, it is not limited thereto and may be a stationary/rotate-type X-ray CT apparatus (fourth generation CT) in which a plurality of X-ray detection elements arranged in an annular shape are fixed to a fixed frame and the X-ray tube **11** rotates around the subject P.

(28) The control device **18** includes, for example, a processing circuit having a processor such as a central processing unit (CPU) and a drive mechanism including a motor, an actuator, and the like. The processing circuit realizes these functions by, for example, a hardware processor executing a program stored in a storage device (storage circuit).

(29) The hardware processor is, for example, a circuit (circuitry) such as a central processing unit (CPT), a graphics processing unit (GPU), an application specific integrated circuit (ASIC), a programmable logic device (for example, a simple programmable logic device (SPLD) or a complex programmable logic device (CPLD)), or a field programmable gate array (FPGA). The program may be configured to be embedded directly in the circuit of the hardware processor instead of being stored in the storage device. In this case, the hardware processor realizes a function by reading and executing the program embedded in the circuit. The hardware processor is not limited to a single circuit and may be configured as one hardware processor by combining a plurality of independent circuits to realize each function. The storage device may be a (hardware) non-transitory storage medium. A plurality of components may be integrated into one hardware processor to realize each function.

(30) For example, the control device **18** rotates the rotating frame **17**, tilts a gantry of the gantry device **10**, moves the top plate **33** of the bed device **30** by vertical movement or the like, and causes the X-ray tube **11** to emit (expose) X-rays. The control device **18** may be provided in the gantry device **10** or in the console device **40**.

(31) The electrocardiograph **21** detects a weak current generated according to excitement of the heart of the subject P through a probe **22**. The electrocardiograph **21** outputs temporal changes in the detected current as an electrocardiogram. The electrocardiogram is an example of “biometric information.” The electrocardiogram is used to determine timing when the X-ray CT apparatus **1A** exposes X-rays in electrocardiographic synchronous helical scanning of the subject P. The electrocardiogram is used to determine data (hereinafter referred to as “priority data”) of a target for which data transfer to the receiver **23** or the console device **40** is preferentially performed among detection data acquired according to electrocardiographic synchronous helical scanning.

(32) FIG. 2 is a diagram showing an example of an electrocardiogram. On the electrocardiogram, characteristic waveforms such as P waves, Q waves, R waves, S waves, and T waves appear in a heartbeat cycle. FIG. 2 shows an example of the most characteristic R-wave electrocardiogram. In R waves, a systole in which the heart contracts comes after a nearly constant time. This systole is

followed by a diastole in which the heart expands. These systoles and diastoles are periods in which the size of the heart drastically changes. The period from immediately after a diastole to immediately before a systole of the next heartbeat cycle is a period in which changes in the size of the heart are relatively mild, which is called an equal amount diastole.

(33) Electrocardiographic synchronous helical scanning is a scanning method for acquiring projection data at a timing when temporal changes in electrocardiographic waveforms are small during this relaxation period. Electrocardiographic synchronous helical scanning includes a method of collecting projection data at corresponding timing from projection data acquired at a plurality of phases, a method of determining an intermittent X-ray exposure period (hereinafter referred to as an “X-ray exposure period”) at corresponding timings and exposing the subject P to X-rays during the X-ray exposure period, and the like. In either case, an electrocardiogram is acquired at the time of scanning the subject P. and projection data necessary for reconstruction is identified based on electrocardiographic waveforms indicated by the acquired electrocardiogram.

(34) Since the X-ray exposure period may differ depending on the individual subject P or the state of the subject P at the time of examination, an electrocardiogram of the subject P may be acquired before scanning is performed and the X-ray exposure period may be determined based on the acquired electrocardiogram at the time of determining the X-ray exposure period. Here, an electrocardiogram acquired before scanning is performed is referred to as a “pre-scan electrocardiogram” in order to distinguish it from an electrocardiogram acquired at the time of performing scanning. Although a preliminary electrocardiogram may be acquired at any time before the start of scanning, it is desirable to acquire it at the timing of breathing exercises performed in a conventional examination procedure, or the like in consideration of avoiding a decrease in examination efficiency. In the present embodiment, it is assumed that the X-ray exposure period is set in a sufficiently wide range such that it includes at least a priority period which will be described later. A heartbeat cycle is an example of a “biological motion cycle.” Although electrocardiographic synchronous helical scanning when the X-ray exposure period is set will be exemplified below, a method of determining the priority period in the first embodiment is also applicable to electrocardiographic synchronous helical scanning when the X-ray exposure period is not set.

(35) Return to description of FIG. 1. The bed device **30** is a device that introduces the subject P that is a scanning target into the inside of the rotating frame **17** of the gantry device **10** by carrying and moving the subject P. The bed device **30** includes, for example, a base **31**, a bed driving device **32**, the top plate **33**, and a support frame **34**.

(36) The base **31** includes a housing that movably supports the support frame **34** in the vertical direction (Y-axis direction). The bed driving device **32** includes a motor and an actuator. The bed driving device **32** moves the top plate **33** on which the subject P is placed along the support frame **34** in the longitudinal direction (Z-axis direction) of the top plate **33**. The top plate **33** is a plate-shaped member on which the subject P is placed. The bed driving device **32** retracts the top plate **33** and inserts it into an opening of the gantry **20**. The bed driving device **32** advances the top plate **33** and pulls it out from the gantry **20**.

(37) The bed driving device **32** may move not only the top plate **33** but also the support frame **34** in the longitudinal direction of the top plate **33**. In contrast to this, the gantry device **10** may be movable in the Z-axis direction, and the rotating frame **17** may be controlled to come around the subject P according to the movement of the gantry device **10**. Both the gantry device **10** and the top plate **33** may be movable.

(38) The console device **40** includes, for example, a memory **41**, a display **42**, an input interface **43**, and a processing circuit **50**. Although the console device **40** will be described as a separate body from the gantry device **10** in embodiments, the gantry device **10** may include some or all components of the console device **40**. The console device **40** is an example of a “terminal device.”

(39) The memory **41** is realized by, for example, a random access memory (RAM), a

semiconductor memory element such as a flash memory, a hard disk, an optical disc, or the like. The memory **41** stores, for example, detection data, projection data, reconstructed image data, CT image data, and the like. This data may be stored in an external memory with which the X-ray CT apparatus **1A** can communicate instead of the memory **41** (or in addition to the memory **41**). The external memory is controlled by, for example, a cloud server that manages the external memory when the cloud server receives a read/write request.

(40) The display **42** displays various types of information. For example, the display **42** displays a medical image (CT image) generated by the processing circuit, an electrocardiogram output by the electrocardiograph **21**, a graphical user interface (GUI) image through which various operations by an operator such as a doctor or an engineer are received, and the like. The display **42** is, for example, a liquid crystal display, a cathode ray tube (CRT), an organic electroluminescence (EL) display, or the like. The display **42** may be provided on the gantry device **10**. The display **42** may be a desktop type or a display device (for example, a tablet terminal) capable of wirelessly communicating with the main body of the console device **40**.

(41) The input interface **43** receives various input operations performed by an operator and outputs an electric signal indicating the content of the received input operations to the processing circuit **50**. For example, the input interface **43** receives an input operation of converting generated CT image data into three-dimensional image data or cross-sectional image data of an arbitrary cross section as an input to the image processing function **54** which will be described later.

(42) The input interface **43** receives an operation of inputting various conditions (a scanning plan) when generating a CT image of the subject P, such as collection conditions when collecting detection data or projection data, reconstruction conditions when reconstructing a CT image, and image processing conditions when generating a post-processed image from a CT image, for example. The input interface **43** receives an operation of inputting transfer conditions when transferring detection data to the console device **40**, for example.

(43) For example, the input interface **43** receives an operation of inputting phase information as a detection data transfer condition. The phase information is information related to a heartbeat cycle and is, for example, information indicating a specific phase in the heartbeat cycle of the subject P or information indicating a section (specific section) before and after the specific phase. The phase information is used to determine priority data from detection data acquired through electrocardiographic synchronous helical scanning.

(44) FIG. **3** is a diagram showing an example of a method of determining priority data based on phase information. The example of an electrocardiogram shown in FIG. **3** is the same as that shown in FIG. **2**. Generally, in electrocardiographic synchronous helical scanning, a target phase (reconstruction center) of reconstruction processing is about 75% of R-R time (a time width between adjacent R wave peaks), and projection data of a period of about 5% before and after the reconstruction center (that is, a period of 70% to 80%) is required in order to generate a CT image of the reconstruction center. The example of FIG. **3** is an example of a case in which the reconstruction center and a priority data acquisition period (hereinafter referred to as a “priority period”) are determined based on this idea.

(45) In this case, the input interface **43** is configured to receive an operation of inputting a value “75%” indicating the reconstruction center and a value “5%” indicating the width of the priority period as phase information. The reconstruction center and the priority period are determined based on an electrocardiogram acquired during scanning (hereinafter referred to as “scanning electrocardiogram”).

(46) For example, the input interface **43** may be configured to receive an input operation for causing the display **42** to display a scanning electrocardiogram and designating a reconstruction center and a priority period for the displayed scanning electrocardiogram. Temporal changes in the R wave may differ for each heartbeat cycle. Therefore, the input interface **43** may be configured to receive an input operation for designating a reconstruction center and a priority period for each



heartbeat cycle.

(47) The input interface **43** is realized by, for example, a mouse, a keyboard, a touch panel, a track ball, a switch, a button, a joystick, a camera, an infrared sensor, a microphone, or the like. The input interface **43** may be realized by a display device (for example, a tablet terminal) capable of wirelessly communicating with the main body of the console device **40**.

(48) In the present description, the input interface **43** is not limited to the one provided with physical operation parts such as a mouse and a keyboard. For example, examples of the input interface **43** include an electric signal processing circuit that receives an electric signal corresponding to an input operation from an external input device provided separately from the device and outputs the electric signal to a control circuit. The input interface **43** is an example of an “input unit.”

(49) Return to description of FIG. **1**. The processing circuit **50** controls the overall operation of the X-ray CT apparatus **1A**. The processing circuit **50** includes, for example, a control function **51**, a preprocessing function **52**, a reconstruction processing function **53**, an image processing function **54**, a first acquisition function **55A**, a determination function **56A**, and a second acquisition function **57**. The processing circuit **50** realizes these functions by, for example, a hardware processor executing a program stored in a storage device (storage circuit).

(50) The hardware processor means, for example, a circuit such as a CPU, a GPU, an integrated circuit for a specific application, a programmable logic device or a composite programmable logic device, or a field programmable gate array. The program may be directly embedded in the circuit of the hardware processor instead of being stored in the storage device. The hardware processor is not limited to the one configured as a single circuit and may be configured as one hardware processor by combining a plurality of independent circuits to realize each function. The storage device may be a (hardware) non-transitory storage medium. A plurality of components may be integrated into one hardware processor to realize each function.

(51) Components included in the console device **40** or the processing circuit **50** may be decentralized and realized by a plurality of hardware devices. The processing circuit **50** may be realized by a processing device capable of communicating with the console device **40** instead of being a component included in the console device **40**. The processing device is, for example, a workstation connected to one X-ray CT apparatus, or a device (e.g., a cloud server) connected to a plurality of X-ray CT apparatuses and collectively executing the same processing as that of the processing circuit **50** which will be described below.

(52) Each function included in the processing circuit **50** may be distributed to a plurality of circuits or may be configured to be available by activating application software stored in the memory **41**. For example, the control function **51**, the preprocessing function **52**, the reconstruction processing function **53**, and the image processing function **54** are included in the processing circuit **50**, and the first acquisition function **55A**, the determination function **56A**, and the second acquisition function **57** may be configured to be available by activating application software stored in the memory **41**.

(53) The control function **51** controls various functions of the processing circuit **50** based on an input operation received by the input interface **43**. For example, the control function **51** stores an input scanning plan in the memory **41** and executes scanning of the subject **P** according to the scanning plan stored in the memory **41**. For example, the control function **51** executes detection data collection processing in the gantry device **10**, and the like by controlling the X-ray high voltage device **14**, the DAS **16**, the control device **18**, and the bed driving device **32**.

(54) The preprocessing function **52** generates projection data by performing preprocessing (logarithmic conversion processing, offset correction processing, interchannel sensitivity correction processing, beam hardening correction, and the like) on detection data output by the DAS **16** according to the scanning plan and stores the generated projection data in the memory **41**.

(55) The reconstruction processing function **53** generates CT image data by performing reconstruction processing (according to a filter correction back projection method, a sequential

approximation reconstruction method, and the like) on the projection data generated by the preprocessing function 52 according to the scanning plan and stores the generated CT image data in the memory 41.

(56) The image processing function 54 converts the CT image data into three-dimensional image data or cross-sectional image data of an arbitrary cross section by a known method based on an input operation received by the input interface 43. Conversion into the three-dimensional image data may be performed by the preprocessing function 52.

(57) The first acquisition function 55A acquires a scanning electrocardiogram and stores the electrocardiogram in the memory 41.

(58) The determination function 56A determines priority data from detection data acquired through electrocardiographic synchronous helical scanning based on the scanning electrocardiogram. Specifically, the determination function 56A determines, as the priority data, detection data acquired in a priority period determined based on the scanning electrocardiogram in a period in which electrocardiographic synchronous helical scanning is performed. The determination function 56A instructs the second acquisition function 57 to acquire the determined priority data.

(59) The second acquisition function 57 acquires the detection data acquired by performing electrocardiographic synchronous helical scanning on the subject P from the gantry device 10 and stores the acquired detection data in the memory 41. The detection data acquired by the second acquisition function 57 is used to generate projection data by the preprocessing function 52. Then, the reconstruction processing function 53 performs reconstruction processing using the projection data generated by the preprocessing function 52 to generate a CT image.

(60) FIG. 4 is an image diagram showing a method in which the X-ray CT apparatus 1A of the first embodiment transfers priority data from the gantry device 10 to the console device 40. Although the gantry device 10 exposes X-rays in each discretely set X-ray exposure period in electrocardiographic synchronous helical scanning, as described above, the DAS 16 outputs a signal indicating that X-rays are not detected even at a timing when X-rays are not exposed during scanning. Accordingly, detection data indicating that X-rays have been detected (data in a non-blank portion in the figure, which becomes projection data by preprocessing) and detection data indicating that X-rays have not been detected (data in a blank portion in the figure) are alternately included in detection data output by the DAS 16, as shown in FIG. 4.

(61) In this case, the determination function 56A recognizes a priority period based on phase information input through the input interface 43 and determines detection data acquired in the priority period as priority data. The determination function 56A instructs the second acquisition function 57 to acquire the determined priority data from the gantry device 10. Specifically, the determination function 56A notifies the second acquisition function 57 of the recognized priority period, and the second acquisition function 57 acquires the detection data of the notified priority period from the gantry device 10 in the order in which the detection data is acquired.

(62) The determination function 56A may be configured to acquire all priority data among all acquired detection data and then acquire a part or all of the remaining detection data (hereinafter referred to as “non-priority data”) from the gantry device 10. For example, in the example of FIG. 4, non-priority data is detection data other than priority data among detection data of an X-ray exposure period, and detection data indicating that X-rays have not been detected.

(63) As a result, the console device 40 can shorten a waiting time until detection data required for reconstruction processing is transferred and can rapidly start reconstruction processing. Specifically, reconstruction processing is started after waiting for the entire detection data to be transferred to the console device 40 conventionally, whereas reconstruction processing can be started after waiting for a time required for priority data transfer according to the transfer method of the present embodiment.

(64) Although a case in which the second acquisition function 57 acquires all priority data from the gantry device 10 among all the acquired detection data and then acquires a part or all of non-

priority data from the gantry device **10** has been described in the example of FIG. **4**, the second acquisition function **57** may be configured to acquire all the priority data from the gantry device **10** and then delete a part or all of the non-priority data from the gantry device **10**. For example, the second acquisition function **57** may instruct the gantry device **10** to delete the non-priority data based on an input operation of a user or may instruct the gantry device **10** to delete the non-priority data based on preset conditions regarding handling of the non-priority data, and the like.

(65) FIG. **5** is a flowchart showing an example of a flow of processing in which the X-ray CT apparatus **1A** determines priority data. The processing flow shown in FIG. **5** is started after scanning of the subject **P** according to electrocardiographic synchronous helical scanning is completed, that is, after detection data with respect to the subject **P** is acquired by the gantry device **10**. First, the first acquisition function **55A** acquires a scanning electrocardiogram from the electrocardiograph **21** and stores the scanning electrocardiogram in the memory **41** (step **S101**).

(66) Subsequently, the determination function **56A** acquires phase information for determining priority data from detection data acquired by the gantry device **10** via the input interface **43** (step **S102**). The determination function **56A** stores the acquired phase information in the memory **41**. The determination function **56A** determines a priority period based on the acquired scanning electrocardiogram and the phase information (step **S103**).

(67) Subsequently, the second acquisition function **57** acquires detection data acquired in the priority period determined by the determination function **56A** from the gantry device **10** as priority data (step **S104**) and stores the acquired priority data in the memory **41**. When the priority data is acquired from the gantry device **10**, the preprocessing function **52** performs preprocessing on the acquired priority data, and the reconstruction processing function **53** starts reconstruction processing using the preprocessed priority data. Here, it is assumed that the gantry device **10** deletes detection data transferred to the console device **40** from the gantry device **10** after transfer of the detection data is completed.

(68) Subsequently, the second acquisition function **57** determines whether or not there is detection data (hereinafter referred to as “data required to be acquired”) to be acquired by the console device **40** among detection data (non-priority data) other than the priority data (step **S105**). For example, the second acquisition function **57** causes the display **42** to display a display indicating that data required to be acquired can be designated and receives an input of an operation for designating data required to be acquired via the input interface **43**. In this case, the second acquisition function **57** determines that “there is data required to be acquired” when the operation for designating data required to be acquired is input and determines that “there is no data required to be acquired” when the operation for designating data required to be acquired is not input. For example, the second acquisition function **57** may determine presence or absence of data required to be acquired based on conditions and the like preset with respect to data required to be acquired.

(69) Here, if it is determined that “there is data required to be acquired” (step **S105**—YES), the second acquisition function **57** acquires the data required to be acquired from the gantry device **10** (step **S106**) and stored the acquired data required to be acquired in the memory **41**. On the other hand, if it is determined that “there is no data required to be acquired” (step **S105**—NO), the second acquisition function **57** skips step **S106** and proceeds to step **S107**.

(70) Subsequently, the second acquisition function **57** determines whether or not to delete other detection data (hereinafter referred to as “unacquired data”) that has not been acquired from the gantry device **10** (step **S107**). The second acquisition function **57** may determine whether or not to delete the unacquired data based on an input operation of a user, preset conditions, or the like, as in the case of data required to be acquired. Here, if it is determined that the unacquired data will be deleted (step **S107**—YES), the second acquisition function **57** instructs the gantry device **10** to delete the unacquired data (step **S108**). On the other hand, if it is determined that the unacquired data will not be deleted (step **S107**—NO), step **S108** is skipped, and the processing flow ends.

(71) According to the X-ray CT apparatus **1A** of the first embodiment configured in this manner,

detection data necessary for reconstruction processing can be preferentially transferred from the gantry device **10** to the console device **40**, and thus reconstruction processing can be rapidly started after execution of scanning on the subject P.

## Second Embodiment

(72) FIG. **6** is a diagram showing a configuration example of an X-ray CT apparatus **1B** according to a second embodiment. The X-ray CT apparatus **1B** differs from the X-ray CT apparatus **1A** of the first embodiment in that the processing circuit **50** includes a first acquisition function **55B** instead of the first acquisition function **55A** and the processing circuit **50** includes a determination function **56B** instead of the determination function **56A**. Since the other components of the X-ray CT apparatus **1B** are the same as those of the X-ray CT apparatus **1A**, description thereof is omitted here by assigning the same reference numerals as those in FIG. **1** to the same components as those of the X-ray CT apparatus **1A** in FIG. **6**.

(73) The first acquisition function **55B** differs from the first acquisition function **55A** in that it acquires exposure information indicating X-ray exposure timing in electrocardiographic synchronous helical scanning instead of a scanning electrocardiogram of the subject P. The first acquisition function **55B** stores the acquired exposure information in the memory **41**.

(74) The determination function **56B** differs from the determination function **56A** in that it determines priority data based on exposure information instead of a scanning electrocardiogram. Specifically, the determination function **56B** determines, as priority data, detection data acquired in a period in which detection data indicating detection of X-rays is acquired (X-ray exposure period). This may be rephrased as that the determination function **56B** sets the X-ray exposure period as a priority period. The determination function **56B** instructs the second acquisition function **57** to acquire the determined priority data.

(75) FIG. **7** is a flowchart showing an example of a flow of processing in which the X-ray CT apparatus **1B** determines priority data. Among processes shown in the flowchart of FIG. **7**, the same processes as those of the method of determining priority data in the first embodiment are designated by the same reference numerals as those in FIG. **5**, and description thereof is omitted here. First, the first acquisition function **55B** acquires exposure information indicating X-ray exposure timing in electrocardiographic synchronous helical scanning performed on the subject P (step **S201**).

(76) Here, it is assumed that the control device **18** of the gantry device **10** records a timing at which X-rays are exposed at the time of performing electrocardiographic synchronous helical scanning as log information. The first acquisition function **55B** acquires the log information from the control device **18**, extracts exposure information from the acquired log information, and stores the exposure information in the memory **41**. When the same log information as described above is stored in the memory **41** as log information of the control function **51**, the first acquisition function **55B** acquires the log information of the control function **51** from the memory **41** and extracts exposure information from the log information of the control function **51**.

(77) Subsequently, the determination function **56B** acquires the exposure information from the memory **41** and determines a priority period based on the acquired exposure information (step **S202**). Specifically, the determination function **56B** recognizes an X-ray exposure period in electrocardiographic synchronous helical scanning based on the exposure information and determines the recognized X-ray exposure period as a priority period.

(78) In this case, the second acquisition function **57** acquires detection data acquired in the X-ray exposure period as priority data from the gantry device **10** in step **S104**. FIG. **8** is an image diagram showing a method in which the X-ray CT apparatus **1B** of the second embodiment transfers priority data from the gantry device **10** to the console device **40**. As described above, since the X-ray exposure period is set such that it includes at least a priority period in the first embodiment, the detection data of the X-ray exposure period including the priority data is transferred from the gantry device **10** to the console device **40** in the second embodiment.

(79) According to the X-ray CT apparatus 1B of the second embodiment configured in this manner, detection data of the X-ray exposure period including priority data necessary for reconstruction processing can be preferentially transferred from the gantry device 10 to the console device 40, and thus reconstruction processing can be rapidly started after execution of scanning of the subject P.

(80) The method of transferring detection data in the second embodiment preferentially transfers detection data of the X-ray exposure period. Accordingly, the method of transferring detection data in the second embodiment has a longer waiting time until reconstruction processing can be started than the method of transferring detection data in the first embodiment, but a priority period can be mechanically determined based on the actual X-ray exposure period and thus it is possible to shorten a waiting time until the start of reconstruction processing while simplifying the configuration with respect to determination of the priority period.

#### Modified Examples

(81) Although a case in which priority data is preferentially transferred when detection data is transferred from the gantry device 10 to the console device 40 has been described in the first embodiment, this transfer method may be applied to data transfer in the gantry device 10. As described above, detection data is stored in the memory of the DAS 16 first, transmitted from the memory of the DAS 16 to the receiver 23 via the transmitter (not shown), and transferred to the console device 40 by the receiver 23. Therefore, the transfer method of the first embodiment may be applied to data transfer from the DAS 16 to the receiver 23.

(82) FIG. 9 is an image diagram when the transfer method of the first embodiment is applied to data transfer from the DAS 16 to the receiver 23. In this case, among detection data stored in the memory of the DAS 16, priority data is preferentially transferred to the receiver 23. In this case, when a data transfer request is received from the console device 40, the receiver 23 may transfer detection data received from the DAS 16 to the console device 40 in the order of reception. In this case, the first acquisition function 55A, the determination function 56A, and the second acquisition function 57 related to determination of a priority period may be provided in the receiver 23 or the DAS 16.

(83) Similarly to this, the transfer method of the second embodiment may be applied to data transfer from the DAS 16 to the receiver 23. FIG. 10 is an image diagram when the transfer method of the second embodiment is applied to data transfer from the DAS 16 to the receiver 23. In this case, among detection data stored in the memory of the DAS 16, priority data is preferentially transferred to the receiver 23. In this case, when a data transfer request is received from the console device 40, the receiver 23 may transfer detection data received from the DAS 16 to the console device 40 in the order of reception. In this case, the first acquisition function 55B, the determination function 56B, and the second acquisition function 57 related to determination of a priority period may be provided in the receiver 23 or the DAS 16.

(84) Although the detection data transfer methods have been described in the first embodiment and the second embodiment, the transfer methods of the embodiments may be used as a projection data transfer method when a projection data is generated in a detection data transfer source or when detection data is used as projection data as it is. Although a case in which a transfer destination device serves as a main agent in acquiring detection data from a transfer source device has been described in the first embodiment and the second embodiment, the transfer method of the embodiments is also applicable when the transfer source device serves as a main agent in transmitting detection data to a transfer destination.

(85) Although the embodiments of the X-ray CT apparatuses 1A and 1B (hereinafter referred to as "X-ray CT apparatus 1") have been described above, the method of transferring detection data by the X-ray CT apparatus 1 may be applied to other medical image diagnostic apparatuses. Medical image diagnostic apparatuses to which the X-ray CT apparatus can be applied may be anyone that generates a medical image by performing reconstruction processing on projection data based on detection data, and may be, for example, a positron emission tomography (PET)-CT apparatus, a

magnetic resonance imaging (MRI) apparatus, an angiography imaging apparatus, and the like.

(86) The detection data transfer method in the present embodiment is applicable to a two-stage transfer type X-ray CT apparatus that performs biometric information synchronous scanning. Biometric information synchronous scanning may be performed in synchronization with periodic biological motion of a subject. For example, biometric information synchronous scanning may be respiratory synchronous scanning performed in synchronization with the respiration of a subject, in addition to electrocardiographic synchronous scanning performed in synchronization with the heartbeat of a subject described in the above embodiment. For example, the scanning method may be helical scanning or non-helical scanning.

(87) According to at least one embodiment described above, the X-ray CT apparatus of the embodiment can start reconstruction processing more rapidly in a two-stage transfer type X-ray CT apparatus by including a first acquisition unit that acquires biometric information of a subject at a timing when biometric information synchronous scanning has been performed, a determination unit that determines priority data among X-ray detection data acquired in biometric information synchronous scanning based on the biometric information, and a second acquisition unit that acquires priority data from a storage device that holds detection data.

(88) While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, submissions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

## Claims

1. An X-ray CT apparatus that acquires projection data of a subject based on X-ray detection data according to biometric information synchronous scanning and generates a CT image of the subject based on the projection data, the apparatus comprising: a gantry device that performs radiation and detection of X-rays in the biometric information synchronous scanning and stores the X-ray detection data acquired in the biometric information synchronous scanning on a storage device included in the gantry device; and processing circuitry configured to acquire biometric information of the subject at a timing when the biometric information synchronous scanning has been performed, determine, as priority data, particular detection data that is a target for which data transfer will be preferentially performed first among the X-ray detection data acquired in the biometric information synchronous scanning based on the biometric information, and acquire the determined priority data from the storage device included in the gantry device.
2. The X-ray CT apparatus according to claim 1, wherein the processing circuitry is further configured to determine, as the priority data, certain detection data acquired in a priority period determined based on the biometric information in a period in which certain the detection data has been acquired.
3. The X-ray CT apparatus according to claim 2, wherein the processing circuitry is further configured to input phase information regarding periodic biometric movement of the subject, and determine the priority period based on the biometric information and the phase information.
4. The X-ray CT apparatus according to claim 2, wherein the processing circuitry is further configured to acquire the certain X-ray detection data of the priority period among the detection data stored in the gantry device from the gantry device as the priority data.
5. The X-ray CT apparatus according to claim 3, wherein the phase information is information indicating a specific phase in a biological motion cycle of the subject, or information indicating a specific section before and after the specific phase, and the processing circuitry is further

configured to determine detection data at the specific phase or detection data in the specific section as the priority data.

6. The X-ray CT apparatus according to claim 4, wherein the processing circuitry is included in a terminal device included in the X-ray CT apparatus, the terminal having a projection data reconstruction processing function, and the terminal device is configured to perform reconstruction processing on the priority data acquired from the gantry device by the processing circuitry.

7. The X-ray CT apparatus according to claim 4, wherein the processing circuitry is further configured to acquire all the priority data among the X-ray detection data acquired with respect to the subject from the gantry device, and then acquire some or all of the remaining X-ray detection data from the gantry device.

8. The X-ray CT apparatus according to claim 4, wherein the processing circuitry is further configured to acquire all the priority data from the gantry device, and then delete some or all of the remaining X-ray detection data based on an input operation of a user or based on preset conditions regarding handling of the non-priority data.

9. An X-ray CT apparatus that acquires projection data of a subject based on X-ray detection data according to biometric information synchronous scanning and generates a CT image of the subject based on the projection data, the apparatus comprising: a gantry device that performs radiation and detection of X-rays in the biometric information synchronous scanning and stores the X-ray detection data acquired in the biometric information synchronous scanning on a storage device included in the gantry device; and processing circuitry configured to acquire exposure information indicating an X-ray exposure timing in the biometric information synchronous scanning, determine, as priority data, particular detection data that is a target for which data transfer will be preferentially performed first among the X-ray detection data acquired in the biometric information synchronous scanning based on the exposure information, and acquire the determined priority data from the storage device included in the gantry device, wherein the X-ray detection data includes data indicating that X-rays have been detected and/or data indicating that X-rays have not been detected, and the processing circuitry is further configured to acquire the data indicating that X-rays have been detected as the priority data.

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