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VIRTUAL REALITY SHARING METHOD AND SYSTEM

Abstract

A virtual reality sharing system comprises a VR-server that composites a plurality of camera-captured videos obtained by capturing videos of a same real space from different viewpoints to create a VR video, an AR-server that draws and creates an AR object (ARO), and a viewer virtual reality sharing terminal (terminal), wherein the VR server, the AR-server, and the terminal being communicatively connected via a network, wherein an input interface of the terminal accepts a setting input operation about a viewer's viewpoint for taking in the VR video, the terminal transmits data indicating a position and direction of the viewer's viewpoint to the VR-server and the AR-server, receives the VR video and drawing data of the ARO viewed as seen from the viewer's viewpoint from the VR-server and the AR-server, superimposes the ARO on the received VR video, and displays the superimposed VR video on the display of the terminal.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to a virtual reality sharing method and system, and relates to a method and system for sharing a Mixed Reality (MR) space formed with a real space and a virtual space (AR object, also referred to as an Augmented Reality object) among a plurality of persons.

BACKGROUND ART

[0002] Patent Literature 1 discloses a technique "including a first image acquiring step of acquiring a first three-dimensional image based on a three-dimensional video by a first three-dimensional imaging portion worn by a first user and a virtual object image based on the position attitude of the first three-dimensional imaging portion, a second image acquiring step of acquiring a second three-dimensional image based on a three-dimensional video by a second three-dimensional imaging portion installed in a space where the first user is present and a virtual object image based on the position attitude of the second three-dimensional imaging portion, a selection step of selecting an image corresponding to an instruction of a second user from among the first three-dimensional image and second three-dimensional image, and a presentation step of presenting the selected image to the second user (excerpted from Abstract)".

CITATION LIST

Patent Literature

[0003] Patent Literature 1: JP-A-2006-293604

SUMMARY OF INVENTION

Technical Problem

[0004] According to Patent Literature 1, for sharing an MR space with a viewer at a remote site, a fixed camera arranged in a real space is used in addition to an HMD for an experiencer (operator). This enables selection, as a line of sight of a viewer, from either the line of sight of the HMD for the experiencer or that of the fixed camera, and thus sharing of the MR space can be realized based on the selected line of sight.

[0005] However, in Patent Literature 1, the viewer at the remote site is only allowed to share the MR space with a fixed line of sight of either the HMD for the experiencer or the fixed camera. This causes a problem that the viewer is only allowed to share the MR space with a limited line of sight.

[0006] The present invention has been made in view of the problem above, and an object of the present invention is to increase flexibility in selecting a line of sight for sharing an MR space by a viewer.

Solution to Problem

[0007] In order to solve the problem above, the present invention includes the features recited in the scope of claims. One of the aspects thereof is a virtual reality sharing method, comprising the steps of: acquiring a first camera-captured video generated by capturing a video of a real space at a first viewpoint of a first virtual reality sharing terminal; as a first displaying step, causing the first virtual reality sharing terminal to display an AR object to be superimposed on the real space; acquiring a second camera-captured video generated by capturing a video of the real space at a second viewpoint different from the first viewpoint; as a VR video creating step, generating a VR video by compositing the first camera-captured video and the second camera-captured video;

[0008] as a viewpoint acquiring step, acquiring setting input information about a viewer's viewpoint for taking in the VR video, the setting input information having been accepted at a second virtual reality sharing terminal different from the first virtual reality shared terminal; and as a second displaying step, superimposing the AR object viewed from the viewer's viewpoint on the VR video viewed from the viewer's viewpoint and causing the second virtual reality sharing terminal to display the VR video.

Advantageous Effects of Invention

[0009] According to the present invention, it is possible to increase flexibility in selecting a line of sight for sharing an MR space by a viewer. The objects, configurations, and advantageous effects other than those described above will be clarified in the embodiments to be described below.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a schematic diagram of a virtual reality sharing system according to a first embodiment.

[0011] FIG. **2**A illustrates appearance of an experiencer HMD and participant HMD which are virtual reality sharing systems.

[0012] FIG. **2**B illustrates appearance of a viewer HMD which is a virtual reality sharing system.

[0013] FIG. **3** is a block diagram of the experiencer HMD.

[0014] FIG. **4** is a block diagram of the participant HMD.

[0015] FIG. **5** is a block diagram of the viewer HMD.

[0016] FIG. **6** is a block diagram of a VR server.

[0017] FIG. **7** is a block diagram of an AR server.

[0018] FIG. **8** is a diagram for explaining an example of detecting positions of the experiencer HMD and participant HMD.

[0019] FIG. **9** is a diagram for explaining generation of a VR video.

[0020] FIG. **10** is a diagram for explaining normalization of a VR video.

[0021] FIG. **11** illustrates a flowchart of an MR experience program.

[0022] FIG. **12** illustrates a flowchart of an MR participation program.

[0023] FIG. **13** is a diagram for further explaining a position of an AR object.

[0024] FIG. **14** illustrates a flowchart of an MR viewing program.

[0025] FIG. **15** illustrates a flowchart of a VR creation program.

[0026] FIG. **16** illustrates a flowchart of an AR drawing program.

[0027] FIG. **17** illustrates an exemplary method of selecting a position of a viewpoint by a viewer.

[0028] FIG. **18** is a schematic diagram of a virtual reality sharing system according to a second embodiment.

[0029] FIG. **19** is a schematic diagram of a modification of the virtual reality sharing system according to the second embodiment.

[0030] FIG. **20** is a block diagram of a participant HMD of the virtual reality sharing system according to a third embodiment.

[0031] FIG. **21** illustrates a flowchart of an MR participation program according to the third embodiment.

[0032] FIG. **22** is a schematic diagram of a virtual reality sharing system according to a fourth embodiment.

[0033] FIG. **23** illustrates a flowchart of an AR drawing program according to the fourth embodiment.

DESCRIPTION OF EMBODIMENTS

[0034] Hereinafter, embodiments of the present invention will be described with reference to the drawings. Throughout all the drawings, the common elements and steps are provided with the same reference signs, and are not described in detailed repetitively.

[0035] In the field of games, telemedicine, and maintenance, a technique of adding an AR object created by use of computer graphics (CG) to a background image of a real space captured by a camera is used. In order to add an AR object, a video capturing a real object which is called an AR trigger or marker is obtained together with a video capturing a background, and an AR object associated with the AR trigger or marker is composited with the background video.

[0036] In particular, in Mixed Reality (MR), using a head-mounted display (HMD) integrally provided with a camera and a display allows an AR object to be drawn in accordance with the position and orientation of the HMD to be superimposed on a background video taken by a camera equipped in the HMD or a background video viewed through the HMD and displayed, as a video of a virtual space, on the HMD.

[0037] The present embodiment can provide simulated experience through a video and enables sharing of the simulated experience among a plurality of persons, by means of a video of a virtual space, particularly, using Virtual Reality (VR) allowing images of a space in an ultra-wide area (for example, 360°) to be continuously displayed in accordance with a motion of a person who is wearing an HMD.

First Embodiment

(System Configuration and HMD)

[0038] FIG. **1** is a schematic diagram of a virtual reality sharing system **100** according to a first embodiment.

[0039] The virtual reality sharing system **100** is a system that allows sharing of a virtual space including an MR space **6** among an experiencer **11** having the right to operate an AR object **4***b*, participants **12***a*, **12***b*, **12***c*, **12***d*, **12***e* who are present in the same real space as that of the experiencer **11** and visually recognize the AR object **4***b*, and viewers **13***a*, **13***b*, **13***c* who are present in a real space (remote site) different from that of the experiencer **11** and participants **12***a* to **12***e*. Advantageously, the virtual reality sharing system **100** enables not only the experiencer **11** and participants **12***a* to **12***e* who are present in the same real space, but also the viewers **13***a* to **13***c* who are in a remote site to share and experience the virtual reality including the MR space **6**.

[0040] In the MR space **6**, the AR object **4***b* associated with a real object **4***a* as an AR marker is superimposed and displayed on the real object **4***a*. In FIG. **1**, the real object **4***a* is an instrument to be operated which is a new product, and the AR object **4***b* is an operation means. FIG. **1** illustrates an example in which the experiencer **11** is demonstrating how to operate the new product with the AR object **4***b*.

[0041] An experiencer HMD **1** (hereinafter, may be abbreviated as "HMD **1**") worn by the experiencer **11** and participant HMDs **2***a* to **2***e* (hereinafter, may be abbreviated as "HMDs **2***a* to **2***e*") worn by the participants **12***a* to **12***e*, respectively, transmit and receive network signals **10***a*, **10***b*, **10***c*, **10***d*, **10***e*, **10***f*, **10***g*, **10***h*, **10***i* to and from access points **5***a* to **5***c* installed in the MR space **6**. The experiencer HMD **1** and the participant HMDs **2***a* to **2***e* are virtual reality sharing terminals.

[0042] Viewer information terminal **3***a* (hereinafter, may be abbreviated as "information terminal **3***a*") operated by the viewer **13***a* and viewer HMDs **3***b*, **3***c* (hereinafter, may be abbreviated as "HMDs **3***b*, **3***c*") worn by the viewers **13***b*, **13***c*, respectively, transmit and receive network signals **10***j*, **10***k*, **10***l*, **10***m*, **10***n* to and from access points **5***d*, **5***e*. The viewer information terminal **3***a* and the viewer HMDs **3***b*, **3***c* are also virtual reality sharing terminals.

[0043] The access points **5***a* to **5***c* are connected to a network **7** outside the MR space **6**, and serve as intermediary media for communication among a VR server **8** and AR server **9** located on the network **7**, and the HMD **1** and HMDs **2***a* to **2***e*. On the network **7**, access points **5***d*, **5***e* for a remote site are also located, and serve as intermediary media for communication among the VR server **8**, the AR server **9**, the viewer HMDs **3***b*, **3***c*, and the information terminal **3***a*.

[0044] Displaying a three-dimensional image of the AR object **4***b* on the HMD **1**, HMDs **2***a* to **2***e*, and HMDs **3***b*, **3***c* can realize display with reality in which the front and rear positional relation between the real object **4***a* and the AR object **4***b* is reflected.

[0045] FIG. **2**A illustrates appearance of the experiencer HMD **1** and participant HMDs **2***a* to **2***e* which are the virtual reality sharing terminals, and FIG. **2**B illustrates appearance of the viewer HMDs **3***b*, **3***c* which are the virtual reality sharing terminals.

[0046] First, a configuration common to the experiencer HMD **1**, participant HMDs **2***a* to **2***e*, and the viewer HMDs **3***b*, **3***c* will be described. Each of the experiencer HMD **1**, the participant HMDs **2***a* to **2***e*, and the viewer HMDs **3***b*, **3***c* includes a left projector **22***a*, a right projector **22***b*, a screen **23**, a nose pad **24**, a processor **25**, a speaker **26**, a microphone **27**, a left temple **28***a*, a right temple **28***b*, and a bridge **28***c*. The left temple **28***a*, the right temple **28***b*, and the bridge **28***c* may be collectively called a frame housing **28**. The wearer puts the HMD on his or her face via the frame housing **28** and the nose pad **24**.

[0047] Each of the experiencer HMD **1** and participant HMDs **2***a* to **2***e* further includes a camera **21** and a ranging camera **29**. The camera **21** is mounted so as to take a video of the background that is a real space in front of a line of sight of the wearer of the HMD. The ranging camera **29** measures a distance to the real object **4***a* to be captured as a portion of the background video.

[0048] The wearer of each of the experiencer HMD **1** and participant HMDs **2***a* to **2***e* transparently views the background video of the real space in front thereof through a screen **23**, or views the background video taken by the mounted camera **21** and projected on the screen **23**. The left projector **22***a* and the right projector **22***b* project the AR object **4***b* on the screen **23** as a video to be viewed by the left eye and a video to be viewed by the right eye so that the AR object **4***b* is three-dimensionally displayed as if the AR object **4***b* is present at a predetermined distance in the real space. In the viewer HMDs **3***b*, **3***c*, a VR video, which will be described later, and the AR object **4***b* are superimposed and then displayed.

[0049] For displaying a video of an MR space on the HMDs, the occlusion techniques are applied to process the drawing data of the AR object, so that the video of the MR space can be displayed with more reality. Using the occlusion techniques enables, based on the front and rear distance relation between the real object **4***a* and the AR object **4***b*, such displaying that, when a portion of the real object **4***a* is in front of a portion of the AR object **4***b*, the portion of the AR object **4***b* is hidden in the portion of the real object **4***a*.

[0050] The processor **25**, the camera **21**, the speaker **26**, and the microphone **27** are arranged in the frame housing **28**. Note that the arrangement thereof does not have to be the same as that illustrated in FIG. **2**A and FIG. **2**B.

(Block Diagram of 3D Virtual Reality Display Apparatus)

[0051] FIG. **3** is a block diagram of the experiencer HMD **1**. In FIG. **3**, the processor **25** is surrounded by a broken line, and is connected to the camera **21**, the ranging camera **29**, the left projector **22***a*, the right projector **22***b*, the screen **23**, the speaker **26**, the microphone **27**, an orientation sensor **250**, a gyro sensor **251**, and an acceleration sensor **252**.

[0052] The processor **25** includes a CPU **254**, a RAM **255**, a video RAM **256**, a FROM **257**, a feature extraction processor **260**, a distance calculation processor **261**, the orientation sensor **250**, the gyro sensor **251**, the acceleration sensor **252**, and an internal bus **262**. The elements above are connected to each other via the internal bus **262**. In some cases, the processor **25** may be configured without the orientation sensor **250**, the gyro sensor **251**, and the acceleration sensor **252**.

[0053] The left projector **22***a* and the right projector **22***b* project an image for the left eye and an image for the right eye onto the screen **23**, respectively and independently, so as to realize 3D-display of a video. Alternatively, they may be other display apparatuses capable of realizing 3D-display such as an optical system using holographic lenses.

[0054] A wireless communication interface **253** selects appropriate processing from among several types of communication processing of, for example, mobile communication such as 4G and 5G, wireless LAN, and the like and connects the HMD **1** to the network **7** via any of the access points **5***a*, **5***b*, **5***c*.

[0055] The FROM **257** includes, as processing programs, a basic program **258** and an MR experience program **259**. The CPU **254** loads these processing programs and executes them on the RAM **255**. In addition, the FROM **257** retains data necessary for executing the processing programs. The FROM **257** may be a single memory medium as illustrated in FIG. **3**, or configured with a plurality of memory media, and moreover, the FROM **257** may be a non-volatile memory medium other than a Flash ROM.
[0056] The CPU **254** stores video data to be transmitted to the left projector **22***a* and the right projector **22***b* in the video RAM **256**. The CPU **254** reads the video data from the video RAM **256**, whereby the video data is projected from the left projector **22***a* and the right projector **22***b* onto the screen **23**.
[0057] The feature extraction processor **260** extracts an outline (edge) of a real object from a background video taken by the camera **21**, and performs the processing to set an inflection point and a vertex in the outline as feature points. The distance data obtained by the distance calculation processor **261** is combined with these feature points. A set of feature point data forming the outline is associated with the background video.
[0058] The orientation sensor **250**, the gyro sensor **251**, and the acceleration sensor **252** are used to trace, for example, the position of the HMD **1** and the capturing direction of the camera (equivalent to the line of sight of the experiencer **11**). Using the positions obtained by using the access points **5***a*, **5***b*, **5***c* whose arrangement positions have been already known, which will be described later, and the line-of-sight directions in the vertical and lateral directions obtained by the orientation sensor **250** and the acceleration sensor **252** and also tracing the motion of the HMD **1** by the gyro sensor **251** or the like enables detection of change in the position and direction caused by the motion of the wearer (experiencer **11**) of the HMD **1**.
[0059] FIG. **4** is a block diagram of the participant HMDs **2***a* to **2***e*. In FIG. **4**, the FROM **257** retains the basic program **258** and an MR participation program **263**. The HMDs **2***a* to **2***e* have the same hardware configuration as that of the HMD **1**, but differs from the HMD **1** in that the MR participation program **263** which is an application program is stored in place of the MR experience program **259** of the HMD **1**.
[0060] FIG. **5** is a block diagram of the viewer HMDs **3***b*, **3***c*. In FIG. **5**, the camera **21** and the ranging camera **29** are omitted, and the FROM **264** retains a basic program **265** and an MR viewing program **266**. Furthermore, the viewer HMDs **3***b*, **3***c* include, instead of the left projector **22***a*, the right projector **22***b*, and the screen **23**, an immersive (non-transparent, shielding) display **30**.
[0061] FIG. **6** is a block diagram of the VR server **8**. In FIG. **6**, the VR server **8** includes a network interface (network IF) **81** for a wired LAN and the like, a CPU **82**, a RAM **83**, a storage **84**, and an internal bus **87**. The elements above are connected to each other via the internal bus **87**.
[0062] The storage **84** may be configured with, other than the Flash ROM, a hard disk drive or the like. The storage **84** includes a VR creation program **85** as a processing program, and the CPU **82** loads the VR creation program **85** and executes it on the RAM **83**. The storage **84** further includes VR data **86**, and retains data necessary for executing the processing program.
[0063] FIG. **7** is a block diagram of the AR server **9**. In FIG. **7**, the AR server **9** includes a network IF **91** for a wired LAN and the like, a CPU **92**, a RAM **93**, a storage **94**, and an internal bus **97**. The elements above are connected to each other via the internal bus **97**.
[0064] The storage **94** may be configured with, other than the Flash ROM, a hard disk drive or the like. The storage **94** includes an AR drawing program **95** as a processing program, and the CPU **92** loads the AR drawing program **95** and executes it on the RAM **93**. The storage **94** further includes AR data **96**, and retains data necessary for executing the processing program. The storage **94** may archive a previously created AR object as the AR data **96**, and urge the experiencer to use it during execution of the processing program.
(Generation of VR Video)

[0065] FIG. **8** is a diagram for explaining an exemplary method of detecting the positions of the HMD **1** and HMDs **2***a* to **2***e* worn by the experiencer **11** and participants **12***a* to **12***e*. In FIG. **8**, the access points **5***a* to **5***c* which are installed in the MR space **6** and whose installation positions have been already known are used to detect the positions of the HMD **1** and HMDs **2***a* to **2***e*. The position calculation method is common to the HMD **1** and HMDs **2***a* to **2***e*, and thus in the following, an example of the HMD **1** will be described.

[0066] The HMD **1** at the position of a point P, receives the network signals **10***g* to **10***i* from the access points **5***a* to **5***c*, and then calculates distances to the access points **5***a* to **5***c* based on the strength of the received signals. In FIG. **8**, where a distance to the access point **5***a* is r1, a distance to the access point **5***b* is r2, and a distance to the access point **5***c* is r3, one point on a surface on which a spherical surface whose distance from the access point **5***a* is r1, a spherical surface whose distance from the access point **5***b* is r2, and a spherical surface whose distance from the access point **5***c* is r3 intersect to each other is the point P, and thus the presence range within the MR space **6** is narrowed down. The HMD **1** can identify the position of the point P based on, in addition to the information about the received strength, the height of the head on which the HMD **1** is worn, an image visible through the camera **21**, and information from various sensors.

[0067] Regarding the direction in which the HMD **1** at the point P faces, that is, the direction of the line-of-sight of the experiencer **11**, the orientation sensor **250** is used to define the lateral direction thereof and the acceleration sensor **252** is used to define the vertical direction thereof.

[0068] While experiencing MR, the position of the experiencer **11** varies, and also his or her line of sight changes in accordance with the motion of the head. The change above can be detected by tracing the movement using the acceleration sensor **252**, the gyro sensor **251**, and the like. When it is detected that the HMD **1** after moving is still, for example, position detection using the access points **5***a* to **5***c* may be performed again to reset the cumulative error in tracing using the sensors.

[0069] The method of calculating the position and direction of the HMD **1** is not limited to the method described above. For example, a method using a video marker instead of the access points **5***a* to **5***c* and also using the ranging camera **29** in addition to the equipped camera **21** may be employed so as to measure a distance to the video maker by capturing the video marker using the camera **21**, or, calculate the movement based on change in the video marker captured using the camera **21**.

[0070] FIG. **9** is a diagram for explaining how to generate a VR video.

[0071] In order to generate a VR video, images taken by the cameras of the experiencer HMD **1** and participant HMDs **2***a* to **2***e* are pasted on the surface of the upper hemisphere with the radius R. When any of the HMD among the experiencer HMD **1** and participant HMDs **2***a* to **2***e*, which is at the position of a point E, faces a point PE on the surface of the upper hemisphere and is taking a video, the camera-captured video is pasted to an area having the point PE on its center. In the same manner, when the HMD which is at the position of a point F faces a point PF on the surface of the upper hemisphere and is taking a video, the camera-captured video is pasted to an area having the point PF on its center. In an area where the two areas overlap to each other, the areas are stitched to each other at the borders of the objects appearing in the camera-captured videos to form a consecutive VR video. All the experiencer HMD **1** and participant HMDs **2***a* to **2***e* perform this processing. As a result, it is possible to obtain a VR video in which a video is pasted to an area which is not the entire area of the upper hemisphere but includes a line of sight of the experiencer **11** or those of the participants **12***a* to **12***e*.

[0072] In stitching the two overlapping areas to each other, correcting and finely adjusting the position and direction of the HMD so as to make the size and position of the objects at the border match and using results of the adjustment as the position and direction data of the HMD enables improvement in the accuracy of the position and direction of the HMD.

[0073] FIG. **10** is a diagram for explaining normalization of a VR video.

[0074] FIG. **10** illustrates a case of taking a video of a point K from a point H and a case of taking a video of the point K from a point G. In the two cases, the angle of view of the camera **21** during taking a video is the same with each other, and thus a video-taking area in the case of taking the video from the point G which is closer to the point K is narrower than the other case. Conversely, the same subject appears larger in a capturing screen. In generating a VR video for viewers, where the distance between the point G and the point K is d2 and the distance between the point H and the point K is d1 and in the case of pasting a video P**2** taken from the point G to an area having the point K on its center, the video P**2** is converted to a video as if it was taken from the point H on the surface of the upper hemisphere. In the case where the ratio of the two capturing ranges is d2/d1, a normalized video can be obtained by normalizing the video P**2** taken from the point G at this ratio. An area for displaying the normalized video P**2** is smaller than an area P**1** of a video actually taken from the point H.

(MR Experience Program)

[0075] FIG. **11** is a flowchart of the MR experience program **259**.

[0076] The HMD **1** is started, and logs in to the user management processing to share the MR space **6** (step S**101**). The user management processing is not illustrated in the system configuration of FIG. **1**, and the server for the user management processing may be provided independently, or the functions thereof may be provided in the VR server **8** and the AR server **9**. Upon completion of log-in to the user management processing, the user is registered as the experiencer **11** in the VR server **8** and the AR server **9**.

[0077] The camera **21** and ranging camera **29** of the HMD **1** starts capturing videos (step S**102**). The camera-captured video includes distance data to a real object. The video may be taken, for example, at 30 fps (frame per second) and stored, and subsequent steps may be performed in synchronization with a camera-capturing cycles.

[0078] The HMD **1** detects the position of the HMD **1** in the MR space **6** (step S**103**).

[0079] The HMD **1** detects a direction in which the camera **21** is taking a video (step S**104**). The position information about the HMD **1** and the detected direction of capturing serve as meta data of the camera-captured video.

[0080] From step S**105** to step S**111**, the flow branches in two and the processes are performed in parallel. Step S**105** to step S**110** are processes related to the processing with the AR server **9**, and step S**111** to step S**113** are processes related to the processing with the VR server **8**.

[0081] In step S**105**, the HMD **1** transmits the data of the position and capturing direction of the HMD **1** to the AR server **9**.

[0082] The HMD **1** selects an AR object to be used for the MR experience, for example, from a list stored in the AR server **9**, and generates it as data to be displayed (step S**106**).

[0083] The HMD **1** receives the drawing data of the selected AR object and displays it on the screen **23** (step S**107**).

[0084] When the experiencer **11** performs an operation on the displayed AR object **4***b* (step S**108**), the HMD **1** sets parameters indicating the performed operation content, such as an arrangement position in the MR space **6**, size, and orientation. The parameters such as the arrangement position, direction, and the like are relative values with the position and direction of the HMD **1** being as a reference. The HMD **1** transmits the set parameters to the AR server **9**, and the AR server **9** transmits the drawing data of the AR object **4***b* in which the parameters are reflected to the HMD **1**.

[0085] The HMD **1** receives the drawing data of the AR object **4***b* in which the set parameters are reflected, and displays the received data (step S**109**). In displaying, the HMD **1** processes the drawing data of the AR object **4***b* so that, in the relation such that a portion of the real object **4***a* is in front of a portion of the AR object **4***b*, based on the distance relation between the real object **4***a* and the AR object **4***b*, the portion of the AR object **4***b* appears hidden in the portion of the real object **4***a*.

[0086] The plurality of AR objects may be processed in one step, or the limited number of AR objects may be processed in one step and the processing of the whole AR objects can be performed over a plurality of camera-capturing cycles. The AR object that has been generated once remains in the MR space **6** unless the experiencer **11** cancels it. In the case where the experiencer **11** moves and thus the position and direction changes, the data of the drawn AR object to be received in step S**109** includes all the AR objects which have been already generated. In step S**110**, the HMD **1** determines whether the camera-capturing cycle has been reached (Time), and if not yet reached (step S**110**: No), the HMD **1** returns the processing to step S**106**, and if already reached (step S**110**: Yes), the HMD **1** determines whether the program is to be terminated (step S**114**).

[0087] In parallel with step S**105** to step S**110**, the HMD **1** transmits the data of the position and capturing direction of the HMD **1** (step S**111**) and camera-captured video data to the VR server **8** (step S**112**). The camera-captured video data is distance data between the background video taken by the camera **21** and the real object **4***a* measured by the ranging camera **29**.

[0088] The HMD **1** determines whether the camera-capturing cycle is reached (step S**113**), stands by until the cycle has been reached (step S**113**: Yes), checks whether the program is to be terminated (step S**114**), and if not to be terminated (step S**114**: No), continues the steps from step S**103** in the subsequent camera cycle. When it is to be terminated (step S**114**: Yes), the HMD **1** terminates the series of processes.

[0089] FIG. **12** is a flowchart of the MR participation program **263**. The processing illustrated in FIG. **12** is executed in the participant HMDs **2***a* to **2***e*. In the following, an example of the HMD **2***a* will be described.

[0090] The participant **12***a* wearing the participant HMD **2***a* logs into the user management processing to share the MR experience (step S**121**). Upon completion of log-in to the user management processing, the user is registered as a participant in the VR server **8** and the AR server **9**.

[0091] The HMD **2***a* starts capturing videos with the camera **21** mounted on the HMD **2***a* (step S**122**). The HMD **2***a* may perform the subsequent steps in synchronization with the camera-capturing cycle.

[0092] The HMD **2***a* detects the position of the HMD **2***a* in the MR space **6** (step S**123**).

[0093] The HMDs **2***a* detects a direction in which the camera is taking a video (line of sight of the participant) of the HMD **2***a* (step S**124**) and associates it with the camera-captured video.

[0094] Step S**125** to step **127** are processes related to the processing with the AR server **9**, and step S**128** to step S**129** are processes related to the processing with the VR server **8**.

[0095] The HMD **2***a* transmits the data of the position and direction of the HMDs **2***a* to the AR server **9** (step S**125**), receives the drawing data of the AR object generated by the experiencer from the AR server **9** (step S**126**), and displays the received drawing data on the screen **23** of the HMD **2***a* (step S**127**).

[0096] The drawing data of the AR object **4***b* to be received is data drawn to correspond to the participant HMD **2***a* based on the data of the position and direction of the HMD **2***a* transmitted in step S**125**.

[0097] In displaying, the HMD **2***a* processes the drawing data of the AR object **4***b* so that, in the relation such that a portion of the real object **4***a* is in front of a portion of the AR object **4***b*, based on the distance relation between the real object **4***a* and the AR object **4***b*, the portion of the AR object **4***b* appears hidden in the portion of the real object **4***a*.

[0098] FIG. **13** is a diagram for further explaining the position of the AR object **4***b*.

[0099] The experiencer **11** is at a position T and generates the AR object **4***b* at a position U. The magnitude of a vector Vtu from the point T to the point U is the distance between the experiencer **11** and the AR object **4***b*. At this time, it is assumed that the participant **12***a* is at a position S and views the AR object **4***b*. Where the vector between the position T of the experiencer **11** and the position S of the participant **12***a* is Vts, a vector Vsu between the position S of the participant **12***a* and the position U of the AR object **4***b* is given by (vector Vtu-vector Vts). Thus, the distance between the participant **12***a* and the AR object **4***b* is determined based on the magnitude of the

vector Vsu, and in displaying the AR object **4***b* on the participant HMD **2***a*, the front and rear distance relation between the distance to the AR object **4***b* obtained based on the magnitude of the vector Vsu and the distance to the real object obtained by the ranging camera **29** is evaluated.
[0100] In parallel with step S**125** to step S**127**, the HMD **2***a* transmits the data of the position and capturing direction of the HMD **2***a* (step S**128**) and camera-captured video data to the VR server **8** (step S**129**).
[0101] The HMD **2***a* determines whether the camera-capturing cycle is reached (step S**130**), stands by until the cycle has been reached (step S**130**: Yes), checks whether the program is to be terminated (step S**131**), and if not to be terminated (step S**131**: No), continues the steps from step S**123** in the subsequent camera cycle. When it is to be terminated (step S**131**: Yes), the HMD **1** terminates the series of processes.
(MR Viewing Program)
[0102] FIG. **14** is a flowchart of the MR viewing program **266**. The processing illustrated in FIG. **14** is executed in the viewer information terminal **3***a* and the viewer HMDs **3***b*, **3***c*. Hereinafter, an example of the HMD **3***b* will be described.
[0103] The viewer **13***b* wearing the viewer HMD **3***b* logs into the user management processing to share the MR experience (step S**141**). Upon completion of log-in to the user management processing, the user is registered as a viewer in the VR server **8** and the AR server **9**.
[0104] The HMD **3***b* receives the drawing data of the AR object **4***b* (initial data of the AR object **4***b*) from the AR server **9**. In parallel therewith, the HMD **3***b* receives VR video data (VR initial data) from the VR server **8** (step S**143**).
[0105] The HMD **3***b* displays the AR object **4***b* and the VR video on the display **30** of the HMD **3***b* (step S**144**).
[0106] The AR object **4***b* and VR video in these steps are displayed, as if the HMD **3***b* was at a default origin, for example, at a position and in a direction which oppose the experiencer **11** on the surface of the upper hemisphere.
[0107] The VR video data includes, for each real object **4***a*, the meta data of the positions and directions of the HMD **1** and HMDs **2***a* to **2***e* that have performed capturing and the distance data to the real object **4***a*. The VR server **8** calculates the distance to the real object **4***a* based on the relation between the positions of the HMD **1** and HMDs **2***a* to **2***e* that have performed capturing and the position of viewpoint of a viewer of the viewer HMD **3***b* (viewpoint position is obtained by detecting the motion of the head of the viewer).
[0108] Then, the AR server **9** corrects the distance to the AR object **4***b* based on the position of the AR object **4***b* and the relation between the real object **4***a* and the viewpoint position of the viewer HMDs **3***b*. At this time, the AR server **9** process the drawing data of the AR object **4***b* so that, in the relation such that a portion of the real object **4***a* is in front of a portion of the AR object **4***b*, the portion of the AR object **4***b* appears hidden in the portion of the real object **4***a*.
[0109] Note that the default position and direction of the HMD **3***b* may be changed to the position and direction set by the viewer **13***b*, and the position and direction after being changed and set may be used as a starting point when the MR viewing program is started.
[0110] The viewer **13***b* moves his or her head while viewing the VR video, whereby the viewpoint and line of sight of the viewer **13***b* is moved. When the HMD **3***b* detects that the head has been rotated to the left, the VR server **8** causes the VR video to shift to the right relatively. When the HMD **3***b* detects that the head has been moved forward, the HMD **3***b* enlarges the VR video and displays it. This creates the MR experience that makes the viewer **13***b* feel as if he or she had approached.
[0111] The HMD **3***b* detects the motion of the head of the viewer **13***b* using the orientation sensor **250**, the gyro sensor **251**, the acceleration sensor **252**, and the like. The HMD **3***b* transmits the detected motion information to the AR server **9** (step S**146**), and also transmits it to the VR server **8** (step S**148**).

[0112] The HMD **3***b* receives update data of the AR object **4***b* viewed from the position and direction of the viewpoint of the HMD **3***b* of the viewer **13***b* based on the transmitted motion information (step S**147**). Furthermore, the HMD **3***b* receives, from the VR server **8**, update data of the VR video viewed from the position and direction of the viewpoint of the HMD **3***b* of the viewer **13***b* (step S**149**).
[0113] In the same manner as the process in step S**144**, the HMD **3***b* superimposes the AR object **4***b* and the VR video and displays them, considering the distance relation between the real object **4***a* and the AR object **4***b* (step S**150**). This allows the viewer **13***b* to view the MR experience.
[0114] The HMD **3***b* determines whether a displaying period has been reached based on an update unit (frame rate) of an image frame (step S**151**), stands by until the period is reached (step S**151**: Yes), checks whether the MR viewing program is to be terminated (step S**152**), and if not to be terminated (step S**152**: No), continues the steps from step S**145** in the subsequent display period. When the MR viewing program is to be terminated (step S**152**: Yes), the HMD **3***b* terminates the series of processes.
[0115] FIG. **15** is a flowchart of the VR creation program **85**.
[0116] Various types of processing are provided to the registered HMD **1** of experiencer **11**, HMDs **2***a* to **2***e* of participants **12***a* to **12***e*, and the information terminal **3***a* and HMDs **3***b*, **3***c* of the viewers **13***a* to **13***c*. The processing by the VR creation program **85** includes the receiving processes in step S**161** to step S**165** and the transmitting processes in step S**165** to step S**171**.
[0117] The VR server **8** provides the HMD **1** and HMDs **2***a* to **2***e* of the experiencer **11** and participants **12***a* to **12***e* with the receiving processes.
[0118] The VR server **8** receives the camera-captured video data of the HMD **1** and HMDs **2***a* to **2***e* (step S**161**), together with the data of the positions and directions of the HMDs that have generated the camera-captured videos (step S**162**).
[0119] The VR server **8** normalizes the received camera-captured video data (step S**163**), and pastes it on the upper hemispherical surface to add it to the VR video data (step S**164**).
[0120] The VR server **8** switches to the HMD which has transmitted a request to receive the camera-captured video data (step S**165**: Yes), and returns the processing to step S**161**. In the case where there is no HMDs transmitting a receiving request (step S**165**: No), the VR server **8** determines whether the processing is to be terminated (step S**172**).
[0121] The VR server **8** provides the information terminal **3***a* and HMDs **3***b*, **3***c* of the viewers **13***a* to **13***c* with the transmitting processes.
[0122] The VR server **8** determines whether a target to be provided with transmission is a new apparatus (step S**166**), and when the transmission providing target is a new apparatus (step S**166**: Yes), acquires start point data of the transmission providing target and transmits the initial data of the VR video thereto (step S**167**).
[0123] When the transmission providing target is not a new apparatus (step S**166**: No) or after having transmitted the initial data of the VR video (step S**167**), the VR server **8** receives, from the HMD that is the transmission providing target, motion data indicating the motion of the transmission providing target HMD (step S**168**).
[0124] The VR server **8** calculates the position and direction of the transmission providing target HMD and the like based on the motion data, cuts out a portion of an area from the VR video data of the upper hemispherical surface (step S**169**), and transmits the cut-out VR video data (VR video update data) to the transmission providing target HMD (step S**170**).
[0125] In the case another HMD or information terminal is requesting transmission of the VR video data (step S**171**: Yes), the VR server **8** switches to the other transmission providing target HMD (or information terminal) and returns the processing to step S**166**. In the case where there is no other HMDs or information terminals requesting transmission (step S**171**: No), the VR server **8** determines whether the processing is to be terminated (step S**172**). Upon receiving an instruction to terminate the processing (for example, in the case of receiving the termination of the MR

experience from the HMD **1** of the experiencer **11**), the VR server **8** terminates the processing (step S**172**: Yes).

[0126] In absence of an instruction to terminate the processing (step S**172**: No), the VR server **8** returns the processing to the process immediately after the start of the processing, and continues the processes in step S**161** and step S**166**.

(AR Drawing Program)

[0127] FIG. **16** is a flowchart of the AR drawing program **95**.

[0128] The AR server **9** provides the HMD **1**, HMDs **2***a* to **2***e*, HMDs **3***b*, **3***c*, and information terminal **3***a* of the registered experiencer **11**, participants **12***a* to **12***e*, and viewers **13***a* to **13***c* with various types of processing. The processing by the AR server **9** mainly includes the processes in step S**181** to step S**187** to be provided to the experiencer HMD **1**, the processes in step S**188** to step S**191** to be provided to the participant HMDs **2***a* to **2***e*, and the processes in step S**192** to step S**197** to be provided to the viewer HMDs **3***b*, **3***c* and the information terminal **3***a*.

[0129] In step S**181**, the AR server **9** determines whether a request has been transmitted from the experiencer HMD, and determines the type thereof. In absence of transmission of a request (step S**181**: No), the AR server **9** stands by until a request is transmitted.

[0130] In the case of a new request (step S**181**: new), the AR server **9** receives selection data of the AR object from the HMD **1** (step S**182**), and transmits the default drawing data of the selected AR object (step S**183**). Then, the AR server **9** proceeds the processing to step S**187**.

[0131] In the case of an operation request (step S**181**: operation), the AR server **9** receives the data of the operation parameters from the HMD **1** (step S**184**), redraws the AR object in accordance with the operation parameters (step S**185**), and transmits the data of the redrawn AR object to the HMD **1** (step S**186**). Then, the AR server **9** proceeds the processing to step S**187**.

[0132] In step S**187**, the AR server **9** determines whether a subsequent request has been received. Upon receiving a subsequent request (step S**187**: Yes), the AR server **9** continues the processing, and if not receiving (step S**187**: No), the AR server **9** proceeds the processing to the termination determination (step S**198**).

[0133] In step S**188**, the AR server **9** receives the data of the position and direction of the registered one (transmission target participant HMD) of the participants HMDs **2***a* to **2***e*. Then, the AR server **9** redraws the AR object **4***b* being selected by the HMD **1** of the experiencer **11** in accordance with the data of the position and direction received in step S**188** (step S**189**), and transmits the data of the redrawn AR object to the transmission target participant HMD (step S**190**).

[0134] In step S**191**, in the case where the registered participant HMDs **2***a* to **2***e* are left unprocessed or the position and direction of the registered participant changes (step S**191**: Yes), the AR server **9** returns the processing to step S**188**. In the case where all the registered participant HMDs **2***a* to **2***e* have been processed (step S**191**: No), the AR server **9** proceeds the processing to the termination determination (step S**198**).

[0135] In step S**192**, the AR server **9** determines whether the information terminal **13***a* of the viewer **3***a* or the viewer HMDs **3***b* or **3***c* which is a transmission providing target is a new apparatus (step S**192**). When the transmission providing target is a new apparatus (step S**192**: Yes), the AR server **9** transmits the initial data of the AR object **4***b* thereto (step S**193**). In the same manner as the case of the VR video, the initial data is, for example, data drawn on the upper hemisphere surface assuming a position and a direction which oppose the HMD **1** for the experiencer **11**.

[0136] When it is not a new apparatus (step S**192**: No) or after having transmitted the ARO drawing (initial) data (step S**193**), the AR server **9** receives data of motion information about a viewer terminal that is a transmission providing target, for example, the HMD **3***b* (step S**194**), and calculates the position and direction of the transmission providing target viewer terminal. Then, the AR server **9** redraws the AR object **4***b* in accordance with the received motion data (step S**195**), and transmits the data of the redrawn AR object to the transmission providing target viewer terminal (step S**196**).

[0137] The AR server **9** determines whether any other transmission providing target viewer terminal is left unprocessed. When it remains (step S**197**: Yes), the AR server **9** returns the processing to step S**192**, and when all the transmission providing target viewer terminals have been processed (step S**197**: No), the AR server **9** proceeds the processing to the termination determination (step S**198**).
[0138] The AR server **9** determines whether the processing is to be terminated (step S**198**). Upon receiving a termination instruction, the AR server **9** terminates a series of processes (step S**198**: Yes). In absence of a termination instruction (step S**198**: No), the AR server **9** returns the processing to step S**180** and continues the processing.
[0139] In the above, the case where the HMD **1**, HMD **2***a* to **2***e*, HMD **3***b*, **3***c* and the information terminal **3***a* process the drawing data of the AR object **4***b* so that, in the relation such that a portion of the real object **4***a* is in front of a portion of the AR object **4***b*, based on the distance relation between the real object **4***a* and the AR object **4***b*, the portion of the AR object **4***b* appears hidden in the portion of the real object **4***a* has been described. However, the processing above may be performed by the AR server **9**. In this case, in the processing on each of the HMD **1**, HMD **2***a* to **2***e*, HMD **3***b*, **3***c*, and the information terminal **3***a*, a step of transmitting, in addition to the data of the position and direction, data of the real object **4***a* included in the VR video data acquired from the VR server **8** to the AR server **9** is added. More particularly, the data to be transmitted is video data that is created from the viewpoint of how the real object **4***a* is visible, based on a composite video of a plurality of pieces of capturing data using the data of the positions and directions based on each of the HMDs. Meanwhile, in the processing on the AR server **9**, a step of receiving the data above from each of the HMD **1**, HMD **2***a* to **2***e*, HMD **3***b*, **3***c* and the information terminal **3***a* is added.
[0140] FIG. **17** illustrates an exemplary method of selecting a position of a viewpoint when the viewers **13***a* to **13***c* view a VR video. In particular, setting a viewpoint for viewing the real object **4***a* and the AR object **4***b* enables the viewer to observe the real object **4***a* and the AR object **4***b* with his or her preferable viewpoint.
[0141] Three-dimensional arrows **301**, **302** are examples of pointers for selecting a viewpoint position and a line-of-sight direction. The viewer operates the three-dimensional arrows **301**, **302** to select which position of a viewpoint in the MR space **6** is to be used for viewing a VR video. At this time, the viewer is allowed to specify which line of sight direction is to be selected with the broken lines. Furthermore, rotating the MR space **6** enables the viewer to decide the positions and directions of the three-dimensional arrows **301**, **302** three-dimensionally. Using pointers allowing the viewer to flexibly select the position and direction, such as the three-dimensional arrows **301**, **302**, enables the user to select a viewpoint position and line-of-sight direction. For example, like the case of using the three-dimensional arrows **301**, **302**, in the case of dividing the processing of flexibly selecting a position and direction into two steps, firstly, determining the positions of the three-dimensional arrows **301**, **302** and then changing the line-of-sight directions of the three-dimensional arrows **301**, **302**, an operation of grasping arrow portions at the tips of the dotted lines and moving them may be performed to determine the directions.
[0142] In the viewer HMDs **3***b*, **3***c* or the viewer information terminal **3***a*, an input interface, for example, in the case of audio input, the microphone **27** or a switch (not illustrated in FIG. **5**) is used to enter a mode for displaying a pointer for allowing the viewer to select a line-of-sight position and line-of-sight direction, and in such a mode, the three-dimensional arrow is displayed. When the mode above is terminated, display of three-dimensional arrow is cancelled, and instead, the display is switched to a video from the selected line-of-sight position and line-of-sight direction.
[0143] According to the virtual reality sharing system **100** of the first embodiment, the viewers **13***a* to **13***c* at the remote site can view the MR experience using the VR video generated from the camera-captured videos by the experiencer **11** and participants **12***a* to **12***e*. The VR video can be

generated based on the camera-captured videos viewed from various angles, and thus the viewers **13***a* to **13***c* can continuously and approximately arbitrarily select the line of sight.

[0144] Furthermore, the virtual reality sharing terminals (HMD **1**, HMDs **2***a* to **2***e*) for the experiencer **11** and participants **12***a* to **12***e* contribute to generation of a VR video, and the virtual reality sharing terminals for the viewers **13***a* to **13***c* (informational terminal **3***a* and HMDs **3***b*, **3***c*) are able to share the MR experience using the VR video.

Second Embodiment

[0145] FIG. **18** is a schematic diagram of a virtual reality sharing system **100***a* according to a second embodiment. The virtual reality sharing system **100***a* according to the second embodiment is different from the virtual reality sharing system **100** according to the first embodiment illustrated in FIG. **1** in that a fixed camera **14** is arranged. The captured video by the fixed camera **14** is provided to the VR server **8** using the network signal **10***p*, and is used as video data for creating a VR video together with the camera-captured videos taken by the virtual reality sharing terminals for the experiencer **11** and participants **12***a* to **12***e*.

[0146] As the fixed camera **14**, using, for example, a 360° camera to obtain a video of an upper hemisphere enables sharing of a video of an area that cannot be covered by the virtual reality sharing terminals for the experiencer **11** and participants **12***a* to **12***e*. This allows the VR video to be generated as the video of the upper hemisphere without any breaks, and thus the VR video having no break can be observed as a background video from the virtual reality sharing terminals of the viewers **13***a* to **13***c*. Furthermore, in the case where the virtual reality sharing terminals for the experiencer **11** and participants **12***a* to **12***e* can partially capture images which are high-definition more than the 360° camera, combining these images enables provision of a high-quality VR video.

[0147] FIG. **19** is a schematic diagram of a modification of a virtual reality sharing system **100***b*. The virtual reality sharing system **100***b* differs from the virtual reality sharing system **100***a* in that fixed cameras **14***b*, **14***c* each having a limited angle of view are arranged instead of the fixed camera **14***a* that is a 360° camera.

[0148] FIG. **19** illustrates only the fixed cameras **14***b*, **14***c*, however, preferably, the fixed cameras are arranged at the four corners of the MR space **6**, respectively, to cover the entire MR space to be captured. Alternatively, the fixed cameras are arranged so that videos of the entire object can be captured from many directions. The captured videos by the fixed cameras **14***b*, **14***c* are provided to the VR server **8** using network signals **10***q*, **10***r*, and used as video data for creating a VR video together with the camera-captured videos captured by the virtual reality sharing terminals for the experiencer **11** and participants **12***a* to **12***e*.

[0149] According to the virtual reality sharing system **100***b*, a relatively high-quality VR video can be obtained as compared with the case of the virtual reality sharing system **100***a*.

[0150] Furthermore, in the virtual reality sharing system **100***a*, a VR video that can be obtained is the one as if a video is pasted on the inside of the upper hemispherical surface, and thus the viewers **13***a* to **13***c* can obtain the VR video with the viewpoint being set to the inside, whereas in the virtual reality sharing system **100***b*, the viewers **13***a* to **13***c* can obtain the VR video with the AR object **4***b* as the center and the viewpoint being outside the AR object **4***b*.

[0151] As described above, according to the second embodiment, the same advantageous effects as those of the first embodiment can be obtained with a small number of additional facilities. Furthermore, it is possible to obtain a VR video, in which videos are pasted on the entire upper hemispherical surface and has the viewpoint inside thereof, and a VR video having an object on the center and the viewpoint from the outside, whereby the entire MR space **6** can be easily grasped from the virtual reality sharing terminal for the viewers **13***a* to **13***c*.

Third Embodiment

[0152] FIG. **20** is a block diagram of a participant HMD **2***f* of a virtual reality sharing system according to a third embodiment. In the third embodiment, the virtual reality sharing systems **100**, **100***b*, **100***c* illustrated in FIG. **1**, FIG. **18**, and FIG. **19** use a participant HMD **2***f* instead of the participant HMDs **2***a* to **2***e* of the first and second embodiments.

[0153] The screen **23** of the participant HMD **2***f* differs from the participant HMDs **2***a* to **2***e* according to the first and second embodiments in that it includes a shutter **231** and a half mirror **232**.

[0154] When the shutter **231** is controlled to the open state, the participant HMD **2***f* functions as a transparent type HMD. That is, the background video of the real space and the AR object **4***b* projected from a projector **22** (generic term for the left-projector **22***a* and right-projector **22***b*) can be viewed on the half mirror **232**.

[0155] On the other hand, when the shutter **231** is controlled to the close state, the AR object **4***b* and the VR video are superimposed and projected from the projector **22**. In this case, the participant HMD **2***f* functions as an immersive type HMD. In the same manner as the viewers **13***a* to **13***c*, this allows the participants **12***a* to **12***e* to flexibly select a viewpoint position and line-of-sight direction to experience the MR viewing.

[0156] FIG. **21** is a flowchart of an MR participation program **263***a*.

[0157] After being started, the HMD **2***f* logs into the user management processing to share the MR experience (step S**211**). Upon completion of log-in to the user management processing, the user is registered as a participant in the VR server **8** and the AR server **9**.

[0158] The HMD **2***f* starts taking a video with cameras (step S**212**). The HMD **2***f* may perform the subsequent steps in synchronization with the camera-capturing cycle.

[0159] The HMD **2***f* detects the HMD position in the MR space (step S**213**), detects the capturing direction of the camera of the HMD **2***f* (step S**214**), and associates them as meta data of the camera-captured video.

[0160] In step S**218**, the HMD **2***f* transmits the data of the position and direction of the HMD **2***f* to the AR server **9**. The HMD **2***f* receives the drawing data of the AR object **4***b* generated by the experiencer **11** (step S**219**).

[0161] In the case where the shutter **231** is closed (step S**215**: Yes), the HMD **2***f* can be used as an immersive type HMD. In this case, the HMD **2***f* transmits the motion information about the HMD **2***f* to the VR server **8** (step S**216**), receives the VR video data that corresponds to the motion information from the VR server (step S**217**), and proceeds the processing to step S**222**.

[0162] In the case where the shutter **231** is open (step S**215**: No), the HMD **2***f* can be used as a transparent type HMD. This case does not require VR videos, and thus the HMD **2***f* proceeds the processing to step S**222**.

[0163] In step S**222**, the HMD **2***f* superimposes the AR object **4***b* on the VR video received in step S**217**. On the other hand, in the case of being used as a transparent type HMD, the HMD **2***f* merely projects the AR object **4***b* onto the screen **23**, whereby the AR object **4***b* is superimposed on the background video viewed transparently through the shutter **231** and the half mirror **232**. Then, the HMD **2***f* proceeds the processing to step S**223**.

[0164] Here, it is determined whether the HMD **2***f* is inside or outside the MR space **6** by using the distances from the access points **5***a* to **5***c*. When the HMD **2***f* is in the MR space **6**, the user can select either an immersive type or a transparent type via the input interface. When it is determined that the HMD **2***f* is outside the MR space **6**, the HMD **2***f* is automatically switched to the immersive type (shutter **231** is closed).

[0165] In step S**220**, the HMD **2***f* transmits the data of the position and direction of the HMD **2***f* (step S**220**) and camera-captured video data (step S**221**) to the VR server **8**. Then, the HMD **2***f* proceeds the processing to step S**223**.

[0166] The HMD **2***f* determines whether the camera-capturing cycle has been reached (step S**223**), stands by until the cycle is reached (step S**223**: Yes), checks whether the MR participation program is to be terminated, and if not to be terminated (step S**224**: No), continues the steps from step S**213** in the subsequent camera cycle. When it is to be terminated (step S**224**: Yes), the HMD **2***f* terminates the processing of the MR participation program.

[0167] As described above, according to the third embodiment, the same advantageous effects as those of the first embodiment and second embodiment are obtained, and moreover, the participants **2***a* to **2***e* are allowed to switch the viewing in the MR space **6** in the same manner as the viewers **13***a* to **13***c*, between the AR viewing and the VR viewing.

Fourth Embodiment

[0168] FIG. **22** is a schematic diagram of a virtual reality sharing system **100***c* according to a fourth embodiment.

[0169] In the virtual reality sharing system **100***c* illustrated in FIG. **22**, experiencers **11***a* to **11***f* and participants **12***f* to **12***i* are present in the MR space **6**.

[0170] The experiencers **11***a* to **11***f* and participants **12***f* to **12***i* wear the HMDs on their heads, respectively. The HMDs transmit and receive the network signal, which are not illustrated in FIG. **22** for preventing FIG. **22** from being complicated.

[0171] In the virtual reality sharing system **100***c*, the plurality of experiencers **11***a* to **11***f* is divided into the left side experiencers including the experiencers **11***a* to **11***c* and the right side experiencers including the experiencers **11***d* to **11***f*. The experiencers **11***a* to **11***f* hold operation controllers **15***a* to **15***f*, respectively, and generate and operate AR objects **4***c* to **4***e* using the operation controllers **15***a* to **15***f*. Each of the operation controllers **15***a* to **15***f* has a built-in sensor for detecting the motion thereof, and generates and moves the AR object **4***c* to **4***e* in accordance with the motion thereof.

[0172] In the virtual reality sharing system **100***c*, the AR objects **4***c* to **4***e* generated by the operation controllers **15***a* to **15***f* are virtual attacking objects for attacking the experiencers **11***a* to **11***c* or experiencers **11***d* to **11***f* on the opposite side. In this e-sport using the MR space **6**, an experiencer hits the attacking object to the experiencers **11***a* to **11***c* or experiencers **11***d* to **11***f* on the opposite side to make the experiencer who is hit by the attacking object leave, and compete the number of experiencers the experiencer can eliminate within a predetermined period of time.

[0173] In the case where each of the participants **12***f* to **12***i* uses the participant HMD **2***f* according to the third embodiment to be worn as a transparent type HMD, he or she can see the experiencers **11***a* to **11***f* on both sides in the MR space **6**, and also view the AR objects **4***c* to **4***e* which are superimposed thereon. In the case of using the HMD to be worn as an immersive type HMD, each of the participants **12***f* to **12***i* can view the VR video and the AR object superimposed thereon as if they were the experiencers **11***a* to **11***f*. Furthermore, in the same manner as the embodiments that have been described, the viewers **13***a*, **13***b*, **13***c* can flexibly select the viewpoint positions and line-of-sight directions to view the inside of the MR space **6**.

[0174] FIG. **23** is a flowchart of the AR drawing program **95**.

[0175] The AR server **9** executes the processes of step S**231** to step S**236** to be provided to the experiencer HMD **1**, the processes of step S**188** to step S**191** to be provided to the participant HMDs **2***a* to **2***f* illustrated in FIG. **16**, and the processes of step S**192** to step S**197** to be provided to the viewer HMDs **3***b*, **3***c* and the information terminal **3***a* illustrated in FIG. **16**.

[0176] The AR server **9** determines whether a request has been transmitted from any of the operation controllers **15***a* to **15***f* held by the experiencer HMD **1** (transmission requesting terminal), and determines the type thereof. In absence of transmission of a request (step S**231**: No), the AR server **9** stands by until a request is transmitted.

[0177] Upon receiving a setting request (step S**231**: setting), the AR server **9** receives setting data of at least one of the AR objects **4***c* to **4***e* from the transmission requesting terminal (step S**232**), and sets one of the AR objects **4***c* to **4***e*, which is generated by one of the operation controllers **15***a* to **15***f* held by a person wearing the experiencer HMD **1**, and the parameters. Moving the operation controllers **15***a* to **15***f* in an “AR object setting” mode in accordance with a predetermined pattern causes the AR objects **4***c* to **4***e* to be automatically generated.

[0178] Upon receiving an operation request (step S**231**: operation), the AR server **9** receives the motion data of the operation controllers **15***a* to **15***f* (step S**233**), draws one of the AR objects **4***c* to **4***e* in accordance with the motion data (step S**234**), and transmits the data of one of the AR objects

4*c* to **4***e* which has been drawn (step S**235**).

[0179] The AR server **9** determines whether a subsequent request has been transmitted, and determines whether to continue the processing (step S**236**: Yes) or to proceed the processing to the termination determination in step S**198** (step S**236**: No). The loop of step S**234** and step S**235** indicated by the dashed line indicates repetition of drawing and transmission of the AR objects **4***c* to **4***e*. The AR objects **4***c* to **4***e* generated by operations of the operation controllers have parameters for self-propelling. Each of the AR objects **4***c* to **4***e* generated as an attacking object self-propels toward an opponent experiencer in accordance with a predetermined speed pattern. The AR objects **4***c* to **4***e* automatically disappear when they hit an experiencer or go out of a predetermined area or the MR space **6**.

[0180] In step S**198**, the AR server **9** determines whether to terminate the processing, and upon receiving a termination instruction, the AR server **9** terminates the processing (step S**199**: Yes) while in absence of a termination instruction (step S**199**: No), the AR server **9** returns the processing to step S**231**, step S**188**, and step S**192** and continues the processing.

[0181] As described above, according to the fourth embodiment, the same advantageous effects as those of the first to third embodiments can be obtained, and moreover, a virtual reality sharing system including a plurality of experiencers can also be shared.

[0182] It should be noted that the invention is not limited to the embodiments described with reference to FIG. **1** to FIG. **23**. For example, in the embodiments described above, although the VR video is generated by combining the camera-captured videos by a plurality of virtual reality sharing terminals that is present in the MR space **6**, however, the VR video may be generated by combining camera-captured videos captured at different times from different positions and viewpoints by one virtual reality sharing terminal.

[0183] Furthermore, all the plurality of virtual reality sharing terminals that is present in the MR space **6** may be experiencer HMDs.

[0184] Furthermore, creating a VR video and then storing it in the VR server **8** enables the viewers **13***a* to **13***c* to, not only share the virtual reality with the experiencer **11** and participants **12***a* to **12***e* in real time, but also read the VR video that has been already created later to share the virtual reality.

[0185] It should be noted that the present invention allows a part of the configuration of one embodiment to be replaced with a part of other embodiments. Furthermore, configurations of other embodiments may be added to configurations of a certain embodiment. All of these are included in the scope of the present invention. The numerical values and messages appearing in the text and drawings are merely examples, and thus the advantageous effects of the present invention are not impaired even if different ones are used.

[0186] It should be also noted that some or all of the functions and the like of the invention may be implemented by hardware, for example, by designing them by an integrated circuit. Furthermore, a microprocessor unit, a CPU, or the like may interpret and execute an operation program, thereby causing them to be implemented by software. Still further, the implementation range of the software is not limited, and hardware and software may be used in combination.

REFERENCE SIGNS LIST

[0187] **1**: experiencer HMD [0188] **2***a*-**2***f*: participant HMD [0189] **3***a*: viewer information terminal [0190] **3***b*, **3***c*: viewer HMD [0191] **4***a*: real object [0192] **4***b*-**4***d*: AR object [0193] **5***a*-**5***e*: access point [0194] **6**: MR space [0195] **7**: network [0196] **8**: VR server [0197] **9**: AR server [0198] **10***a*-**10***r*: network signal [0199] **11**, **11***a*-**11***f*: experiencer [0200] **12***a*-**12***i*: participant [0201] **13***a*-**13***c*: viewer [0202] **14**, **14***a*-**14***c*: fixed camera [0203] **15***a*-**15***f*: operation controller [0204] **21**: camera [0205] **22**: projector [0206] **22***a*: left projector [0207] **22***b*: right projector [0208] **23**: screen [0209] **24**: nose pad [0210] **25**: processor [0211] **26**: speaker [0212] **27**: microphone [0213] **28**: frame housing [0214] **28***c*: bridge [0215] **29**: ranging camera [0216] **30**: display [0217] **82**: CPU [0218] **83**: RAM [0219] **84**: storage [0220] **85**: VR creation program [0221] **86**: VR data [0222] **87**:

internal bus [0223] **91**: network IF [0224] **92**: CPU [0225] **93**: RAM [0226] **94**: storage [0227] **95**: AR drawing program [0228] **96**: AR data [0229] **97**: internal bus [0230] **100**, **100*a*-100*c***: virtual reality sharing system [0231] **231**: shutter [0232] **232**: half mirror [0233] **250**: orientation sensor [0234] **251**: gyro sensor [0235] **252**: acceleration sensor [0236] **253**: wireless communication interface [0237] **254**: CPU [0238] **255**: RAM [0239] **256**: video RAM [0240] **258**, **265**: basic program [0241] **259**: MR experience program [0242] **260**: feature extraction processor [0243] **261**: distance calculation processor [0244] **262**: internal bus [0245] **263**, **263*a***: MR participation program [0246] **266**: MR viewing program [0247] **301**, **302**: three-dimensional arrow [0248] P**1**: area [0249] P**2**: video

Claims

1. A virtual reality sharing terminal comprising: a display, an input interface, a communication interface, and a processor, the processor being configured to: when the input interface accepts a setting input operation about a viewer's viewpoint for taking in a virtual reality (VR) video that composites a plurality of camera-captured videos obtained by capturing videos of a same real space from different viewpoints, transmit, from the communication interface, data indicating a position and direction of the viewer's viewpoint to a virtual reality (VR) server that creates the VR video and an augmented reality (AR) server that draws and creates an augmented reality (AR) object; via the communication interface, receive the VR video viewed from the viewer's viewpoint from the VR server, and receive drawing data of the AR object viewed from the viewer's viewpoint from the AR server; and superimpose the AR object based on the drawing data on the VR video viewed from the viewer's viewpoint, and then display the VR video on the display, wherein the plurality of camera-captured videos includes a first camera-captured video and a second camera-captured video, wherein the first camera-captured video includes meta data indicating a relative position of a real object viewed from a first viewpoint, the real object being a display trigger of the AR object, wherein the second camera-captured video includes meta data indicating a relative position of the real object viewed from a second viewpoint, wherein the processor being configured to: via the communication interface, receive the VR video in which the relative position viewed from the first viewpoint and the relative position viewed from the second viewpoint are added from the VR server; compare a position of the real object captured in the VR video viewed from the viewer's viewpoint with a position of the AR object viewed from the viewer's viewpoint; when the position of the real object is closer than that of the AR object, display the VR video in which the real object hides at least a portion of the AR object; and when the position of the real object is farther from the position of the AR object, display the VR video in which the AR object hides at least a portion of the real object.
2. The virtual reality sharing terminal according to claim 1, wherein the processor is configured to display a pointer indicating a viewpoint position and line-of-sight direction of the viewer's viewpoint on the display, and the input interface accepts an input operation using the pointer.
3. The virtual reality sharing terminal according to claim 2, wherein the processor is configured to: execute either a viewpoint setting mode or a viewing mode, in the viewpoint setting mode, display the pointer on the display, and in the viewing mode, not display the pointer in the display, superimpose the AR object on the VR video viewed from the viewer's viewpoint, and then display the VR video.
4. The virtual reality sharing terminal according to claim 1, wherein the processor is configured to: via the communication interface, receive the VR video composited the first camera-captured video, which is generated by capturing a video of the real space from the first viewpoint, and the second camera-captured video, which is generated by capturing a video of the real space from the second viewpoint at a same time when the first camera-captured video captured, from the VR server.
5. The virtual reality sharing terminal according to claim 1, wherein the processor is configured to:

via the communication interface, receive the VR video composited the first camera-captured video, which is generated by capturing a video of the real space from the first viewpoint, and the second camera-captured video, which is generated by capturing a video of the real space from the second viewpoint at a time different from that when the first camera-captured video captured, from the VR server.

6. The virtual reality sharing terminal according to claim 1, wherein the first camera-captured video is a generated video generated by capturing a video of the real space from the first viewpoint, the second camera-captured video is a generated video generated by capturing a video of the real space from the second viewpoint at a same time when capturing the video of the real space from the first viewpoint, and the VR video is a composite video composited the first camera-captured video and the second camera-captured video.

7. The virtual reality sharing terminal according to claim 1, wherein the first camera-captured video is a generated video generated by capturing a video of the real space from the first viewpoint, the second camera-captured video is a generated video generated by capturing a video of the real space from the second viewpoint at a time different from that when capturing the video of the real space from the first viewpoint, and the VR video is a composite video composited the first camera-captured video and the second camera-captured video.

8. An information terminal comprising: a display, an input interface, a communication interface, and a processing circuit, the processing circuit being configured to: when the input interface accepts a setting input operation about a viewer's viewpoint for taking in a virtual reality (VR) video that composites a plurality of camera-captured videos obtained by capturing videos of a same real space from different viewpoints, transmit, from the communication interface, data indicating a position and direction of the viewer's viewpoint to a virtual reality (VR) server that creates the VR video and an augmented reality (AR) server that draws and creates an augmented reality (AR) object; via the communication interface, receive the VR video viewed from the viewer's viewpoint from the VR server, and receive drawing data of the AR object viewed from the viewer's viewpoint from the AR server; and superimpose the AR object based on the drawing data on the VR video viewed from the viewer's viewpoint, and then display the VR video on the display, wherein the plurality of camera-captured videos includes a first camera-captured video and a second camera-captured video, wherein the first camera-captured video includes meta data indicating a relative position of a real object viewed from a first viewpoint, the real object being a display trigger of the AR object, wherein the second camera-captured video includes meta data indicating a relative position of the real object viewed from a second viewpoint, wherein the processing circuit being configured to: via the communication interface, receive the VR video in which the relative position viewed from the first viewpoint and the relative position viewed from the second viewpoint are added from the VR server; compare a position of the real object with a position of the AR object; when the position of the real object is closer than that of the AR object, display the VR video in which the real object hides at least a portion of the AR object; and when the position of the real object is farther from the position of the AR object, display the VR video in which the AR object hides at least a portion of the real object.

9. The information terminal according to claim 8, wherein the processing circuit is configured to display a pointer indicating a viewpoint position and line-of-sight direction of the viewer's viewpoint on the display, and the input interface is configured to accept an input operation using the pointer.

10. The information terminal according to claim 9, wherein the processing circuit is configured to: execute either a viewpoint setting mode or a viewing mode, in the viewpoint setting mode, display the pointer on the display, and in the viewing mode, not display the pointer in the display, superimpose the AR object on the VR video viewed from the viewer's viewpoint, and then display the VR video.

11. The information terminal according to claim 8, wherein the processing circuit is configured to:

via the communication interface, receive the VR video composited the first camera-captured video, which is generated by capturing a video of the real space from the first viewpoint, and the second camera-captured video, which is generated by capturing a video of the real space from the second viewpoint at a same time when the first camera-captured video captured, from the VR server.

12. The information terminal according to claim 8, wherein the processing circuit is configured to: via the communication interface, receive the VR video composited the first camera-captured video, which is generated by capturing a video of the real space from the first viewpoint, and the second camera-captured video, which is generated by capturing a video of the real space from the second viewpoint at a time different from that when the first camera-captured video captured, from the VR server.

13. The information terminal according to claim 8, wherein the first camera-captured video is a generated video generated by capturing a video of the real space from the first viewpoint, the second camera-captured video is a generated video generated by capturing a video of the real space from the second viewpoint at a same time when capturing the video of the real space from the first viewpoint, and the VR video is a composite video composited the first camera-captured video and the second camera-captured video.

14. The information terminal according to claim 8, wherein the first camera-captured video is a generated video generated by capturing a video of the real space from the first viewpoint, the second camera-captured video is a generated video generated by capturing a video of the real space from the second viewpoint at a time different from that when capturing the video of the real space from the first viewpoint, and the VR video is a composite video composited the first camera-captured video and the second camera-captured video.

15. The information terminal according to claim 8, wherein the information terminal is a head-mounted display.

16. A virtual reality sharing method by an information terminal, the information terminal comprising a display, an input interface, a communication interface, and a processing circuit, the virtual reality sharing method comprising: accepting, by the input interface, a setting input operation about a viewer's viewpoint for taking in a virtual reality (VR) video that composites a plurality of camera-captured videos obtained by capturing videos of a same real space from different viewpoints; transmitting, by the communication interface, data indicating a position and direction of the viewer's viewpoint to a virtual reality (VR) server that creates the VR video and an augmented reality (AR) server that draws and creates an augmented reality (AR) object; receiving, by the communication interface, the VR video viewed from the viewer's viewpoint from the VR server, and drawing data of the AR object viewed from the viewer's viewpoint from the AR server; superimposing, by the processing circuit, the AR object based on the drawing data on the VR video viewed from the viewer's viewpoint; and displaying on the display, by the processing circuit, the VR video with the AR object superimposed, wherein the plurality of camera-captured videos includes a first camera-captured video and a second camera-captured video, wherein the first camera-captured video includes meta data indicating a relative position of a real object viewed from a first viewpoint, the real object being a display trigger of the AR object, wherein the second camera-captured video includes meta data indicating a relative position of the real object viewed from a second viewpoint, wherein the virtual reality sharing method further comprises: receiving, by the communication interface, the VR video in which the relative position viewed from the first viewpoint and the relative position viewed from the second viewpoint are added from the VR server; comparing, by the processing circuit, a position of the real object with a position of the AR object; displaying on the display, by the processing circuit, the VR video in which the real object hides at least a portion of the AR object when the position of the real object is closer than that of the AR object; and displaying on the display, by the processing circuit, the VR video in which the AR object hides at least a portion of the real object when the position of the real object is farther from the position of the AR object.

17. The virtual reality sharing method according to claim 16, further comprising: displaying on the display, by the processing circuit, a pointer indicating a viewpoint position and line-of-sight direction of the viewer's viewpoint, and accepting, by the input interface, an input operation using the pointer.
18. The virtual reality sharing method according to claim 17, further comprising: executing, by the processing circuit, either a viewpoint setting mode or a viewing mode, wherein, in the viewpoint setting mode, the pointer is displayed on the display, and wherein, in the viewing mode, the pointer is not displayed in the display, and the VR video is display on the display superimposing the AR object.
19. The virtual reality sharing method according to claim 16, wherein the first camera-captured video is a generated video generated by capturing a video of the real space from the first viewpoint, the second camera-captured video is a generated video generated by capturing a video of the real space from the second viewpoint at a same time when capturing the video of the real space from the first viewpoint, and the VR video is a composite video composited the first camera-captured video and the second camera-captured video.
20. The virtual reality sharing method according to claim 16, wherein the first camera-captured video is a generated video generated by capturing a video of the real space from the first viewpoint, the second camera-captured video is a generated video generated by capturing a video of the real space from the second viewpoint at a time different from that when capturing the video of the real space from the first viewpoint, and the VR video is a composite video composited the first camera-captured video and the second camera-captured video.