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X-RAY IMAGING SYSTEM AND X-RAY IMAGE DISPLAY METHOD

Abstract

An X-ray imaging system according to this invention includes an X-ray irradiator for irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; an X-ray detector; a load information acquirer for acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays; a display; and a controller. The controller executes control for identifiably displaying at least an X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of legs of the subject in loaded action on the display based on the load information.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS
[0001] The related application number JP2024-024949, X-ray imaging system and X-ray image display method, Feb. 21, 2024, KAWAMURA Takahiro, upon which this patent application is based are hereby incorporated by reference.
BACKGROUND OF THE INVENTION
Field of the Invention
[0002] The present invention relates to an X-ray imaging system and an X-ray image display method.
Description of the Background Art
[0003] X-ray imaging systems including optical image capturers are known in the art. Such a system is disclosed in Japanese Patent Laid-Open Publication No. JP 2021-058570, for example.
[0004] The above Japanese Patent Laid-Open Publication No. JP 2021-058570 discloses a radiography system for capturing a radiographic image using X-rays. In this radiography system, video is captured while a joint is moved under a load to observe movements of the joint and bones in walking or the like.
[0005] Here, in a case in which X-ray images of a subject during loaded action such as walking action in which a load is applied are captured as in the radiography system disclosed in the above Japanese Patent Laid-Open Publication No. JP 2021-058570, a physician may make diagnosis by observing a state of the bones or the joint in the timing in which the largest load is applied to one of the subject's legs. However, in the case in which the X-ray images are captured while the subject is in loaded action, it is difficult for the physician to identify the maximum load timing in which the largest load is applied to one of the legs only by seeing the X-ray images. For this reason, it is desired to realize easy identification of an X-ray image that corresponds to the maximum load timing in which the largest load is applied to one of the legs.
SUMMARY OF THE INVENTION
[0006] The present invention is intended to solve the above problem, and one object of the present invention is to provide an X-ray imaging system and an X-ray image display method capable of realizing easy identification of an X-ray image that corresponds to a maximum load timing in which the largest load is applied to one of legs.
[0007] An X-ray imaging system according to a first aspect of the present invention includes an X-ray irradiator for irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; an X-ray detector for detecting the X-rays with which the subject is irradiated by the X-ray irradiator and that pass through the subject; a load information acquirer for acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays using the X-ray detector; a display for displaying an X-ray image(s) generated based on the detection of the X rays using the X-ray detector; and a controller for executing control for identifiably displaying at least the X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of the legs in

the loaded action of the subject on the display based on the load information acquired by the load information acquirer.
[0008] An X-ray image display method according to a second aspect of the present invention includes a step of irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; a step of detecting the X-rays that pass through the subject; a step of acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays; and a step of displaying an X-ray image(s) generated based on the detection of the X-rays, wherein the step of displaying the X-ray image(s) includes a step of identifiably displaying at least the X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of the legs in the loaded action of the subject based on the load information acquired.
[0009] In the aforementioned X-ray imaging system according to the first aspect and the aforementioned X-ray image display method according to the second aspect, as described above, at least an X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of legs of a subject in loaded action based on load information acquired is identifiably displayed. Accordingly, since the X-ray image that corresponds to the maximum load timing is identifiably displayed, easy identification of the X-ray image that corresponds to the maximum load timing in which the largest load is applied to one of the legs can be realized by allowing visual recognition of the X-ray image displayed that corresponds to the maximum load timing.
[0010] The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0011] FIG. **1** is a schematic view showing an entire configuration of an X-ray imaging system according to a first embodiment.
[0012] FIG. **2** is a block diagram showing the overall configuration of the X-ray imaging system according to the first embodiment.
[0013] FIG. **3** is a schematic view showing an exemplary display screen of a display displaying an X-ray image and an optical image.
[0014] FIG. **4** is a view showing an exemplary display screen displaying a plurality of X-ray images and a plurality of optical images in alignment with each other.
[0015] FIG. **5** is a flowchart illustrating control processing in an X-ray image display method using the X-ray imaging system according to the first embodiment.
[0016] FIG. **6** is a block diagram showing an overall configuration of an X-ray imaging system according to a second embodiment.
[0017] FIG. **7** is a flowchart illustrating detection of a position of a leg in a height direction according to the second embodiment.
[0018] FIG. **8** is a chart schematically showing exemplary periodic change of difference between a position of a toe of a right leg and a position of a toe of a left leg in an upward\downward direction of an optical image **80**.
[0019] FIG. **9** is a schematic chart illustrating setting of X-ray irradiation timing.
[0020] FIG. **10** is a view showing an exemplary display screen of the display displaying an X-ray image corresponding to a maximum load timing.
[0021] FIG. **11** is a flowchart illustrating control processing of an X-ray image display method using the X-ray imaging system according to the second embodiment.
[0022] FIG. **12** is a schematic view showing an entire configuration of an X-ray imaging system

according to a third embodiment.

[0023] FIG. **13** is a schematic diagram illustrating setting of X-ray irradiation timing based on detection results of a pressure sensor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0024] Embodiments embodying the present invention will be described with reference to the drawings.

First Embodiment

(Configuration of X-Ray Imaging System)

[0025] The following description describes a configuration of an X-ray imaging system **100** according to a first embodiment of the present invention with reference to FIGS. **1** to **4**.

[0026] As shown in FIG. **1**, the X-ray imaging system **100** is a system including a medical X-ray imaging apparatus (so-called X-ray fluoroscopy system) for capturing X-ray images **70** (see FIG. **3**) as video by successively irradiating a subject **101** with X-rays, and is configured to capture the X-ray images of the subject as an imaging target. For example, before and after artificial joint replacement surgery in a knee joint or the like, X-ray images of the subject **101** are captured during walking action as loaded action in which a load is applied to the subject's legs. In this capture of the images, since bones overlap each other in the knee joint in the X-ray image **70** of the subject's knee being bent, visibility decreases in the X-ray image **70**. For this reason, a physician will use the X-ray image **70** in a timing in which the knee is extended and receives a load to make diagnosis. In the first embodiment, the X-ray imaging system **100** provides assistance for identification of the X-ray image **70** that corresponds to a maximum load timing in which a largest load is applied to one of the legs in the loaded action from the plurality of X-ray images **70**, which are successively captured and each of which is captured as one frame of video. Here, in a case in which the loaded action is walking action, the subject can walk in place or walk on a treadmill.

[0027] As shown in FIG. **2**, the X-ray imaging system **100** includes an X-ray irradiator **10**, an X-ray detector **20**, an optical image capturer **30**, a moving mechanism **40**, a controller **50**, and a display **60**. In the X-ray imaging system **100**, the X-rays with which the subject is irradiated by the X-ray irradiator **10** are detected by the X-ray detector **20** to capture the X-ray images of the subject **101**. In the X-ray imaging system **100**, optical images **80** (see FIG. **3**) of the exterior of the subject **101** are captured by the optical image capturer **30**. As shown in FIG. **1**, in the X-ray imaging system **100**, for example, the X-ray irradiator **10**, the X-ray detector **20**, the optical image capturer **30**, and the moving mechanism **40** are installed in an imaging room **110**, and the controller **50** and the display **60** are installed outside the imaging room **110**. Here, the controller **50** and the display **60** may be installed inside the imaging room **110**. Also, the optical image capturer **30** is an example of a “load information acquirer” in the claims. Also, the optical image **80** is an example of “load information” in the claims.

[0028] The X-ray irradiator **10** irradiates the subject **101** during the loaded action with the X-rays. The X-ray irradiator **10** includes an X-ray tube **11** and a collimator **12**. The X-ray irradiator **10** is configured to irradiate the subject **101** with the X-rays from the X-ray tube **11**. The X-ray tube **11** is configured to emit X-rays for irradiation when a predetermined voltage is applied. The collimator **12** includes a plurality of position-adjustable shielding plates (collimator leaves). The collimator **12** is configured to specify (adjust) an irradiation field of the X-rays emitted from the X-ray tube **11** for irradiation by shielding a part of the X-rays from the X-ray tube **11**. The collimator **12** is arranged in proximity to the X-ray tube **11** in an X-ray irradiation direction of the X-ray tube **11**.

[0029] The X-ray detector **20** is configured to detect the X-rays with which the subject is irradiated by the X-ray irradiator **10** and that pass through the subject **101**. For example, the X-ray detector **20** is movably arranged in a bed **21** of the X-ray fluoroscopy system. The X-ray detector **20** includes a flat panel detector (FPD). The X-ray detector **20** outputs signals based on the X-rays detected to the controller **50**.

[0030] The X-ray irradiator **10** is movably held in the imaging room **110** by the moving mechanism

40. Here, a vertical (upward/downward) direction is defined as a Z direction, and two directions perpendicular to each other in horizontal directions are defined as X and Y directions. The moving mechanism **40** is configured to movably hold the X-ray irradiator **10**. The moving mechanism **40** includes a support **41** supporting the X-ray irradiator **10**. The moving mechanism **40** moves the X-ray irradiator **10** with the X-ray irradiator facing the bed **21** in which the X-ray detector **20** is arranged. The moving mechanism **40** swings the bed **21** and the support **41** together with each other to an erected/laid orientation, for example. Also, the support **41** changes a distance between the X-ray irradiator **10** and the bed **21** in which the X-ray detector **20** is arranged. In the first embodiment, the bed **21** is orientated in the erected orientation to capture images of the subject **101** in the walking action from an X-direction side, which is a horizontal-direction side. In other words, the X-ray irradiator **10** and the X-ray detector **20** are arranged with facing each other in the horizontal direction (X direction). The moving mechanism **40** includes an electric motor as a drive source, for example.

[0031] The optical image capturer **30** captures the optical images **80** (see FIG. **3**) of the subject **101** during the loaded action. The optical image capturer **30** acquires the optical images **80** as load information to identify a state of the load applied to the leg in the loaded action of the subject **101** separately from the detection of the X-rays using the X-ray detector **20**. In the first embodiment, the optical image capturer **30** is arranged on an exterior surface of the collimator **12**. The optical image capturer **30** is arranged with facing an X-ray irradiation direction side of the X-ray irradiator **10**. The optical image capturer **30** captures the optical images **80** of the subject **101** from an X-ray irradiator **10** side when the X-ray irradiator **10** faces toward the subject **101** and the X-ray detector **20**. The optical image capturer **30** is an optical camera, for example. The optical image capturer **30** includes an imaging element such as a CCD (Charge Coupled Device) image sensor or CMOS (Complementary Metal Oxide Semiconductor) image sensor, for example. The optical image capturer **30** transmits and receives signals to and from the controller **50** through a wireless or wired connection. The optical image capturer **30** outputs signals detected by the image sensor to the controller **50**. The optical image capturer **30** is configured to be directed by the controller **50** to capture the optical images **80** in timings that are synchronized with detection of the X-rays using the X-ray detector **20** separately from the detection of the X-rays using the X-ray detector **20**.

[0032] The controller **50** performs control of X-ray imaging using the X-ray irradiator **10** and the X-ray detector **20**, and control relating to the capture of the optical images **80** using the optical image capturer **30**. Specifically, the controller **50** includes a CPU (Central Processing Unit). The controller **50** controls the X-ray imaging and the capture of the optical images **80** based on parameters and various programs, which are previously set and stored in a storage. Also, the controller **50** controls displaying of the X-ray and optical images **70** and **80** on the display **60**.

[0033] As shown in FIG. **3**, the display **60** displays the X-ray image **70** that is generated by the controller **50** based on the detection of the X-rays using the X-ray detector **20**. Also, the display **60** displays the optical image **80** that is generated by the controller **50** based on the image capture using the optical image capturer **30**. The display **60** includes a liquid crystal display, for example.

(Control of Displaying of X-Ray and Optical Images)

[0034] As shown in FIG. **4**, in the first embodiment, the controller **50** is configured to control the display **60** to identifiably display the X-ray image **70** that corresponds to the maximum load timing based on the optical images **80** captured (acquired) by the optical image capturer **30**. In the first embodiment, the X-ray images **70** of a knee joint in a right leg as the one of the legs, and the optical images **80** including parts from knee joints to toes are acquired and displayed on the display **60**.

[0035] Specifically, in the first embodiment, the controller **50** generates a plurality of X-ray images **70** by successively irradiating the subject **101** in the loaded action with the X-rays. The controller **50** directs the X-ray irradiator **10** to successively irradiate the subject with the X-rays at a predetermined irradiation rate, which is previously set, and acquires detection signals of the X-rays with which the subject is irradiated at the predetermined irradiation rate and that are detected by the X-ray detector from the X-ray detector **20**. The predetermined irradiation rate is ten exposures per second, for example. The controller **50** generates the plurality of X-ray images **70** based on the detection signals of the X-rays from the X-ray detector **20**. Each of the plurality of X-ray images **70** is an image of each frame of video, for example.

[0036] Also, the controller **50** acquires the optical images **80** as video captured by the optical image capturer **30** at a frame rate not smaller than the X-ray irradiation rate. In the first embodiment, the controller **50** sets an imaging rate (period) of the optical image capturer **30** at the same frame rate as the X-ray irradiation rate. The controller **50** captures the optical images **80** as video at the same frame rate and with the same timing as the X-ray irradiation rate at which the plurality of X-ray images **70** are acquired. The optical images **80** as video include a plurality of optical images **80** as still images. The controller **50** generates the plurality of optical images **80**, which are images of the exterior of the subject **101** successively captured, based on signals from the optical image capturer **30**. The controller **50** controls operations of the X-ray irradiator **10** and the X-ray detector **20**, and an operation of the optical image capturer **30** to synchronize these operations with each other so that a timing in which each of the plurality of X-ray images **70** is captured as one frame of video is synchronized with a timing in which each of the plurality of optical images **80** is captured as one frame of video.

[0037] In the first embodiment, to display the X-ray image **70** that corresponds to the maximum load timing, the controller **50** captures the X-ray images **70** and the optical images **80** as video during a period of one cycle of the walking action. For example, the controller **50** captures the X-ray images **70** and the optical images **80** as video during a period of time of a series of motions from a state in which a foot of the one of the legs leaves the ground through a state in which a foot of another of the legs leaves the ground and to a state in which the foot of the one of the legs leaves the ground again in the walking action of the subject **101** as the period of one cycle of the walking action. Accordingly, the plurality of X-ray images **70** and the plurality of optical images **80** generated by the controller **50** include one X-ray image **70** and one optical image **80** that correspond to the maximum load timing in which the largest load is applied to the one of the legs in the walking action.

[0038] As shown in FIG. **4**, in the first embodiment, the controller **50** directs the display **60** to display one of the plurality of X-ray images **70** generated and one of the plurality of optical images **80** generated in alignment with each other for each frame. In other words, since the plurality of X-ray images **70** include the X-ray image **70** that corresponds to the maximum load timing, and the plurality of optical images **80** includes the optical image **80** that corresponds to the maximum load timing, in the first embodiment, the controller **50** displays the X-ray image **70** that corresponds to the maximum load timing in association with the optical image **80** that corresponds to the maximum load timing on the display **60** by displaying the X-ray image **70** that corresponds to the maximum load timing and the optical image **80** that corresponds to the maximum load timing in alignment with each other on the display **60**. The physician determines which of the plurality of optical images **80** is the optical image **80** that corresponds to the maximum load timing in the plurality of optical images **80** based on the exterior of the leg by visually recognizing the plurality of optical images **80** displayed on the display **60** frame by frame. For example, the physician determines the optical image **80** that corresponds to the maximum load timing in consideration of comparison of one of the optical images **80** with the optical images at previous and following timings, a position and an angle of the leg, and the like. As a result, the physician can identify the X-ray image **70** that corresponds to the maximum load timing from the plurality of X-ray images **70**. In other words, the controller **50** executes control for identifiably displaying the X-ray image **70** that corresponds to the maximum load timing from the plurality of X-ray images **70** on the display by displaying the plurality of X-ray images **70** and the optical images **80** acquired (captured) in timings that are synchronized with detection of the X-rays using the X-ray detector **20** in alignment with each other on the display **60**.

[0039] For example, the controller **50** displays each pair of the X-ray image **70** and the optical image **80** that are acquired at the same timing as each other in alignment with each other on right and left sides on the display **60** with the image pairs each of which includes the X-ray image **70** and the optical image **80** that are acquired at the same timing as each other being displayed in alignment with each other in a vertical direction in chronological order frame by frame. The X-ray image **70** and the optical image **80** displayed on the display **60** may have the same size as each other or different sizes from each other.

[0040] In the first embodiment, the physician who watches the display **60** can identify the optical image **80** that corresponds to the maximum load timing based on the plurality of optical images **80** displayed on the display **60**. Also, the physician can identify the X-ray image **70** that is displayed in association with (in alignment with) the optical image **80** that corresponds to the maximum load timing as the X-ray image **70** that corresponds to the maximum load timing.

X-Ray Image Display Method of First Embodiment

[0041] Control processing of an X-ray image display method using the X-ray imaging system **100** according to the first embodiment is now described with reference to FIG. **5**. The control processing of the image display method including steps **401** to **406** is performed by the controller **50**.

[0042] The frame rates of the X-ray images **70** and the optical images **80** are first set in step **401**. In other words, the X-ray irradiation rate of the X-ray irradiator **10** and an acquisition rate of the detection signals of the X-rays detected by the X-ray detector **20** are set to synchronize with an acquisition rate of the optical images **80** captured by the optical image capturer **30**.

[0043] Subsequently, in step **402**, the subject **101** during the walking action as the loaded action is successively irradiated with the X-rays at the set irradiation rate. Subsequently, in step **403**, the X-rays that pass through the subject **101** are detected by the X-ray detector **20**. Subsequently, in step **404**, the plurality of X-ray images **70** are generated and acquired by acquiring signals representing detection results of the X-rays detected.

[0044] Subsequently, in step **405**, the optical images **80** are acquired as the load information to identify the state of the load applied to the leg of the subject **101** in the walking action separately from the X-ray detection. In the first embodiment, the optical images **80** as video are captured by the optical image capturer **30** at the frame rate that is set to synchronize with the timing of X-ray irradiation in step **402**. The optical images **80** (the plurality of optical images **80** as still images) as video are generated based on the signals from the optical image capturer **30**.

[0045] Subsequently, in step **406**, the X-ray images **70** generated by the X-ray detection are displayed on the display **60**. In the first embodiment, in step **406**, the X-ray image **70** that corresponds to the maximum load timing in the walking action of the subject **101** is identifiably displayed on the display **60** based on the optical images **80** acquired. In other words, the X-ray image **70** that corresponds to the maximum load timing is identifiably displayed from the plurality of X-ray images **70** by displaying the plurality of X-ray images **70** and the optical images **80** acquired in timings that are synchronized with detection of the X-rays using the X-ray detector **20** in alignment with each other on the display **60**.

[0046] Any one of the control process for generating the X-ray images **70** in step **404** and the control process for acquiring (generating) the optical images **80** in step **405** can be executed prior to another.

Advantages of First Embodiment

[0047] In the first embodiment, the following advantages are obtained.

[0048] In the first embodiment, as described above, at least the X-ray image **70** that corresponds to a maximum load timing in which a largest load is applied to one of legs of the subject **101** in walking action (loaded action) based on the optical image **80** (load information) acquired is identifiably displayed. Accordingly, since the X-ray image **70** that corresponds to the maximum load timing is identifiably displayed, easy identification of the X-ray image **70** that corresponds to the maximum load timing in which the largest load is applied to the one of the legs can be realized by visual recognition of the X-ray image **70** displayed that corresponds to the maximum load timing.

[0049] Also, since the optical image capturer **30** (load information acquirer) acquires the optical images **80** (load information) to identify a state of the load applied to the leg in the loaded action of the subject **101** separately from the detection of the X-rays using the X-ray detector **20**, it is possible to reduce a load of control processing on the controller **50** as compared with a case in which image processing for extracting bone parts from the X-ray images **70** is performed and processing for identifying the state of the load applied to the legs is performed based on positions and shapes of the extracted bone parts.

[0050] In addition, the following additional advantages can be obtained by the first embodiment added with configurations discussed below.

[0051] That is, in the first embodiment, as described above, the controller **50** controls the display **60** to identifiably display the X-ray image **70** which is captured by capturing an image of at least one of an ankle joint, a knee joint, and a hip joint in the one of the legs and that corresponds to the maximum load timing based on the optical image **80** (load information) acquired by the optical image capturer **30** (load information acquirer). According to this configuration, in a case in which the state of the joint under the loaded action is observed by confirming the X-ray images **70**, which are captured by capturing an image of at least one of the ankle joint, the knee joint and the hip joint, it is possible to realize effective and easy identification of the X-ray image **70** that corresponds to the maximum load timing in which the largest load is applied to the one of the legs.

[0052] Also, in the first embodiment, the X-ray imaging system **100** includes the optical image capturer **30** for capturing the optical images **80** of the subject **101** during the loaded action. Here, since images of states of an exterior of the subject **101** are captured as the optical images **80** captured by the optical image capturer **30**, easier identification of a state of the load applied to the leg in the loaded action can be realized. Accordingly, easier identification of the X-ray image **70** that corresponds to the maximum load timing can be realized by identification of the X-ray image **70** that corresponds to the maximum load timing based on the optical images **80**.

[0053] Also, in the first embodiment, the X-ray imaging system **100** includes the optical image capturer **30** for capturing the optical images **80** of the subject **101** during the loaded action. The optical image capturer **30** is arranged in the collimator **12**, which is at least one of the support **41** supporting the X-ray irradiator **10** and the collimator **12** for specifying an irradiation field of the X-rays with which the subject is irradiated by the X-ray irradiator **10**. According to this configuration, since the optical image capturer **30** is arranged in the collimator **12**, which is at least one of the support **41** supporting the X-ray irradiator **10** and the collimator **12**, a direction in which the X-rays are emitted for irradiation by the X-ray irradiator **10** can agree with a direction in which the optical images **80** are captured by the optical image capturer **30**. Consequently, further easier identification of the X-ray image **70** that corresponds to the maximum load timing can be realized by visual comparison of the optical images **80** with the X-ray images **70**.

[0054] Also, in the first embodiment, the X-ray imaging system **100** includes the optical image capturer **30** for capturing the optical images **80** of the subject **101** during the loaded action. The controller **50** displays the X-ray image **70** that corresponds to the maximum load timing in association with the optical image **80** captured by the optical image capturer **30**. According to this configuration, since the X-ray image **70** that corresponds to the maximum load timing is displayed in association with the optical image **80** captured, easy recognition whether the X-ray image **70** that is associated with the optical image **80** is the X-ray image **70** that corresponds to the maximum load timing can be realized by visual recognition of the optical image **80**. Consequently, further easier identification of the X-ray image **70** that corresponds to the maximum load timing can be realized.

[0055] Also, in the first embodiment, the controller **50** displays the X-ray image **70** that corresponds to the maximum load timing and the optical image **80** that corresponds to the maximum load timing in alignment with each other on the display **60**. According to this configuration, since the X-ray image **70** and the optical image **80** displayed in alignment with each other on the display **60** can be easily compared with each other, further easier identification of the X-ray image **70** that corresponds to the maximum load timing can be realized by visual recognition of the optical image **80** that corresponds to the maximum load timing.

[0056] Also, in the first embodiment, the controller **50** controls the display **60** to identifiably display the X-ray image **70** that corresponds to the maximum load timing from a plurality of X-ray images **70** acquired by successively irradiating the subject **101** who is in the loaded action with the X-rays. According to this configuration, the visually recognition of the plurality of X-ray images **70** acquired by successively irradiating the subject with X-rays allows confirmation of movements of the joint and bones of the subject **101**, which change with the loaded action, and allows easy identification of the X-ray image **70** that corresponds to the maximum load timing in the loaded action.

[0057] Also, in the first embodiment, the controller controls **50** the display to identifiably display the X-ray image **70** that corresponds to the maximum load timing from the plurality of X-ray images **70** by displaying the plurality of X-ray images **70** that include the X-ray image **70** that corresponds to the maximum load timing and the optical images **80** acquired in timings that are synchronized with detection of the X-rays using the X-ray detector **20** in alignment with each other on the display **60**. According to this configuration, since the plurality of X-ray images **70** acquired by successively irradiating the subject with X-rays and the optical images **80** acquired in timings that are synchronized with the plurality of X-ray images are displayed in alignment with each other, identification of the X-ray image **70** that corresponds to the maximum load timing from the plurality of X-ray images **70** can be easily made by determination of the captured optical images **80** of the exterior of the subject **101**.

Second Embodiment

[0058] The following description describes a configuration of an X-ray imaging system **200** according to a second embodiment with reference to FIGS. **6** to **10**. Dissimilar to the first embodiment in which a physician identifies the X-ray image **70** that corresponds to the maximum load timing based on the optical images **80** displayed, the X-ray image **70** that corresponds to the maximum load timing is automatically identified by control processing by using a controller **250** in this second embodiment. The same configurations in the Figures as those of the first embodiment are illustrated with the same reference numerals, and their description is omitted.

Configuration of X-Ray Imaging System of Second Embodiment

[0059] As shown in FIG. **6**, the X-ray imaging system **200** according to the second embodiment includes the X-ray irradiator **10**, the X-ray detector **20**, the optical image capturer **30**, the moving mechanism **40**, the controller **250**, and the display **60**. Similar to the controller **50** according to the first embodiment, the controller **250** performs control of X-ray imaging using the X-ray irradiator **10** and the X-ray detector **20**, and control relating to capture of optical images **80** using the optical image capturer **30**. Here, the controller **250** has a hardware configuration similar to the controller **50** according to the first embodiment.

[0060] In the second embodiment, the controller **250** acquires the maximum load timing based on the optical images **80** acquired by the optical image capturer **30**. Specifically, the controller **250** acquires the maximum load timing on a basis of a position of another of the legs of the subject **101** in a height direction based on the optical images **80** acquired as the load information. The controller **250** controls the display **60** to identifiably display the X-ray image **70** that corresponds to the maximum load timing based on the maximum load timing acquired.

[0061] In the second embodiment, as shown in FIG. **7**, prior to X-ray imaging, the controller **250** acquires the optical images **80** of the subject **101** in walking action. For example, prior to X-ray imaging, the controller **250** acquires the optical images **80** as video by capturing images of the subject **101** who repeats the walking action by using the optical image capturer **30**. The controller **250** acquires the optical image **80**, which are acquired as video, as a plurality of optical images **80** each of which is a still image for each frame, and also acquires the position of the another of the legs in the height direction in each of the plurality of optical images **80**.

[0062] The controller **250** acquires the position of a left leg as the another of the legs in the height direction in a case in which X-ray images **70** of the knee joint of a right leg as the one of the legs are acquired. The controller **250** acquires the position of the left leg in a vertical direction as the height direction by applying image processing, such as pattern matching, to each of the plurality of optical images **80** acquired. The controller **250** detects, for example, a distance D1, which is a difference between the position of a toe of the right leg and a toe of the left leg in an upward/downward direction of each optical image **80**, as the position of the left leg in the height direction.

[0063] As shown in FIG. **8**, a value of the distance D1 periodically rises and drops in the walking action. A timing in which the distance D1 becomes the largest in one cycle of walking action is the maximum load timing in which the largest load is applied to the right leg as the one of the legs in the one cycle of walking action. The controller **250** acquires the optical images **80** as video for a plurality of cycles of walking action prior to X-ray imaging. The controller **250** acquires changes of the distance D1 in the walking action of the subject **101** for the plurality of cycles by applying processing for detecting the distance D1 to each of the plurality of optical images **80** acquired as still images for each frame of the video.

[0064] As shown in FIG. **9**, in the second embodiment, the controller **250** is configured to acquire the maximum load timing based on the value of distance D1 and a determination threshold in the X-ray imaging, and to direct the X-ray irradiator **10** to irradiate the subject with X-rays in the maximum load timing acquired. The controller **250** sets the determination threshold, which is used to determine the maximum load timing, based on periodic values of the distance D1 in the walking action of the subject **101** acquired for the plurality of cycles prior to X-ray imaging. For example, the determination threshold can be acquired based on the maximum value of the distance D1 acquired in the plurality of cycles prior to X-ray imaging. A value that is obtained by multiplying an average of the maximum values of the distance D1 in each of the plurality of cycles by a predetermined ratio can be set as the determination threshold, for example. Here, the determination threshold may be a predetermined value that is previously set.

[0065] In the X-ray imaging, the controller **250** acquires the optical images **80** captured by the optical image capturer **30** as real-time video, and acquires a timing in which a magnitude of the distance D1 detected in the acquired optical image **80** exceeds the set determination threshold as the maximum load timing. The controller **250** is configured to direct the X-ray irradiator **10** to irradiate the subject with X-rays in a timing in which the value of the distance D1 detected in the optical image **80** acquired in real time during the loaded action exceeds the determination threshold in the X-ray imaging. Accordingly, in the second embodiment, the X-ray image **70** that corresponds to the maximum load timing is captured by controlling timing of X-ray irradiation based on the optical images **80**.

[0066] As shown in FIG. **10**, the controller **250** displays one X-ray image **70** that is generated by detecting the X-rays with which the subject is irradiated in the maximum load timing on the display **60** as the X-ray image **70** that corresponds to the maximum load timing. That is, dissimilar to the first embodiment in which one X-ray image **70** that corresponds to the maximum load timing is identifiably displayed by displaying the plurality of X-ray images **70**, the X-ray image **70** that corresponds to the maximum load timing is identifiably displayed by displaying only one X-ray image **70** that corresponds to the maximum load timing on the display **60** in the second embodiment. Other configurations of the second embodiment are the same as the first embodiment above.

X-Ray Image Display Method of Second Embodiment

[0067] Control processing of an X-ray image display method using the X-ray imaging system **200** according to the second embodiment is now described with reference to FIG. **11**. The control processing of the X-ray image display method including steps **501** to **507** is performed by the controller **250**.

[0068] In step **501**, the determination threshold is first set. For example, the distance D1, which is the difference between the position of the toe of the right leg and the position of the toe of the left leg in the upward/downward direction of the optical image **80**, is acquired based on the optical image **80** acquired in the walking action for the plurality of cycles as a value representing the position of the another (left leg) of the legs of the subject **101** in the height direction. Subsequently, the determination threshold is set to determine the maximum load timing in one cycle based on periodic change of the value of the distance D1.

[0069] Subsequently, the optical image **80** is acquired for X-ray imaging in step **502**. In order to irradiate the subject with X-rays in the maximum load timing, the optical images **80** of the subject **101** during the walking action are acquired as video. The optical images **80** are successively acquired in timings corresponding to a predetermined frame rate to form video with the predetermined frame rate.

[0070] In step **503**, the distance D1 is acquired based on the optical image **80** acquired in step **502**, and it is determined whether the acquired distance D1 is greater than the determination threshold, which is set in step **501**. If it is determined that the distance D1 is greater than the determination threshold, the procedure goes to step **504**. If it is determined that the distance D1 is not greater than the determination threshold, the procedure goes back to step **502** so that the optical image **80** of a new frame is acquired. Here, the control process in step **503** is executed every when the optical image **80**, which is a still image as one frame of video, is acquired for each predetermined frame rate in step **502**.

[0071] In step **504**, the subject is irradiated with X-rays. In other words, it is determined that the maximum load timing is detected if the value of the detected distance D1 in the acquired optical image **80** is greater than the predetermined determination threshold. Correspondingly, the subject is irradiated with the X-rays in the maximum load timing.

[0072] Subsequently, in step **505**, the X-rays with which the subject is irradiated in the maximum load timing are detected. Subsequently, in step **506**, the X-ray image **70** that corresponds to the maximum load timing is generated based on the X-rays detected. Subsequently, in step **507**, the X-ray image **70** that corresponds to the generated maximum load timing is identifiably displayed on the display **60**. In step **507**, the X-ray image **70** that corresponds to the maximum load timing is identifiably displayed on the display **60** by displaying only one X-ray image **70** that corresponds to the maximum load timing, for example.

Advantages of Second Embodiment

[0073] In the second embodiment, the following advantages are obtained.

[0074] In the second embodiment, the controller **250** acquires the maximum load timing based on the optical images **80** (load information) acquired by the optical image capturer **30** (load information acquirer). Also, the controller **250** controls the display **60** to identifiably display the X-ray image **70** that corresponds to the maximum load timing based on the maximum load timing acquired. According to this configuration, since the maximum load timing is automatically acquired by the controller **250**, the X-ray image **70** that corresponds to the maximum load timing can be automatically identified by control processing by using the controller **250**. Consequently, it is possible to reduce time and effort to identify the X-ray image **70** that corresponds to the maximum load timing.

[0075] Also, in the second embodiment, the X-ray imaging system **200** includes the optical image capturer **30** for capturing the optical images **80** of the subject **101** during the loaded action. The controller acquires **250** the maximum load timing on a basis of a position of another of the legs of

the subject **101** in a height direction, which is at least one of the position of the another of the legs of the subject **101** in the height direction and an inclination of a body axis of the subject **101**, based on the optical images **80** acquired as the load information. According to this configuration, the maximum load timing can be easily automatically acquired by determining the positions of the another of the legs of the subject **101** in the height direction in the optical images **80**. Consequently, it is possible to reduce a processing load on the control processing for acquiring the maximum load timing.
[0076] Also, in the second embodiment, the controller **250** is configured to direct the X-ray irradiator **10** to irradiate the subject with X-rays in the maximum load timing acquired. According to this configuration, it is possible to prevent a dose of the X-rays with which the subject **101** is irradiated from increasing as compared with a case in which the plurality of X-ray images **70** are acquired by successively irradiating the subject with the X-rays, while it is possible to easily acquire the X-ray image **70** that corresponds to the maximum load timing.
[0077] The other advantages of the second embodiment are similar to the first embodiment.
Third Embodiment
[0078] The following description describes a configuration of an X-ray imaging system **300** according to a third embodiment with reference to FIGS. **12** and **13**. Dissimilar to the first and second embodiments in which the optical image capturer **30** for capturing the optical images **80** is included, a pressure sensor **330** is included in the third embodiment. The same configurations in the Figures as those of the first and second embodiments are illustrated with the same reference numerals, and their description is omitted. The pressure sensor **330** is an example of the “load information acquirer” in the claims.
Configuration of X-Ray Imaging System of Third Embodiment
[0079] As shown in FIG. **12**, the X-ray imaging system **300** according to the third embodiment includes the X-ray irradiator **10**, the X-ray detector **20**, the pressure sensor **330**, the moving mechanism **40**, the controller **350**, and the display **60**. Similar to the controller **50** according to the first embodiment and the controller **250** according to the second embodiment, the controller **350** performs control of X-ray imaging using the X-ray irradiator **10** and the X-ray detector **20**. In the third embodiment, the controller **350** controls detection of pressure using the pressure sensor **330** and analysis processing based on detection results using the pressure sensor **330**. The controller **350** has a hardware configuration similar to the first and second embodiments.
[0080] The pressure sensor **330** detects pressures applied by the leg of the subject **101** during the walking movement as loaded action. The pressure sensor **330** is a sheet-shaped sensor arranged on a floor of the imaging room **110** to be stepped on by the subject **101** who is in the walking action. The pressure sensor **330** includes, for example, a strain gauge or a capacitive sensor. The pressure sensor **330** detects the pressure applied through the feet by the legs of the subject **101** during the walking action when the subject **101** steps on the pressure sensor, and outputs a signal representing the detection result to the controller **350**. That is, the pressure sensor **330** acquires the detection result of the pressure applied by the leg as load information to identify a state of the load applied to the leg in the waling action as loaded action of the subject **101** separately from the detection of the X-rays using the X-ray detector **20**.
[0081] As shown in FIG. **13**, in the third embodiment, the controller **350** acquires the detection result acquired as load information by the pressure sensor **330**. Subsequently, the controller **350** acquires the maximum load timing by detecting a magnitude of the pressure that is applied by the one of the legs based on the acquired detection result. Also, the controller **350** is configured to direct the X-ray irradiator **10** to irradiate the subject with X-rays in the maximum load timing acquired.
[0082] Similar to the second embodiment, the controller **350** sets a determination threshold for detecting the maximum load timing prior to X-ray imaging. Subsequently, the controller **350** determines a timing in which the magnitude of the pressure that is applied by the one of the legs is

greater than the set determination threshold based on the detection result acquired from the pressure sensor **330** as the maximum load timing, and acquires the X-ray image **70** that corresponds to the maximum load timing by irradiating the subject with X-ray in a timing in which determining the maximum load timing.

[0083] Specifically, similar to the second embodiment, the controller **350** acquires periodic values of the magnitude of the pressure that is applied by the one of the legs based on the detection result from the pressure sensor **330** for a plurality of cycles in the walking action prior to X-ray imaging. In the walking action, the magnitude of pressure applied by the one of the legs periodically varies, and becomes the maximum value in the maximum load timing. Similar to the distance D1 in the second embodiment, the controller **350** sets the determination threshold for determining the maximum load timing based on periodic variation of the magnitude of the pressure that is applied by the one of the legs acquired prior to X-ray imaging. Subsequently, similar to the second embodiment, in a case of X-ray imaging, the controller **350** successively acquires the detection results from the pressure sensor **330**, and determines whether the magnitude of the pressure that is applied by the one of the legs is greater than the set determination threshold every when acquiring each detection result. The controller **350** determines that the maximum load timing is detected in a timing in which the magnitude of the pressure that is applied by the one of the legs is greater than the set determination threshold, and performs control processing for X-ray imaging using the X-ray irradiator **10** and the X-ray detector **20**. Subsequently, similar to the second embodiment, the controller **350** controls the display **60** to display the X-ray image **70** that corresponds to the maximum load timing acquired based on the detection result of the pressure sensor **330**. The other configuration of the third embodiment is similar to the second embodiment.

Advantages of Third Embodiment

[0084] In the third embodiment, the following advantages are obtained.

[0085] In the third embodiment, the X-ray imaging system **300** includes the pressure sensor **330** for detecting a pressure applied by the leg of the subject **101** during loaded action. According to this configuration, it is possible to easily and directly identify a state of a load applied to the leg in the loaded action based on a detection result using the pressure sensor **330**. Accordingly, it is possible to more easily identify the X-ray image **70** that corresponds to the maximum load timing in which the largest load is applied to the one of the legs based on the detection result using the pressure sensor **330**.

[0086] Also, in the third embodiment, the X-ray imaging system **300** includes the pressure sensor **330** for detecting the pressure applied by the leg of the subject **101** during the loaded action. The controller **350** acquires the maximum load timing on a basis of a magnitude of the pressure that is applied by the one of the legs, which is at least one of the magnitude of the pressure that is applied by the one of the legs, and a comparison between the pressure that is applied by the one of the legs and the pressure that is applied by the another of the legs, based on the detection results using the pressure sensor **330** acquired as the load information. According to this configuration, the maximum load timing can be easily automatically acquired by determining the magnitude of the pressure that is applied by the one of the legs. Consequently, it is possible to reduce a processing load on the control processing for acquiring the maximum load timing.

[0087] The other advantages of the third embodiment are similar to the first and second embodiments.

Modified Embodiments

[0088] Note that the embodiment disclosed this time must be considered as illustrative in all points and not restrictive. The scope of the present invention is not shown by the above description of the embodiments but by the scope of claims for patent, and all modifications (modified examples) within the meaning and scope equivalent to the scope of claims for patent are further included.

[0089] For example, while the example in which a subject **101** who is in walking action as loaded action in which a load is applied to legs of the subject is irradiated with X-rays has been shown in the aforementioned first to third embodiments, the present invention is not limited to this. In the present invention, the subject may exercise stepping up/down action in which he or she steps up and down stairs, or bending/stretching action in a standing posture.

[0090] While the example in which the X-ray image **70** which is captured by capturing an image of a knee joint and that corresponds to the maximum load timing is identifiably displayed has been shown in the aforementioned first to third embodiments, the present invention is not limited to this. In the present invention, an X-ray image which is captured by capturing an image of at least one of an ankle joint, the knee joint and a hip joint and that corresponds to the maximum load timing may be identifiably displayed on the display. Also, the X-ray image to be identifiably displayed is not limited to an X-ray image of the joint of the leg, but an X-ray image that includes a pelvis or spine and corresponds to the maximum load timing may be identifiably displayed.

[0091] While the example in which the X-ray images **70**, which are captured by capturing an image of the knee joint, and the optical images **80** including parts from knee joints to toes are acquired has been shown in the aforementioned first and second embodiments, the present invention is not limited to this. In the present invention, the X-ray image and the optical image may have the same captured area as each other or different areas from each other. For example, in a case in which an X-ray image of the knee joint is captured, an optical image of the entire body of the subject may be acquired.

[0092] While the example in which the optical image capturer **30** is arranged to acquire the optical images **80** as load information to identify a state of the load applied to the leg has been shown in the aforementioned first and second embodiments, and the example in which the pressure sensor **330** is arranged to acquire a detection result of a pressure applied by the leg as load information to identify a state of the load applied to the leg has been shown in the aforementioned third embodiment, the present invention is not limited to this. In the present invention, another detection sensor for detecting action of the subject may be arranged as the load information acquirer. For example, a gyro sensor to be worn on the body of the subject may be included as the load information acquirer. Also, a non-contact capacitive sensor, magnetic sensor, or photoelectric sensor may be provided to identify the state of loaded action of the subject. Also, a plurality of types of sensors may also be combined to acquire the load information. For example, the load information may be acquired by combining the optical image capturer with the pressure sensor. That is, a plurality of types of load information may be displayed together with the X-ray image, or a single type of load information may be acquired by averaging results acquired based on the plurality of types of load information.

[0093] While the example in which the optical image capturer **30** is arranged in the collimator **12** for specifying an irradiation field of the X-ray irradiator **10** has been shown in the aforementioned first and second embodiments, the present invention is not limited to this. In the present invention, the optical image capturer may be arranged on the support supporting the X-ray irradiator. Also, the optical image capturer may be arranged at a position spaced away from the X-ray irradiator, such as on a wall or a ceiling surface of the imaging room. For example, the optical image capturer may be arranged on an X-ray detector side. Also, the optical image capturer may capture images of a part of the subject different from a part of the subject that is an imaging target of the X-ray imaging.

[0094] While the example in which the X-ray image **70** is displayed in association with the optical image **80** by displaying the X-ray image **70** in alignment with the optical image **80** has been shown in the aforementioned first embodiment, the present invention is not limited to this. In the present invention, the X-ray image that corresponds to an optical image selected may be displayed when an operation for selecting the optical image is accepted.

[0095] While the example in which the frame rate of the X-ray images **70** and the frame rate of the optical images **80** are synchronized with each other to bring agreement of the timings in which the X-ray images **70** as video are captured with the timings in which the optical images **80** as video are captured has been shown in the aforementioned first embodiment, the present invention is not limited to this. In the present invention, the frame rate of the X-ray images may be different from the frame rate of the optical images. Also, in a case in which the frame rate of the X-ray images agrees with the frame rate of the optical images, a timing in which each X-ray image is captured may disagree with a timing in which each optical image is captured. Similar to this, in a case in which the load information acquirer is another load information acquirer different from the optical image capturer, a rate of acquisition of load information may agree or disagree with the frame rate of X-ray images.

[0096] While the example in which the maximum load timing is acquired on a basis of a position of another of the legs of the subject **101** in a height direction has been shown in the aforementioned second embodiment, the present invention is not limited to this. In the present invention, the maximum load timing may be acquired on a basis of an inclination of a body axis of the subject. Also, in a case in which the position of another of the legs of the subject in the height direction is detected, the position of the another of the legs of the subject in the height may be detected by detecting a position of a floor surface in each optical image. Also, the maximum load timing in loaded action may be detected by detecting movement of a part other than the legs, such as swinging of arms based on each optical image.

[0097] While the example in which the maximum load timing is acquired by detecting a magnitude of a pressure applied by the one of the legs based on detection results acquired as load information by the pressure sensor **330** has been shown in the aforementioned third embodiment, the present invention is not limited to this. In the present invention, the maximum load timing may be acquired on a basis of a comparison between the pressure that is applied by the one of the legs and the pressure that is applied by the another of the legs based on detection results using the pressure sensor acquired as the load information. For example, a difference or a ratio between the pressure applied by the one of the legs and the pressure applied by the another of the legs may be acquired. Also, the maximum load timing may be acquired by combining the magnitude of the pressure that is applied by the one of the legs with the comparison between the pressure that is applied by the one of the legs and the pressure that is applied by the another of the legs. The maximum load timing of the one of the legs may be acquired based on the pressure applied by the another of the legs.

[0098] While the example in which the maximum load timing is acquired, and one X-ray image **70** that corresponds to the maximum load timing is displayed by irradiating the subject with X-ray by the X-ray irradiator **10** in the maximum load timing acquired has been shown in the aforementioned second and third embodiments, the present invention is not limited to this. In the present invention, alternatively, a plurality of X-ray images may be generated and displayed with the X-ray image that corresponds to the maximum load timing being identifiably displayed. For example, when the plurality of X-ray images is displayed in alignment with each other, the X-ray image that is determined as one corresponding to the maximum load timing may be identifiably displayed by highlighting the X-ray images determined, such as by enclosing the X-ray images determined with a frame line. In this alternative case, if the maximum load timing acquired disagrees with each of timings at which the plurality of X-ray images are captured, the X-ray image that is captured in a timing that is closer to the maximum load timing may be acquired as the X-ray image that corresponds to the maximum load timing. Also, the plurality of X-ray images and a plurality items of load information (a plurality of optical images or detection results of the pressure sensor) may be displayed, and the X-ray image that corresponds to the maximum load timing may be identifiably displayed by highlighting the item of load information that corresponds to the maximum load timing in the plurality items of load information. Also, in a case in which the maximum load timing is not acquired, instead of the optical images, numerical values indicating the detection results (load information) acquired by the load information acquirer other than the optical image capturer, such as the pressure sensor, may be displayed in association with (in alignment with) the X-ray images. Also, in a case in which the optical image capturer is arranged as the load information acquirer, instead of the optical images, detection values such as positions of the leg acquired based on the optical images may be displayed in association with the X-ray images.

[0099] While the example in which the maximum load timing is determined based on a set determination threshold has been shown in the aforementioned second and third embodiments, the present invention is not limited to this. In the present invention, the maximum load timing may be acquired without setting the determination threshold. For example, the maximum load timing may be predicted and acquired by acquiring load information, such as optical images, from a subject who repeatedly exercises loaded action in predetermined cycles, and by acquiring the cycle to be taken for a single complete loaded action.

[0100] While the example in which the controllers **50**, **250**, and **350** control X-ray imaging, generation of X-ray images, capture of optical images and acquisition of pressure sensor detection results (acquisition of load information), and acquisition of the maximum load timing based on the load information has been shown in the aforementioned first to third embodiments, the present invention is not limited to this. In the present invention, one or some of the X-ray imaging, the generation of X-ray images, the acquisition of load information, and the acquisition of the maximum load timing may be controlled by control apparatuses different from each other or by a combination of a plurality of control apparatuses. Also, the control apparatus that makes up the controller may include one or some of a personal computer, a processor, a circuit and an integrated circuit.

[0101] While the example in which X-ray imaging of the subject **101** who is in the loaded action is performed by the X-ray fluoroscopy system for rotating the X-ray irradiator **10** together with the bed **21** in which the X-ray detector **20** is arranged has been shown in the aforementioned first to third embodiments, the present invention is not limited to this. In the present invention, the X-ray irradiator and the X-ray detector may be spaced away from each other. For example, X-ray imaging of the subject who is in the loaded action may be performed by a typical ceiling-suspended type X-ray imaging apparatus including an X-ray irradiator supported by a support arranged on a ceiling. Also, X-ray imaging of the subject who is in the loaded action may be performed by a movable X-ray imaging apparatus for hospital rounds or an X-ray fluoroscopy including a C-arm.

[Modes]

[0102] It is understood by those skilled in the art that the exemplary embodiments described above are specific examples of the following aspects.

(Mode Item 1)

[0103] An X-ray imaging system according to mode item 1 includes an X-ray irradiator for irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; an X-ray detector for detecting the X-rays with which the subject is irradiated by the X-ray irradiator and that pass through the subject; a load information acquirer for acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays using the X-ray detector; a display for displaying an X-ray image(s) generated based on the detection of the X-rays using the X-ray detector; and a controller for executing control for identifiably displaying at least the X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of the legs in the loaded action of the subject on the display based on the load information acquired by the load information acquirer.

(Mode Item 2)

[0104] In the X-ray imaging system according to mode item 1, the controller executes control for identifiably displaying the X-ray image which is captured by capturing an image of at least one of an ankle joint, a knee joint and a hip joint in the one of the legs and that corresponds to the maximum load timing on the display based on the load information acquired by the load information acquirer.

(Mode Item 3)
[0105] In the X-ray imaging system according to mode item 1 or 2, the load information acquirer includes at least one of an optical image capturer for capturing optical images of the subject during the loaded action and a pressure sensor for detecting pressures applied by the leg or the legs of the subject during the loaded action.
(Mode Item 4)
[0106] In the X-ray imaging system according to mode item 3, the load information acquirer includes the optical image capturer for capturing the optical images of the subject during the loaded action; and the optical image capturer is arranged in at least one of a support supporting the X-ray irradiator and a collimator for specifying an irradiation field of the X-rays with which the subject is irradiated by the X-ray irradiator.
(Mode Item 5)
[0107] In the X-ray imaging system according to mode item 3 or 4, the load information acquirer includes the optical image capturer for capturing the optical images of the subject during the loaded action; and the controller displays the X-ray image that corresponds to the maximum load timing in association with the optical image captured by the optical image capturer.
(Mode Item 6)
[0108] In the X-ray imaging system according to mode item 5, the controller displays the X-ray image that corresponds to the maximum load timing and the optical image that corresponds to the maximum load timing in alignment with each other on the display.
(Mode Item 7)
[0109] In the X-ray imaging system according to any of mode items 1 to 6, the controller executes control for identifiably displaying the X-ray image that corresponds to the maximum load timing on the display from a plurality of X-ray images acquired by successively irradiating the subject who is in the loaded action with the X-rays.
(Mode Item 8)
[0110] In the X-ray imaging system according to mode item 7, the controller executes control for identifiably displaying the X-ray image that corresponds to the maximum load timing on the display from the plurality of X-ray images by displaying the plurality of X-ray images that include the X-ray image that corresponds to the maximum load timing and the load information acquired in a timing that is synchronized with detection of the X-rays using the X-ray detector in alignment with each other on the display.
(Mode Item 9)
[0111] In the X-ray imaging system according to any of mode items 1 to 8, the controller executes control for acquiring the maximum load timing based on the load information acquired by the load information acquirer, and control for identifiably displaying the X-ray image that corresponds to the maximum load timing based on the maximum load timing acquired on the display.
(Mode Item 10)
[0112] In the X-ray imaging system according to mode item 9, the load information acquirer includes an optical image capturer for capturing optical images of the subject during the loaded action; and the controller acquires the maximum load timing on a basis of at least one of a position of another of the legs of the subject in a height direction and an inclination of a body axis of the subject based on the optical images acquired as the load information.
(Mode Item 11)
[0113] In the X-ray imaging system according to mode item 9, the load information acquirer includes a pressure sensor for detecting a pressure applied by the leg or the legs of the subject during the loaded action; and the controller acquires the maximum load timing on a basis of at least one of a magnitude of the pressure that is applied by the one of the legs, and a comparison between the pressure that is applied by the one of the legs and the pressure that is applied by another of the legs based on detection results using the pressure sensor acquired as the load information.

(Mode Item 12)
[0114] In the X-ray imaging system according to any of mode items 9 to 11, the controller is configured to direct the X-ray irradiator to irradiate the subject with the X-rays in the maximum load timing acquired.
(Mode Item 13)
[0115] An X-ray image display method according to mode item 13 includes a step of irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; a step of detecting the X-rays that pass through the subject; a step of acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays; and a step of displaying an X-ray image(s) generated based on the detection of the X-rays, wherein the step of displaying the X-ray image(s) includes a step of identifiably displaying at least the X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of the legs in the loaded action of the subject based on the load information acquired.

Claims

1. An X-ray imaging system comprising: an X-ray irradiator for irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; an X-ray detector for detecting the X-rays with which the subject is irradiated by the X-ray irradiator and that pass through the subject; a load information acquirer for acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays using the X-ray detector; a display for displaying an X-ray image(s) generated based on the detection of the X-rays using the X-ray detector; and a controller for executing control for identifiably displaying at least the X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of the legs in the loaded action of the subject on the display based on the load information acquired by the load information acquirer.
2. The X-ray imaging system according to claim 1, wherein the controller executes control for identifiably displaying the X-ray image which is captured by capturing an image of at least one of an ankle joint, a knee joint, and a hip joint in the one of the legs and that corresponds to the maximum load timing on the display based on the load information acquired by the load information acquirer.
3. The X-ray imaging system according to claim 1, wherein the load information acquirer includes at least one of an optical image capturer for capturing optical images of the subject during the loaded action and a pressure sensor for detecting pressures applied by the leg or the legs of the subject during the loaded action.
4. The X-ray imaging system according to claim 3, wherein the load information acquirer includes the optical image capturer for capturing the optical images of the subject during the loaded action; and the optical image capturer is arranged in at least one of a support supporting the X-ray irradiator and a collimator for specifying an irradiation field of the X-rays with which the subject is irradiated by the X-ray irradiator.
5. The X-ray imaging system according to claim 3, wherein the load information acquirer includes the optical image capturer for capturing the optical images of the subject during the loaded action; and the controller displays the X-ray image that corresponds to the maximum load timing in association with the optical image captured by the optical image capturer.
6. The X-ray imaging system according to claim 5, wherein the controller displays the X-ray image that corresponds to the maximum load timing and the optical image that corresponds to the maximum load timing in alignment with each other on the display.
7. The X-ray imaging system according to claim 1, wherein the controller executes control for identifiably displaying the X-ray image that corresponds to the maximum load timing on the

display from a plurality of X-ray images acquired by successively irradiating the subject who is in the loaded action with the X-rays.

8. The X-ray imaging system according to claim 7, wherein the controller executes control for identifiably displaying the X-ray image that corresponds to the maximum load timing on the display from the plurality of X-ray images by displaying the plurality of X-ray images that include the X-ray image that corresponds to the maximum load timing and the load information acquired in a timing that is synchronized with detection of the X-rays using the X-ray detector in alignment with each other on the display.

9. The X-ray imaging system according to claim 1, wherein the controller executes control for acquiring the maximum load timing based on the load information acquired by the load information acquirer, and control for identifiably displaying the X-ray image that corresponds to the maximum load timing based on the maximum load timing acquired on the display.

10. The X-ray imaging system according to claim 9, wherein the load information acquirer includes an optical image capturer for capturing optical images of the subject during the loaded action; and the controller acquires the maximum load timing on a basis of at least one of a position of another of the legs of the subject in a height direction and an inclination of a body axis of the subject based on the optical images acquired as the load information.

11. The X-ray imaging system according to claim 9, wherein the load information acquirer includes a pressure sensor for detecting a pressure applied by the leg or the legs of the subject during the loaded action; and the controller acquires the maximum load timing on a basis of at least one of a magnitude of the pressure that is applied by the one of the legs, and a comparison between the pressure that is applied by the one of the legs and the pressure that is applied by another of the legs based on detection results using the pressure sensor acquired as the load information.

12. The X-ray imaging system according to claim 9, wherein the controller is configured to direct the X-ray irradiator to irradiate the subject with the X-rays in the maximum load timing acquired.

13. An X-ray image display method comprising: a step of irradiating a subject who is in loaded action in which a load is applied to legs of the subject with X-rays; a step of detecting the X-rays that pass through the subject; a step of acquiring load information to identify a state of the load applied to the leg or the legs in the loaded action of the subject separately from the detection of the X-rays; and a step of displaying an X-ray image(s) generated based on the detection of the X-rays, wherein the step of displaying the X-ray image(s) includes a step of identifiably displaying at least the X-ray image that corresponds to a maximum load timing in which a largest load is applied to one of the legs in the loaded action of the subject based on the load information acquired.