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IMAGE GENERATION DEVICE, IMAGE GENERATION METHOD, AND STORAGE MEDIUM

Abstract

An image generation device obtains a plurality of first three-dimensional (3D) models, of corresponding ones of a plurality of subjects, generated through a first method on the basis of shooting a predetermined region in which the plurality of subjects are present, and a second 3D model that is based on posture information of a specific subject, among the plurality of subjects, present in the predetermined region during the shooting, the second 3D model corresponding to the specific subject and being generated through a second method different from the first method, and outputs a virtual viewpoint image generated on the basis of the first 3D model of a subject, among the plurality of subjects, that is different from the specific subject, and the second 3D model corresponding to the specific subject.

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Background/Summary

BACKGROUND

Field of the Disclosure

[0001] The present disclosure relates to a technique for generating a virtual viewpoint image using a plurality of cameras.

Description of the Related Art

[0002] A technology called “volumetric capture”, in which a three-dimensional (3D) model of a subject can be generated from an image shot using a plurality of image capturing devices, is attracting attention. The generated 3D model of the subject is arranged in a virtual space the reproduces (or imitates) the shooting environment of the subject, and is observed using a virtual camera that can be operated in the virtual space. By using the virtual camera, in which a viewpoint position, gaze direction, and the like can be set freely in the virtual space, an image can be observed as if the subject had been shot by a physical camera in a real shooting environment. An image observed through a virtual camera is called a “virtual viewpoint image”. The virtual viewpoint image is obtained by specifying a desired viewpoint and angle of view in the virtual space, and it is therefore possible to reproduce an image which would be difficult to actually shoot using a physical camera. A technique called “motion capture” is also used as a shooting method for generating a 3D model. With this technique, a 3D model is generated by obtaining skeleton information of a subject that has been shot and adding a predetermined computer graphic (CG) model to the skeleton information.

[0003] Japanese Patent Laid-Open No. 2022-060058 discloses a technique for generating a single virtual viewpoint image by combining 3D models generated using a common volumetric capture method in a plurality of different spaces that are physically separate, such as a stadium and a studio. For example, a part of the 3D model obtained by shooting in one of the spaces is arranged in another space, and a virtual viewpoint image in that space is generated. However, with this technique, shooting is performed in a plurality of spaces that are different from each other, and it is therefore not possible to sufficiently link the positional relationships, movements, and the like of the subjects present in each of the plurality of spaces. Accordingly, when a plurality of 3D models are generated in different spaces and a single virtual viewpoint image is generated by combining those 3D models, the generated virtual viewpoint image may produce a sense of unnaturalness.

SUMMARY

[0004] The present disclosure provides a technique for generating a desired virtual viewpoint image while linking subjects sufficiently.

[0005] An image generation device according to one aspect of the present disclosure includes: one or more processors; and one or more memories that store a computer-readable instruction for causing, when executed by the one or more processors, the one or more processors to: obtain (i) a plurality of first three-dimensional (3D) models, of corresponding ones of a plurality of subjects, generated through a first method on the basis of shooting a predetermined region in which the plurality of subjects are present, and (ii) a second 3D model that is based on posture information of a specific subject, among the plurality of subjects, present in the predetermined region during the shooting, the second 3D model corresponding to the specific subject and being generated through a

second method different from the first method; and output a virtual viewpoint image generated on the basis of (i) the first 3D model of a subject, among the plurality of subjects, that is different from the specific subject, and (ii) the second 3D model corresponding to the specific subject.
[0006] Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a diagram illustrating an example of the configuration of an image forming system.

[0008] FIG. 2 is a diagram illustrating an example of the arrangement of cameras and sensors.

[0009] FIG. 3 is a diagram illustrating an example of the hardware configuration of a rendering device.

[0010] FIG. 4 is a diagram illustrating an example of the functional configuration of each of apparatuses in the system.

[0011] FIG. 5 is a diagram illustrating an example of data to be recorded.

[0012] FIG. 6 is a diagram illustrating an example of a bounding box.

[0013] FIG. 7 is a diagram illustrating an example of the flow of processing for generating a virtual viewpoint image.

[0014] FIG. 8 is a diagram illustrating an example of a virtual viewpoint image that is output.

[0015] FIG. 9 is a diagram illustrating another example of the functional configuration of each of apparatuses in the system.

[0016] FIG. 10 is a diagram illustrating another example of data to be recorded.

[0017] FIG. 11 is a diagram illustrating an example of the flow of processing in tracking control.

[0018] FIG. 12 is a diagram illustrating another example of the flow of processing for generating a virtual viewpoint image.

[0019] FIGS. 13A to 13C are diagrams illustrating an example of a virtual viewpoint image that is output.

DESCRIPTION OF THE EMBODIMENTS

[0020] Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention. Multiple features are described in the embodiments, but limitation is not made to a disclosure that requires all such features, and multiple such features may be combined as appropriate. Furthermore, in the attached drawings, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

[0021] The following will describe a method for generating a plurality of three-dimensional (3D) models using two methods, namely volumetric capture and motion capture, and combining the 3D models to generate a single virtual viewpoint image. In such a system, a first 3D model, which is generated through the volumetric capture method, and a second 3D model, in which a predetermined CG model is added to a bone model obtained through the motion capture method, can be made to coexist in a single virtual space. "CG" is an acronym for "computer graphics". This makes it possible to generate appealing content in which the first 3D model, which represents a subject realistically, and the second 3D model, which is virtual, move together. The CG model may be an avatar or the like, for example. The CG model is used in a plurality of scenes, and by linking the CG model with the bone model, the shape of the CG model is deformed, and the second 3D model that is suitable for the scene is generated. Although an example will be described in which the CG model is generated only by a computer without involving shooting a subject in a real space, the present disclosure is not limited thereto. A model generated by shooting a subject in real space

with a plurality of cameras using a photogrammetry technique, or a model in which a model generated in this manner is further processed, may be used instead of a CG model. The second 3D model may be generated by linking such a model with a bone model.

[0022] In the present embodiment, the two methods of volumetric capture and motion capture are used to simultaneously shoot a single space in order to reduce a sense of unnaturalness in a virtual viewpoint image generated in this manner. Two or more subjects are present in the one space, and a 3D model of the two or more subjects is generated through the volumetric capture method, whereas a 3D model of some of the subjects is generated through the motion capture method. Because the plurality of subjects for which the 3D models are generated using the plurality of methods are present in a common predetermined region, the plurality of subjects can move in tandem while communicating with each other. At this time, when, for example the 3D model of a single subject is generated through both the volumetric capture and motion capture methods, a plurality of 3D models will be present at a position which overlaps spatially, which may cause a sense of unnaturalness in the generated virtual viewpoint image. The present embodiment therefore provides a technique for reducing such a sense of unnaturalness.

System Configuration

[0023] FIG. 1 illustrates an example of the configuration of an image generation system that generates a virtual viewpoint image, according to the present embodiment. The image generation system according to the present embodiment is configured including two shooting systems, namely a volumetric capture system **101** and a motion capture system **121**. The volumetric capture system **101** shoots images for generating a 3D model of a subject through the volumetric capture method, and the motion capture system **121** shoots images for generating a bone model of the subject using the motion capture method. The image generation system further includes a time server **141**, a storage device **142**, a rendering device **143**, and an information display device **144**.

[0024] The time server **141** outputs a time code (time information) to the volumetric capture system **101** and the motion capture system **121**. In other words, the volumetric capture system **101** and the motion capture system **121** can operate in synchronization using the time code output from the time server **141**. In each of the volumetric capture system **101** and the motion capture system **121**, the same time code is associated with a 3D model generated on the basis of data shot at the same time.

[0025] The volumetric capture system **101** includes a camera group **111** including cameras **112-1** to **112-12**, a hub **113**, and a first object generation device **114**. The cameras **112-1** to **112-12** belonging to the camera group **111** are arranged so as to surround a subject. Each of the cameras **112-1** to **112-12** obtains a two-dimensional (2D) image through shooting. A multi-viewpoint image is obtained by the cameras **112-1** to **112-12** shooting at a timing that is synchronized. The 2D images shot by the plurality of cameras **112-1** to **112-12** are provided to the first object generation device **114** via the hub **113** along with the time code provided from the time server **141**. The first object generation device **114** generates a 3D model of the subject present in the shooting region through the volumetric capture method and outputs the 3D model in combination with the time code to the storage device **142**. The 3D model here is a shape model in which a texture that is based on the shot image is applied to the surface of three-dimensional shape data formed through the volumetric capture method. Note that the volumetric capture system **101** may have a configuration different from that illustrated in FIG. 1. For example, the cameras **112-1** to **112-12** may be connected directly to the first object generation device **114**, and the time code may be provided directly to the first object generation device **114** from the time server **141**. The cameras **112-1** to **112-12** may also be daisy-chained. The time server **141** may also input the time code to the cameras **112-1** to **112-12**, and the cameras **112-1** to **112-12** may output the 2D images along with the time code. The first object generation device **114** may also be constituted by a plurality of devices.

[0026] The motion capture system **121** includes a sensor group **131** including sensors **132-1** to **132-6**, a hub **133**, and a second object generation device **134**. The sensors **132-1** to **132-6** belonging to

the sensor group **131** are arranged so as to surround the subject, and the two-dimensional position of a marker attached to the subject is identified (calculated) through shooting using infrared light. The two-dimensional position of the marker identified by each of the plurality of sensors **132-1** to **132-6** is provided to the second object generation device **134** via the hub **113** along with the time code provided from the time server **141**. The second object generation device **134** calculates the three-dimensional position of the marker on the basis of the information of the two-dimensional position of the marker obtained from each of the sensors **132-1** to **132-6** using the motion capture method, and obtains posture information of the subject. The second object generation device **134** then generates a bone model of the subject using the information that has been calculated and obtained. The second object generation device **134** generates a 3D model by aligning a predetermined CG model to the bone model, and outputs position information of the 3D model in combination with the time code to the storage device **142**. Note that the motion capture system **121** may have a configuration different from that illustrated in FIG. 1. For example, the sensors **132-1** to **132-6** may be connected directly to the second object generation device **134**, and the time code may be provided directly to the second object generation device **134** from the time server **141**. The sensors **132-1** to **132-6** may also be daisy-chained. The time server **141** may also input the time code to the sensors **132-1** to **132-6**, and the sensors **132-1** to **132-6** may output the two-dimensional position information of the marker along with the time code. The second object generation device **134** may also be constituted by a plurality of devices.

[0027] In the present embodiment, the respective systems are calibrated such that a spatial coordinate system used in the volumetric capture system **101** and a spatial coordinate system used in the motion capture system **121** coincide. For example, it is assumed that in the volumetric capture system **101**, the coordinates of a specific point are expressed as (X_v, Y_v, Z_v) , and in the motion capture system **121**, the coordinates of that specific point are expressed as (X_m, Y_m, Z_m) . In this case, if $X_v = X_m$, $Y_v = Y_m$, and $Z_v = Z_m$, the real-space positions of that specific point indicated in both systems coincide. The calibration is performed such that the coordinates match for all points in at least the shooting region. Although it is assumed here that the spatial coordinate systems are calibrated to coincide in both systems, this is not absolutely necessary, and the spatial coordinates of one system may be converted into coordinate values of the spatial coordinate system of the other system.

[0028] The rendering device **143** is an image generation device that generates a virtual viewpoint image using a 3D model stored in the storage device **142** in accordance with a position and direction of a virtual viewpoint set through a UI unit (not shown) operated by a user viewing the virtual viewpoint image. “UI” is an acronym for “user interface”. The UI unit includes an operation unit such as a mouse, a keyboard, operation buttons, a touch panel, and the like, and accepts operations made by a user. The rendering device **143** generates the virtual viewpoint image representing the appearance from the virtual viewpoint by arranging the 3D model obtained from the storage device **142** in the virtual space and rendering that 3D model in accordance with the viewpoint position and direction of a virtual camera. In other words, a virtual viewpoint image is generated which reproduces a scene observed by the virtual camera when the virtual camera is set at a specific viewpoint position to face the virtual space in which the 3D model is arranged. The virtual viewpoint image in the present embodiment includes a desired viewpoint image (virtual viewpoint image) corresponding to a viewpoint and a gaze direction specified by a user as desired. In addition, the virtual viewpoint image in the present embodiment may include an image corresponding to a viewpoint and a gaze direction specified by the user from among a plurality of candidates for viewpoints and gaze directions, an image corresponding to a viewpoint and a gaze direction automatically specified by the device, or the like. The rendering device **143** provides the generated virtual viewpoint image to the information display device **144**, and the information display device **144** obtains and displays the virtual viewpoint image generated by the rendering device **143**. Note that this is merely one example, and for example, the rendering device **143** may

store the virtual viewpoint image in the storage device **142**, and the information display device **144** may perform control to read out the virtual viewpoint image from the storage device **142** and display the virtual viewpoint image.

[0029] Although the present embodiment describes an example in which the 3D model is generated through both the volumetric capture and motion capture methods, the configuration is not limited thereto. That is, the following descriptions can be applied in a system that generates the respective 3D models using two or more of any methods capable of generating a 3D model.

[0030] FIG. **2** illustrates an example of the arrangement of the cameras **112-1** to **112-12** and the sensors **132-1** to **132-6**.

[0031] In FIG. **2**, the 12 cameras **112-1** to **112-12** are disposed so as to surround a shooting region **201** to be shot. The cameras **112-1** to **112-12** shoot the shooting region **201** from mutually-different directions to generate a virtual viewpoint image through volumetric capture, and output the shot image. The cameras **112-1** to **112-12** may be digital cameras, for example, and may be cameras that shoot still images, cameras that shoot moving images, or cameras that shoot both still images and moving images. In the present embodiment and the appended claims, the term “image” is used to include both still images and moving images, unless otherwise specified. Note also that in the present embodiment, an image capturing device that combines an image capturing unit having an image sensor and a lens that focuses light rays onto the image sensor is called a “camera”. The volumetric capture system **101** is configured to generate a virtual viewpoint image in the shooting region **201** using an image captured using a plurality of cameras included in the camera group **111** (the cameras **112-1** to **112-12**). Although the present embodiment describes an example in which 12 cameras are provided, the number of cameras may be any number greater than 1. Additionally, although FIG. **2** illustrates an example in which the cameras **112-1** to **112-12** surround the shooting region **201** from all directions, the configuration is not limited thereto. For example, the cameras may be arranged only in a set angle range centered on a point within the shooting region **201**.

[0032] In FIG. **2**, the six sensors **132-1** to **132-6** are arranged so as to surround the shooting region **201**. The sensors **132-1** to **132-6** shoot the shooting region **201** from mutually-different directions to generate a bone model through motion capture, and obtain the two-dimensional coordinates of a marker attached to the subject as motion data. The motion capture system **121** is configured to generate a bone model of a specific subject present in the shooting region **201** using the images captured using the plurality of sensors included in the sensor group **131** (the sensors **132-1** to **132-6**). Note that the “shooting” by the sensor can be performed in any format as long as the position of the marker attached to the surface of the subject can be detected. For example, the configuration may be such that an invisible marker is detected using an infrared sensor, or such that a visible marker is detected using a camera. Additionally, although the present embodiment describes an example in which six sensors are provided so as to surround the subject, the number of sensors may be any number greater than 1. Furthermore, although FIG. **2** illustrates an example in which the sensors **132-1** to **132-6** surround the shooting region **201** from all directions, the configuration is not limited thereto. For example, the sensors may be arranged only in a set angle range centered on a point within the shooting region **201**.

[0033] Note that the volumetric capture system **101** may be used to generate the bone model, without using the motion capture system **121**. For example, a known method can be used which uses silhouette data extracted having separated a foreground region, which is a subject part, and a background, which is a part other than the foreground region, from the shot images obtained by the cameras **112-1** to **112-12**, and an initial posture model using the bones. For example, the initial posture model is projected onto a selected shot image as a temporary shape model, and a degree of similarity between the projected region and the silhouette data is evaluated. At this time, the degree of similarity increases as the shape (silhouette) of the foreground region corresponding to the posture of the subject becomes more similar to the initial posture of the bones, and the degree of similarity decreases when the shape of the foreground region becomes less similar to the initial

posture of the bones. Next, the initial posture model is deformed to update the temporary shape model, and the degree of similarity between the region where the shape model is projected onto the shot image and the silhouette is evaluated again. In this manner, the degree of similarity between the region where the shape model is projected onto the shot image and the silhouette is repeatedly evaluated while updating the temporary shape model. Then, for example, the bones corresponding to the shape model having the highest degree of similarity can be output as a bone model corresponding to that shot image. Note that when updating the shape model and evaluating the degree of similarity, the bones corresponding to the shape model whose degree of similarity exceeds a predetermined value for the first time may be output as the bone model corresponding to that shot image. Note also that when a subject which moves continuously is being shot, it is possible to use, as the stated initial posture model used to evaluate the degree of similarity in a specific frame, a shape model evaluated as having a degree of similarity that is the highest or that exceeds a predetermined value with respect to the shot image in the previous frame.

[0034] Three-dimensional posture estimation information may also be specified (calculated) by combining (i) two-dimensional posture estimation information of the shot images from all the cameras, obtained through two-dimensional posture estimation from the shot image obtained from each camera, and (ii) camera parameters of all the cameras. In this case, the bone model is generated on the basis of the three-dimensional posture estimation information.

[0035] The bone model may also be generated using a three-dimensional shape generated by the volumetric capture system **101**. For example, artificial intelligence (AI) can be used to estimate 17 parts (bones) that form the human skeleton from a three-dimensional shape. In one example, the three-dimensional shape data can be generated by using the volumetric capture method to shoot a subject for which correct data of the bone model is present, and machine learning can be performed by taking that three-dimensional shape data as input data and the correct data of the bone model as labeled data. In this case, after a trained model is obtained through the machine learning, the three-dimensional shape of the subject obtained through the volumetric capture method is input to the trained model, and the bone model of the subject is output. The 17 bones described above are constituted by the following parts: the waist, the lower abdomen, the upper abdomen, the neck, the head, the right upper arm, the left upper arm, the right forearm, the left forearm, the right hand, the left hand, the right thigh, the left thigh, the right shin, the left shin, the right foot, and the left foot. However, the parts of the person are not limited thereto, and bones defined in more or less detail may be used.

[0036] In FIG. 2, a subject **202** is a subject for which a 3D model is to be generated by the motion capture system **121**, and a marker for detecting a position in the motion capture is attached to the surface of the subject **202**. A subject **203** is a subject for which a 3D model is to be generated by the volumetric capture system **101**. Here, a 3D model is also generated for the subject **202** in the volumetric capture system **101**. However, in the final image after rendering, the 3D model generated through the motion capture method is used for the subject **202**, and the 3D model generated by the volumetric capture method is not used. This processing will be described later.

Device Configuration

[0037] FIG. 3 is a diagram illustrating an example of the hardware configuration of the rendering device **143**. The rendering device **143** includes, for example, a CPU **301**, a ROM **302**, a RAM **303**, an auxiliary storage device **304**, a communication I/F **305**, and a bus **306**. Note that “CPU” is an acronym of “Central Processing Unit”, “ROM” is an acronym of “Read-Only Memory”, and “RAM” is an acronym of “Random Access Memory”. “I/F” is an abbreviation for “interface”. Furthermore, other devices in the image generation system, such as the first object generation device **114** and the second object generation device **134**, may also have the same hardware configuration as that in FIG. 3.

[0038] The CPU **301** is a processor that controls the rendering device **143** as a whole using computer programs, data, and the like stored in one or more memories, such as the ROM **302**, the

RAM **303**, and the like. Note that the rendering device **143** may have one or more dedicated pieces of hardware different from the CPU **301**, and at least some of the processing performed by the CPU **301** may be performed by the dedicated hardware. The dedicated hardware includes, for example, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a digital signal processor (DSP), and the like. The CPU **301** is an example of a processor, and the rendering device **143** may be configured to include one or more of any desired type of processor, such as a microprocessing unit (MPU). The ROM **302** stores programs, parameters, and the like that need not be changed. The RAM **303** temporarily stores programs, data, and the like supplied from the auxiliary storage device **304**, data supplied from the exterior through the communication I/F **305**, and the like. The ROM **302** and the RAM **303** are examples of memories, and the rendering device **143** may be configured to include one or more of any desired type of memory. The auxiliary storage device **304** is configured including a hard disk drive or the like, for example, and stores various types of content data such as images, audio, and the like. The communication I/F **305** is used for communicating with external devices such as the camera group **111** and the like. For example, if the rendering device **143** is connected to external devices by wires, cables for communication are connected to the communication I/F **305**. If the rendering device **143** has a function for communicating wirelessly with external devices, the communication I/F **305** includes an antenna. The bus **306** communicates information by connecting the various parts of the rendering device **143**. Note that if the rendering device **143** has an internal UI unit, the rendering device **143** includes a display unit, an operation unit, and the like in addition to the configuration illustrated in FIG. 3.

[0039] FIG. 4 illustrates an example of the functional configurations of the first object generation device **114**, the second object generation device **134**, and the rendering device **143** in the image generation system. The first object generation device **114** includes an image receiving unit **401** and a foreground extraction unit **402** for each camera, for example. The first object generation device **114** also includes a three-dimensional shape estimation unit **403** and a first 3D model generation unit **404**. The second object generation device **134** includes a sensor value receiving unit **411** and a two-dimensional marker position calculation unit **412** for each sensor, for example. The second object generation device **134** also includes a bone model generation unit **413** and a second 3D model generation unit **414**. The storage device **142** includes a storage unit **421**, for example. The rendering device **143** includes a 3D model position overlap determination unit **431**, a 3D model arrangement control unit **432**, and a rendering unit **433**, for example. Each of the functions can be implemented, for example, by the CPU **301** executing a program stored in the ROM **302**, the auxiliary storage device **304**, or the like. Additionally, at least some of the functions may be implemented by dedicated hardware.

[0040] The image receiving unit **401** receives shot images obtained from shooting performed by each of the cameras **112-1** to **112-12**. The image receiving unit **401** outputs the received shot images to the foreground extraction unit **402**. The foreground extraction unit **402** generates a foreground image from each of the shot images obtained from the image receiving unit **401**, and outputs the foreground image to the three-dimensional shape estimation unit **403**. The foreground extraction unit **402** obtains the foreground image for each camera by, for example, holding an image in which the subject is not present in advance as a background image for each camera, and then extracting a foreground region using the difference between the image shot by the camera and the background image. The three-dimensional shape estimation unit **403** generates a three-dimensional shape of the subject included in this foreground part on the basis of the foreground image obtained on the basis of the shot images from the plurality of cameras, and outputs the three-dimensional shape to the first 3D model generation unit **404**. The three-dimensional shape of the subject is generated by a shape estimation method such as the visual cone intersection method (Visual Hull), for example. Although the three-dimensional shape of the subject is, for example, three-dimensional shape data constituted by a point cloud, the three-dimensional shape is not

limited thereto, and may be expressed in another form, such as by polygons, for example.

[0041] The first 3D model generation unit **404** generates a 3D model by adding texture data obtained from extraction the foreground region to the obtained three-dimensional shape. The first 3D model generation unit **404** then outputs a combination of the generated 3D model, information indicating the position of the 3D model, and the time code obtained from the time server **141** to the storage unit **421**. A cuboid that circumscribes the shape of the 3D model is used as the information indicating the position of the 3D model. This cuboid will be called a “bounding box” hereinafter. The bounding box defines a region corresponding to the position in the virtual space in which the corresponding 3D model is to be arranged. The coordinates of each of the eight vertices of the bounding box are specified as follows, using maximum coordinate values (Xmax, Ymax, and Zmax) and minimum coordinate values (Xmin, Ymin, and Zmin) of each of the XYZ axes of the 3D model shape. [0042] Vertex 1 (Xmin, Ymin, Zmin) [0043] Vertex 2 (Xmax, Ymin, Zmin) [0044] Vertex 3 (Xmin, Ymax, Zmin) [0045] Vertex 4 (Xmax, Ymax, Zmin) [0046] Vertex 5 (Xmin, Ymin, Zmax) [0047] Vertex 6 (Xmax, Ymin, Zmax) [0048] Vertex 7 (Xmin, Ymax, Zmax) [0049] Vertex 8 (Xmax, Ymax, Zmax)

[0050] The sensor value receiving unit **411** receives an infrared light sensor value from each of the sensors **132-1** to **132-6** and outputs those values to the two-dimensional marker position calculation unit **412**. The two-dimensional marker position calculation unit **412** calculates the two-dimensional position of the marker attached to the subject at the sensor position for each sensor on the basis of the corresponding infrared light sensor value obtained from the sensor value receiving unit **411**, and outputs those two-dimensional positions to the bone model generation unit **413**. The bone model generation unit **413** calculates the three-dimensional position of the marker and generates a bone model by combining the two-dimensional position information of the marker for each sensor with information on the positional relationship of each sensor obtained in advance through calibration. The bone model generation unit **413** outputs the generated bone model data to the second 3D model generation unit **414**. The second 3D model generation unit **414** generates a 3D model by adding a CG model prepared in advance to the bone model data obtained from the bone model generation unit **413**. The second 3D model generation unit **414** then outputs a combination of the generated 3D model, bounding box coordinates, which are information indicating the position of the 3D model, and the time code obtained from the time server **141** to the storage unit **421**.

[0051] The storage unit **421** records the 3D model information obtained from the first 3D model generation unit **404** and the 3D model information obtained from the second 3D model generation unit **414**, and manages this information in a 3D model database. Here, FIG. 5 illustrates an example of the data recorded in the storage unit **421** when the shooting of the subject **202** and the subject **203** illustrated in FIG. 2 is taken as an example. “Timecode” in FIG. 5 refers to the time code information output from the time server **141**, and specifies the time in units of frames. For example, if one second's worth of data is recorded when the system is running at 60 frames per second (fps), separate time code information is held as the “time code” for each of the 60 frames corresponding to that one-second period. “ID” is identifier information that is numbered for each 3D model and used to designate the 3D model. “3D Model” is the generated 3D model data. “Kind” indicates the method (system) used to generate the 3D model. For a 3D model generated using the volumetric capture system **101**, a value of “Volumetric” is held as the value of “Kind”. For a 3D model generated using the motion capture system **121**, a value of “Motion” is held as the value of “Kind”. “Coordinates” indicates the spatial coordinates of the eight vertices of the bounding box corresponding to the 3D model. The storage unit **421** manages the time code and the 3D model information in association with each other on a frame-by-frame basis in this manner.

[0052] FIG. 6 schematically illustrates the position (and range), in the spatial coordinate system, of the bounding box of the 3D model for which “Timecode” corresponds to 12:15:30.010, among the data managed as illustrated in FIG. 5. Coordinates **601** are coordinates at the center of the shooting region **201** on a floor, and have world coordinate values (X, Y, Z)=(0, 0, 0), which is a reference

position of the spatial coordinate system handled by the system. A bounding box **602** is a bounding box corresponding to the 3D model generated by shooting the subject **202** using the volumetric capture system **101**. This bounding box is identified using the value of “Coordinates” corresponding to the ID of 1 in FIG. 5. A bounding box **603** is a bounding box corresponding to the 3D model generated by shooting the subject **203** using the volumetric capture system **101**. This bounding box is identified using the value of “Coordinates” corresponding to the ID of 2 in FIG. 5. A bounding box **604** is a bounding box corresponding to the 3D model generated by shooting the subject **202** using the motion capture system **121**. This bounding box is identified using the value of “Coordinates” corresponding to the ID of 3 in FIG. 5. As illustrated in FIG. 6, a 3D model of the subject **202** is generated using both the volumetric capture system **101** and the motion capture system **121**. Because these 3D models are generated on the basis of the same subject **202**, the corresponding bounding boxes (the bounding boxes corresponding to IDs of 1 and 3) overlap. [0053] Returning to FIG. 4, the 3D model position overlap determination unit **431** obtains the information of the 3D model from the storage unit **421**. The 3D model position overlap determination unit **431** then determines whether the 3D model generated by the motion capture system **121** and the 3D model generated by the volumetric capture system **101** overlap. Then, on the basis of the determination result, the 3D model position overlap determination unit **431** determines whether to arrange each 3D model in the virtual space. The determination as to whether the 3D models overlap is processing for identifying whether a 3D model generated on the basis of the same subject is present, and this processing will be described in detail later in the descriptions of the processing given with reference to FIG. 7. For example, as described above, for the subject **202**, the 3D model generated by the motion capture system **121** and the 3D model generated by the volumetric capture system **101** overlap. In this case, the 3D model arrangement control unit **432** can determine not to arrange either the 3D model generated by the motion capture system **121** or the 3D model generated by the volumetric capture system **101** in the virtual space. For example, the 3D model arrangement control unit **432** can determine not to arrange the 3D model of the subject **202** generated by the volumetric capture system **101** in the virtual space.

[0054] The 3D model arrangement control unit **432** arranges the 3D model determined to be arranged by the 3D model position overlap determination unit **431** in the virtual space. However, the 3D model arrangement control unit **432** does not arrange the 3D model determined not to be arranged by the 3D model position overlap determination unit **431** in the virtual space. The virtual space for which a virtual viewpoint image is to be generated is configured by the 3D model arrangement control unit **432** arranging, for each time code, all of the 3D models stored in the storage unit **421** in association with that time code. The rendering unit **433** renders the virtual viewpoint image according to the position and direction of a virtual viewpoint set by a user operation made through the UI unit (not shown) in the virtual space configured by the 3D model arrangement control unit **432**.

Flow of Processing

[0055] An example of the flow of processing for generating the virtual viewpoint image will be described next with reference to FIG. 7. This processing is executed for each time code. An example will be described in which a 3D model generated using the motion capture system **121** is preferentially arranged in a virtual space in this processing. Note that this is merely an example, and the 3D model generated using the volumetric capture system **101** may be preferentially arranged instead. Which 3D model is to be arranged preferentially can be set as desired through a user operation, for example.

[0056] First, the 3D model position overlap determination unit **431** obtains the information of the 3D models from the storage unit **421**, confirms the number of 3D models associated with the time code being processed, and executes initialization processing for performing the processing on the respective 3D models (step **S701**). Here, for example, the number of 3D models associated with the time code being processed is N, and a counter n for counting the 3D models that have been

processed is set to 1.

[0057] The 3D model position overlap determination unit **431** then determines whether the “Kind” of the 3D model being processed (the 3D model having an ID of *n*) is “Motion” (step **S702**). If the “Kind” of the 3D model being processed is determined to be “Motion” (YES in step **S702**), the 3D model position overlap determination unit **431** determines to arrange the “3D model” in the virtual space (step **S703**). In other words, in the present embodiment, the 3D model generated using the motion capture system **121** is preferentially arranged, and thus if the “Kind” of the 3D model being processed is “Motion”, that 3D model is determined to be arranged in the virtual space. On the other hand, if the “Kind” of the 3D model being processed is “Volumetric” (NO in step **S702**), the 3D model position overlap determination unit **431** determines whether another 3D model having a “Kind” of “Motion” is present at a position overlapping the 3D model being processed (step **S704**). Then, if the 3D model position overlap determination unit **431** determines that another 3D model having a “Kind” of “Motion” is present at a position overlapping the 3D model being processed (YES in step **S704**), it is determined that the 3D model being processed is not to be arranged in the virtual space (step **S705**). In other words, if another 3D model is preferentially arranged in the virtual space, the “Volumetric” 3D model present at a position overlapping that 3D model is not arranged in the virtual space. On the other hand, if the 3D model position overlap determination unit **431** determines that another 3D model having a “Kind” of “Motion” is not present at a position overlapping the 3D model being processed (NO in step **S704**), it is determined that the 3D model being processed is to be arranged in the virtual space (step **S705**).

[0058] An example of a method for determining whether the 3D model being processed and another 3D model overlap will be described here. First, it is determined whether a 3D model corresponding to a given bounding box, generated by the volumetric capture system **101**, overlaps with the bounding box of a 3D model generated by the motion capture system **121**. For example, it is determined whether at least one vertex of the bounding box of the 3D model generated by the volumetric capture system **101** is present inside the bounding box of the 3D model generated by the motion capture system **121**. If such a vertex is present, the bounding boxes are determined to overlap. If the bounding boxes overlap in this manner, the degree of overlap is then evaluated. In this evaluation, of the overlapping bounding boxes, a total volume amount V_{all} of the bounding box having the smaller volume and a volume amount V_{lap} of the spatial region overlapping therewith are specified, and the degree of overlap is expressed by a value V_{lap}/V_{all} indicating the percentage of the overlapping region. For example, if this value exceeds a predetermined level, the 3D model being processed and the other 3D model can be determined to overlap. The predetermined level can be, for example, 0.8 (80%). According to such a determination, if the two bounding boxes overlap only in a small part of the spatial region, the 3D models corresponding to those bounding boxes are not determined to overlap, and both the 3D models can be arranged in the virtual space. It is also conceivable that, for example, the two bounding boxes that are based on the results of shooting the same subject overlap sufficiently, and thus only one of the two 3D models corresponding to those bounding boxes can be arranged in the virtual space.

[0059] Note that even if a plurality of 3D models are generated on the basis of the same subject, the degree of overlap described above may not be 1 (100%) due to the shape of the 3D model. For example, if a pre-prepared CG model used when generating the 3D model using the motion capture system **121** is carrying an object on its back or holding an object in its hand, the bounding box is generated also taking that object into account. In contrast, if the subject shot for generating the 3D model is not carrying that object, the object is not reflected in the 3D model generated using the volumetric capture system **101**. Accordingly, the bounding box of the 3D model generated using the motion capture system **121** is specified as being larger than the bounding box corresponding to the volumetric capture system **101** by an amount corresponding to that object. On the other hand, for example, the CG model used when generating a 3D model using the motion capture system **121** can be smaller than the actual subject. In this case, it is assumed that a first bounding box

corresponding to the motion capture system **121** is smaller than a second bounding box corresponding to the volumetric capture system **101**. Here, most of the first bounding box is present within the second bounding box, but if an object is present as described above, the first bounding box may not overlap with the second bounding box. In such a case, using the above-described predetermined level makes it possible to arrange only one of the plurality of 3D models in the virtual space, in consideration of the mismatch between the bounding boxes due to the shapes of the 3D models.

[0060] Although the predetermined level is 0.8 in the example described above, the level is not limited thereto. For example, the predetermined level may be determined on the basis of the shape of the 3D model generated by the motion capture system **121**. For example, in the example illustrated in FIG. 5, the height (the length in the Z-axis direction) of the 3D model having an ID of 1 is 1800, as indicated by the Z value in “Coordinates”, whereas the height of the 3D model having an ID of 3 is 1600 (the unit can be millimeters, for example). In addition, the X and Y values of “Coordinates” vary depending on the puffiness of the clothing of the 3D model, the weight of the 3D model, and the like. In this manner, the size of the bounding box varies depending on the shape of the CG model used in the motion capture system **121**. The degree of overlap between the bounding boxes also varies when the 3D models generated by the volumetric capture system **101** and the motion capture system **121** are arranged at exactly the same position. Accordingly, determining the predetermined level in accordance with the shape of the CG model used in the motion capture system **121** makes it possible to appropriately determine whether the plurality of 3D models are related to the same subject.

[0061] When determining whether to arrange the 3D model being processed in the virtual space, the 3D model position overlap determination unit **431** increments the counter n in order to change the 3D model being processed (step S706). Then, for all the 3D models, the 3D model position overlap determination unit **431** determines whether the processing of steps S702 to S705 is complete, i.e., whether the counter n has reached N+1 (step S707). If the counter n has not reached N+1 (NO in step S707), an unprocessed 3D model remains, and thus the 3D model position overlap determination unit **431** returns the sequence to step S702. On the other hand, if the counter n has reached N+1 (YES in step S707), the 3D model position overlap determination unit **431** moves the sequence to step S708. In step S708, the 3D model arrangement control unit **432** arranges, in the virtual space, the 3D model determined to be arranged. The rendering unit **433** then generates a virtual viewpoint image, which is an image corresponding to observing the virtual space from the position and direction of the virtual viewpoint that has been set (step S709), and the sequence then ends.

[0062] FIG. 8 illustrates an example of a virtual viewpoint image generated in this manner. FIG. 8 illustrates an example of a virtual viewpoint image generated using one frame corresponding to a time code of 12:15:30.010, among the data illustrated in FIG. 5. An object **801** is obtained by rendering the 3D model stored corresponding to the ID of 2 in FIG. 5. This 3D model is arranged in the virtual space as a result of determining that the 3D model has a “Kind” of “Volumetric” but does not overlap with the 3D model having a “Kind” of “Motion” in the determination of step S704. An object **802** is obtained by rendering the 3D model stored corresponding to the ID of 3 in FIG. 5. Because the “Kind” is “Motion”, this 3D model is arranged in the virtual space through the determination of step S702. On the other hand, for the 3D model stored in association with the ID of 1 in FIG. 5, “Kind” is “Volumetric”, and that 3D model is also determined in step S704 to overlap with the 3D model having an ID of 3, for which “Kind” is “Motion”. As such, that 3D model is not arranged in the virtual space. As a result, the object corresponding to this 3D model is not displayed in the virtual viewpoint image.

[0063] As described above, in the present embodiment, a plurality of subjects in a common shooting space are shot using different methods, and a virtual viewpoint image is generated having arranged 3D models generated by corresponding systems in a single virtual space. A plurality of

subjects present in a common space move in tandem while recognizing each other's existence, and thus by performing shooting corresponding to different methods for generating 3D models in the common space, the corresponding 3D models also move in tandem with each other. As a result, even if a plurality of 3D models are generated by mutually-independent systems, it is possible to generate a virtual viewpoint image in which the plurality of 3D models are arranged in a virtual space without a sense of unnaturalness. At this time, for a subject for which a 3D model is to be generated through a plurality of methods, only one of the plurality of 3D models corresponding to that subject is displayed, and the other 3D models among the plurality of 3D models are not arranged in the virtual space. Through this, a plurality of 3D models generated from a common subject can be prevented from being arranged in the virtual space in an overlapping manner. This makes it possible to reduce a sense of unnaturalness in the virtual viewpoint image that is output.

Variation

[0064] When an anomaly occurs when generating a 3D model using the motion capture system **121**, an event can occur where, for example, a virtual 3D model disappears and a 3D model of a real subject generated using the volumetric capture system **101** appears. The present variation will describe a control method for preventing an inappropriate virtual viewpoint image resulting from such an event from being output.

[0065] FIG. **9** illustrates an example of the functional configurations of the first object generation device **114**, the second object generation device **134**, and the rendering device **143** in the image generation system according to the present variation. Of the configuration illustrated in FIG. **9**, functions having the same functions as in FIG. **4** will be given the same reference numerals as in FIG. **4**, and will not be described in detail.

[0066] A second 3D model generation unit **901** in the present variation generates a 3D model on the basis of the bone model data obtained from the bone model generation unit **413**, in the same manner as in the case of FIG. **4**. Then, if a 3D model has been generated, the second 3D model generation unit **901** then outputs a combination of that 3D model, bounding box coordinates, which are information indicating the position of the 3D model, and the time code obtained from the time server **141** to the storage unit **421**. On the other hand, if a 3D model has not been generated, the second 3D model generation unit **901** outputs non-generation information indicating that a 3D model has not been generated to a tracking control unit **903**. For example, if a performer corresponding to the 3D model generated using the motion capture system **121** is no longer present in the shooting region **201**, a 3D model is not generated. Furthermore, if a performer is present in the shooting region **201** but information necessary for generating the 3D model has not been input to the second 3D model generation unit **901** due to some anomaly, such as sensor failure or a data transmission path being cut off, the 3D model will not be generated.

[0067] Here, an example of the data recorded in the storage unit **421** when the subject **202** and the subject **203** illustrated in FIG. **2** are shot is illustrated in FIG. **10**. When "Timecode" is 12:15:30.011, a 3D model having an ID of 3, for which "Kind" is "Motion", is recorded. However, when "Timecode" is 12:15:30.012, a 3D model having an ID of 3 is not recorded. In this case, for example, in the processing illustrated in FIG. **7**, when "Timecode" is 12:15:30.012, a 3D model having an ID of 1 is arranged in the virtual space instead of the 3D model having an ID of 3. However, if such a 3D model is displayed, the display changes from a virtual model to a real model, which can cause a sense of unnaturalness. Accordingly, in the present variation, processing is performed to prevent such a 3D model corresponding to a real subject from being arranged in the virtual space.

[0068] When this 3D model is no longer generated, the second 3D model generation unit **901** outputs the non-generation information of the 3D model to the tracking control unit **903**. A 3D model position overlap determination unit **902** obtains the information of the 3D model from the storage unit **421**, and determines whether to arrange the 3D model in the virtual space by determining the overlap as described above. The 3D model position overlap determination unit **902**

outputs information indicating whether to arrange the 3D model in the virtual space to the tracking control unit **903** and a 3D model arrangement control unit **904**. If a notification indicating the non-generation information of the 3D model has been received from the second 3D model generation unit **901**, the tracking control unit **903** determines the 3D model to be tracked and tracks the 3D model. The tracking control unit **903** outputs information indicating the tracking state, such as whether tracking is being performed, to 3D model arrangement control unit **904**. Here, the 3D model to be tracked is the 3D model generated by the volumetric capture system **101**, for the subject for which the 3D model is generated using the motion capture system **121**. In other words, the 3D model not arranged in the virtual space when a 3D model generated by the motion capture system **121** is present is the 3D model to be tracked. The 3D model arrangement control unit **904** performs processing for arranging the 3D model in the virtual space on the basis of information indicating whether to arrange the 3D model determined by the 3D model position overlap determination unit **902** and information indicating the tracking state by the tracking control unit **903**.

[0069] An example of the flow of processing executed by the tracking control unit **903** will be described here with reference to FIG. **11**. The tracking control unit **903** determines whether non-generation information of the 3D model has been obtained from the second 3D model generation unit **901** (step **S1101**). Then, if the non-generation information of the 3D model has not been obtained (NO in step **S1101**), the tracking control unit **903** sets the tracking state to OFF (step **S1105**), after which the processing ends. However, if the non-generation information of the 3D model has been obtained (YES in step **S1101**), the tracking control unit **903** determines whether the 3D model determined not to be arranged by the 3D model position overlap determination unit **902** is present (step **S1102**). For example, the tracking control unit **903** determines whether a 3D model determined not to be arranged is present in the frame previous to the frame in which the non-generation information of the 3D model was obtained for the first time. The 3D model position overlap determination unit **902** can determine to arrange the 3D model generated by the volumetric capture system **101** at the point in time when the 3D model generated by the motion capture system **121** is no longer present. As such, whether a 3D model determined not to be arranged is present can be determined not in the frame serving as a trigger for obtaining the non-generation information of the 3D model, but rather in the previous frame thereto. It is assumed that at the timing at which the non-generation information of the 3D model is output by the second 3D model generation unit **901**, due to processing delay or the like, the 3D model position overlap determination unit **902** is processing a frame from a timing prior to the frame in which the 3D model is not generated. In this case, the tracking control unit **903** may confirm whether the 3D model determined not to be arranged by the 3D model position overlap determination unit **902** is present at the timing when the non-generation information is obtained.

[0070] If the tracking control unit **903** determines that the 3D model determined not to be arranged is not present (NO in step **S1102**), the tracking state is set to OFF (step **S1105**), and the processing ends. However, if the tracking control unit **903** determines that the 3D model determined not to be arranged is present (YES in step **S1102**), the tracking state is set to ON (step **S1103**). The tracking control unit **903** then tracks the 3D model determined not to be arranged (step **S1104**). Note that the tracking control unit **903** can execute the processing illustrated in FIG. **11** for each frame, for example. Then, if a notification indicating the non-generation information of the 3D model is detected as no longer being obtained from the second 3D model generation unit **901**, the tracking control unit **903** sets the tracking state to OFF and stops the tracking processing.

[0071] An example of the flow of processing for generating the virtual viewpoint image will be described next with reference to FIG. **12**. In this processing, step **S1201**, which is based on tracking, is performed after determining whether to arrange the 3D model in the virtual space according to whether the 3D model overlaps with another 3D model, for all the 3D models corresponding to the frame to be processed, in the processing illustrated in FIG. **7**. Steps in which

processing similar to that illustrated in FIG. 7 is performed will be given the same reference signs and will not be described. In step **S1201**, the 3D model arrangement control unit **904** determines not to arrange the 3D model to be tracked, if the tracking state is ON. For example, in the processing of FIG. 7, the 3D model having an ID of 1 is determined to be arranged in the virtual space when the 3D model having an ID of 3, illustrated in FIG. 10, is not present, but in the present variation, that 3D model is being tracked and is therefore not arranged in the virtual space. In other words, when “Timecode” is 12:15:30.011, the 3D model having an ID of 1 and the 3D model having an ID of 3 are overlapping, and thus the 3D model position overlap determination unit **902** determines not to arrange the 3D model having an ID of 1. On the other hand, when the non-generation information of the 3D model at the point in time when “Timecode” corresponding to the next frame is 12:15:30.012 is obtained from the second 3D model generation unit **901**, the tracking control unit **903** tracks the 3D model having an ID of 1. The 3D model arrangement control unit **904** then determines not to arrange the 3D model having an ID of 1, which is being tracked, in the virtual space. In this manner, if the 3D model having an ID of 1 is present but the 3D model having an ID of 3 is not present, which can be assumed to be due to a failure to generate the 3D model through the motion capture method, the 3D model having an ID of 1 is not arranged in the virtual space. Note that when the 3D model having an ID of 3 is not present and the 3D model having an ID of 1 is also not present, the subject for which those 3D models is to be generated is not present in the shooting region **201**. Accordingly, the 3D model corresponding to the subject is not arranged in the virtual space and is not displayed in the virtual viewpoint image, with no tracking being performed.

[0072] An example of a virtual viewpoint image generated using one frame corresponding to “Timecode” of 12:15:30.012 among the recorded data illustrated in FIG. 10 will be described next. Here, as described above, on the basis of the non-generation information of the 3D model having an ID of 3, the 3D model having an ID of 1 is subject to tracking, the 3D model having an ID of 1 is not arranged, and only the 3D model having an ID of 2 is arranged in the virtual space. FIG. 13A illustrates a virtual viewpoint image generated on the basis of this virtual space. In this manner, a situation where a virtual 3D model generated by the motion capture system **121** suddenly disappears and a real 3D model of the subject generated by the volumetric capture system **101** is displayed can be prevented.

[0073] The foregoing example describes processing in which when the 3D model having an ID of 3 is not generated, the 3D model having an ID of 1, which is the 3D model being tracked, is not arranged in the virtual space, and the object is not displayed in the virtual viewpoint image. However, this is merely an example, and the 3D model from the period where the model was correctly generated in the past may continue to be displayed in the virtual viewpoint image, as indicated by an object **1301** in FIG. 13B, for example. For example, the newest 3D model among the 3D models from the period when the 3D model was correctly generated (among the 3D models generated in the past) may continue to be displayed. In other words, the object **1301** corresponding to the 3D model having an ID of 3, from when “Timecode” is 12:15:30.011, may continue to be displayed. To make it possible to visibly confirm that the 3D model is not being generated, the object when the 3D model is being generated may be displayed in a different format from the object when the 3D model is not being generated, such as the hatched display illustrated in FIG. 13B. Furthermore, as illustrated in FIG. 13C, when it is detected that the 3D model has not been generated due to an anomaly in the motion capture system **121**, information indicating to the user that an anomaly has occurred may be output overlaid on the virtual viewpoint, as indicated by a dialog **1302**.

[0074] As described above, when an anomaly occurs in the generation of the 3D model by the motion capture system **121**, a situation where the virtual 3D model suddenly disappears and the real 3D model of the volumetric capture system **101** appears can be prevented from arising. This makes it possible to prevent inappropriate virtual viewpoint images from being presented.

[0075] The foregoing describes an example in which the volumetric capture method and the motion capture method are used as the methods for generating the 3D models. This is merely an example, however, and other methods may be used to generate the 3D models. For example, when generating a first 3D model for all of the plurality of subjects using a first method and generating a second 3D model for some of the subjects using a second method, the virtual viewpoint image can be generated having preferentially arranged the second 3D model in the virtual space. Note that a 3D model may be generated for a first group of subjects present in the shooting region using the first method, and a 3D model may be generated for a second group of subjects present in the shooting region using the second method. Here, a 3D model for a third group of subjects belonging to both the first group and the second group can be generated using both the first method and the second method. In this case, a virtual viewpoint image that is based on the virtual space in which only the 3D model generated through one of the methods, of the 3D model corresponding to the first method and the 3D model corresponding to the second method, is arranged for the subject belonging to the third group, can be output. In this case, which method of 3D model is to be arranged in the virtual space may be determined in advance in the system, or may be determined by a user operation. Additionally, although the foregoing describes an example in which the 3D models are generated using two methods, the 3D models may be generated using three or more methods.

[0076] According to the present disclosure, a desired virtual viewpoint image can be generated while linking subjects sufficiently.

OTHER EMBODIMENTS

[0077] Embodiment(s) of the present disclosure can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a ‘non-transitory computer-readable storage medium’) to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)TM), a flash memory device, a memory card, and the like.

[0078] While the present disclosure has been described with reference to exemplary embodiments, it is to be understood that the disclosure is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0079] This application claims the benefit of Japanese Patent Application No. 2024-023037, filed Feb. 19, 2024, which is hereby incorporated by reference herein in its entirety.

Claims

1. An image generation device comprising: one or more processors; and one or more memories that store a computer-readable instruction for causing, when executed by the one or more processors,

the one or more processors to: obtain (i) a plurality of first three-dimensional (3D) models, of corresponding ones of a plurality of subjects, generated through a first method on the basis of shooting a predetermined region in which the plurality of subjects are present, and (ii) a second 3D model that is based on posture information of a specific subject, among the plurality of subjects, present in the predetermined region during the shooting, the second 3D model corresponding to the specific subject and being generated through a second method different from the first method; and output a virtual viewpoint image generated on the basis of (i) the first 3D model of a subject, among the plurality of subjects, that is different from the specific subject, and (ii) the second 3D model corresponding to the specific subject.

2. The image generation device according to claim 1, wherein the virtual viewpoint image is generated without using the first 3D models of the specific subject, and is output.

3. The image generation device according to claim 1, wherein the virtual viewpoint image is generated using the second 3D model corresponding to the specific subject instead of the first 3D models of the specific subject, and is output.

4. The image generation device according to claim 3, wherein a position, in a virtual space, of the second 3D model corresponding to the specific subject is a position, in the virtual space, of the first 3D models of the specific subject.

5. The image generation device according to claim 1, wherein in a case where, among a plurality of regions in which corresponding ones of the plurality of first 3D models corresponding to each of the plurality of subjects are present in a virtual space, a first region is present that overlaps by more than a predetermined level with a second region in which the second 3D model is present in the virtual space, the virtual viewpoint image is generated by arranging the second 3D model corresponding to the specific subject at a position of the first region instead of the first 3D model corresponding to the first region, and is output.

6. The image generation device according to claim 1, wherein in a case where the second 3D model corresponding to the specific subject is not generated, the virtual viewpoint image is generated using the second 3D model corresponding to the specific subject generated in the past, and is output.

7. The image generation device according to claim 6, wherein a display of the specific subject in the virtual viewpoint image generated using the second 3D model corresponding to the specific subject generated in the past is different from a display of the specific subject displayed in the virtual viewpoint image when the second 3D model is generated.

8. The image generation device according to claim 1, wherein in a case where the second 3D model corresponding to the specific subject is not generated and the first 3D models of the specific subject are generated, information indicating an anomaly is output.

9. The image generation device according to claim 1, wherein the first method is a volumetric capture method, and the second method is a motion capture method.

10. The image generation device according to claim 1, wherein the first 3D models are generated by generating a three-dimensional shape of each of the plurality of subjects on the basis of shooting of the predetermined region by a plurality of cameras and then applying a texture obtained from the shooting to the three-dimensional shape.

11. The image generation device according to claim 9, wherein the second 3D model is generated by generating a bone model of the specific subject from posture information that is based on information obtained from a plurality of sensors, and then deforming a computer graphics (CG) model to the bone model.

12. An image generation method executed by an image generation device, the method comprising: obtaining (i) a plurality of first three-dimensional (3D) models, of corresponding ones of a plurality of subjects, generated through a first method on the basis of shooting a predetermined region in which the plurality of subjects are present, and (ii) a second 3D model that is based on posture information of a specific subject, among the plurality of subjects, present in the predetermined

region during the shooting, the second 3D model corresponding to the specific subject and being generated through a second method different from the first method; and outputting a virtual viewpoint image generated on the basis of (i) the first 3D model of a subject, among the plurality of subjects, that is different from the specific subject, and (ii) the second 3D model corresponding to the specific subject.

13. A non-transitory computer-readable storage medium that stores a program for causing a computer to: obtain (i) a plurality of first three-dimensional (3D) models, of corresponding ones of a plurality of subjects, generated through a first method on the basis of shooting a predetermined region in which the plurality of subjects are present, and (ii) a second 3D model that is based on posture information of a specific subject, among the plurality of subjects, present in the predetermined region during the shooting, the second 3D model corresponding to the specific subject and being generated through a second method different from the first method; and output a virtual viewpoint image generated on the basis of (i) the first 3D model of a subject, among the plurality of subjects, that is different from the specific subject, and (ii) the second 3D model corresponding to the specific subject.
