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SESSION MANAGER

Abstract

Disclosed are systems and methods for mixed reality collaboration. A method may include receiving persistent coordinate data; presenting a first virtual session handle to a first user at a first position via a transmissive display of a wearable device, wherein the first position is based on the persistent coordinate data; presenting a virtual object to the first user at a second location via the transmissive display, wherein the second position is based on the first position; receiving location data from a second user, wherein the location data relates a position of the second user to a position of a second virtual session handle; presenting a virtual avatar to the first user at a third position via the transmissive display, wherein the virtual avatar corresponds to the second user, wherein the third position is based on the location data, and wherein the third position is further based on the first position.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 18/513,443, filed Nov. 17, 2023, which is a continuation of U.S. application Ser. No. 17/944,079, filed Sep. 13, 2022, now U.S. Pat. No. 11,861,803, issued on Jan. 2, 2024, which is a continuation of U.S. application Ser. No. 17/175,547, filed on Feb. 12, 2021, now U.S. Pat. No. 11,475,644, issued on Oct. 18, 2022, which claims benefit of U.S. Provisional Application No. 62/977,079, filed Feb. 14, 2020, all of which are hereby incorporated by reference in their entirety.

FIELD
[0002] This disclosure relates in general to systems and methods for managing and enabling virtual collaboration, and in particular to systems and methods for managing and enabling virtual collaboration in a mixed reality environment.
BACKGROUND
[0003] Virtual environments are ubiquitous in computing environments, finding use in video games (in which a virtual environment may represent a game world); maps (in which a virtual environment may represent terrain to be navigated); simulations (in which a virtual environment may simulate a real environment); digital storytelling (in which virtual characters may interact with each other in a virtual environment); and many other applications. Modern computer users are generally comfortable perceiving, and interacting with, virtual environments. However, users' experiences with virtual environments can be limited by the technology for presenting virtual environments. For example, conventional displays (e.g., 2D display screens) and audio systems (e.g., fixed speakers) may be unable to realize a virtual environment in ways that create a compelling, realistic, and immersive experience.
[0004] Virtual reality ("VR"), augmented reality ("AR"), mixed reality ("MR"), and related technologies (collectively, "XR") share an ability to present, to a user of an XR system, sensory information corresponding to a virtual environment represented by data in a computer system. This disclosure contemplates a distinction between VR, AR, and MR systems (although some systems may be categorized as VR in one aspect (e.g., a visual aspect), and simultaneously categorized as AR or MR in another aspect (e.g., an audio aspect)). As used herein, VR systems present a virtual environment that replaces a user's real environment in at least one aspect; for example, a VR system could present the user with a view of the virtual environment while simultaneously obscuring his or her view of the real environment, such as with a light-blocking head-mounted display. Similarly, a VR system could present the user with audio corresponding to the virtual environment, while simultaneously blocking (attenuating) audio from the real environment.

[0005] VR systems may experience various drawbacks that result from replacing a user's real environment with a virtual environment. One drawback is a feeling of motion sickness that can arise when a user's field of view in a virtual environment no longer corresponds to the state of his or her inner ear, which detects one's balance and orientation in the real environment (not a virtual environment). Similarly, users may experience disorientation in VR environments where their own bodies and limbs (views of which users rely on to feel "grounded" in the real environment) are not directly visible. Another drawback is the computational burden (e.g., storage, processing power) placed on VR systems which must present a full 3D virtual environment, particularly in real-time applications that seek to immerse the user in the virtual environment. Similarly, such environments may need to reach a very high standard of realism to be considered immersive, as users tend to be sensitive to even minor imperfections in virtual environments-any of which can destroy a user's sense of immersion in the virtual environment. Further, another drawback of VR systems is that such applications of systems cannot take advantage of the wide range of sensory data in the real environment, such as the various sights and sounds that one experiences in the real world. A related drawback is that VR systems may struggle to create shared environments in which multiple users can interact, as users that share a physical space in the real environment may not be able to directly see or interact with each other in a virtual environment.

[0006] As used herein, AR systems present a virtual environment that overlaps or overlays the real environment in at least one aspect. For example, an AR system could present the user with a view of a virtual environment overlaid on the user's view of the real environment, such as with a transmissive head-mounted display that presents a displayed image while allowing light to pass through the display into the user's eye. Similarly, an AR system could present the user with audio corresponding to the virtual environment, while simultaneously mixing in audio from the real environment. Similarly, as used herein, MR systems present a virtual environment that overlaps or overlays the real environment in at least one aspect, as do AR systems, and may additionally allow that a virtual environment in an MR system may interact with the real environment in at least one aspect. For example, a virtual character in a virtual environment may toggle a light switch in the real environment, causing a corresponding light bulb in the real environment to turn on or off. As another example, the virtual character may react (such as with a facial expression) to audio signals in the real environment. By maintaining presentation of the real environment, AR and MR systems may avoid some of the aforementioned drawbacks of VR systems; for instance, motion sickness in users is reduced because visual cues from the real environment (including users' own bodies) can remain visible, and such systems need not present a user with a fully realized 3D environment in order to be immersive. Further, AR and MR systems can take advantage of real world sensory input (e.g., views and sounds of scenery, objects, and other users) to create new applications that augment that input.

[0007] XR systems may be uniquely positioned to enable greater collaboration between people. The ability to present virtual content in a persistent and three-dimensional manner can allow people to more naturally interact with virtual content. For example, arranging virtual objects in three-dimensional space may enable much more natural location recall than what two-dimensional screens can offer. Where a user of a two-dimensional screen may have to hunt through one of forty open tabs to re-open a desired application, a user of an XR system may be able to pinpoint a desired virtual object displayed on a desk (like picking up a real folder placed on a desk). Furthermore, XR systems may enable users to see virtual avatars of other users to simulate the live presence of other people. This may enable more natural collaboration than what a telephone call or even videoconference can offer. It can therefore be desirable to develop systems and methods for enabling deep user collaboration on XR systems.

[0008] XR systems can offer a uniquely heightened sense of immersion and realism by combining virtual visual and audio cues with real sights and sounds. Accordingly, it is desirable in some XR systems to present a virtual environment that enhances, improves, or alters a corresponding real

environment. This disclosure relates to XR systems that enable consistent placement of virtual objects across multiple XR systems.

BRIEF SUMMARY

[0009] Examples of the disclosure describe systems and methods for enabling mixed reality collaboration. According to examples of the disclosure, a method may include receiving persistent coordinate data; presenting a first virtual session handle to a first user at a first position via a transmissive display of a wearable device, wherein the first position is based on the persistent coordinate data; presenting a virtual object to the first user at a second location via the transmissive display, wherein the second position is based on the first position; receiving location data from a second user, wherein the location data relates a position of the second user to a position of a second virtual session handle; presenting a virtual avatar to the first user at a third position via the transmissive display, wherein the virtual avatar corresponds to the second user, wherein the third position is based on the location data, and wherein the third position is further based on the first position.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIGS. **1**A-**1**C illustrate an example mixed reality environment, according to some embodiments.

[0011] FIGS. **2**A-**2**D illustrate components of an example mixed reality system that can be used to generate and interact with a mixed reality environment, according to some embodiments.

[0012] FIG. **3**A illustrates an example mixed reality handheld controller that can be used to provide input to a mixed reality environment, according to some embodiments.

[0013] FIG. **3**B illustrates an example auxiliary unit that can be used with an example mixed reality system, according to some embodiments.

[0014] FIG. **4** illustrates an example functional block diagram for an example mixed reality system, according to some embodiments.

[0015] FIGS. **5**A-**5**C illustrate an example of a mixed reality collaboration session, according to some embodiments.

[0016] FIG. **6** illustrates an example of a session manager architecture, according to some embodiments.

[0017] FIG. **7** illustrates an example of a session instance, according to some embodiments.

DETAILED DESCRIPTION

[0018] In the following description of examples, reference is made to the accompanying drawings which form a part hereof, and in which it is shown by way of illustration specific examples that can be practiced. It is to be understood that other examples can be used and structural changes can be made without departing from the scope of the disclosed examples.

Mixed Reality Environment

[0019] Like all people, a user of a mixed reality system exists in a real environment—that is, a three-dimensional portion of the "real world," and all of its contents, that are perceptible by the user. For example, a user perceives a real environment using one's ordinary human senses—sight, sound, touch, taste, smell—and interacts with the real environment by moving one's own body in the real environment. Locations in a real environment can be described as coordinates in a coordinate space; for example, a coordinate can include latitude, longitude, and elevation with respect to sea level; distances in three orthogonal dimensions from a reference point; or other suitable values. Likewise, a vector can describe a quantity having a direction and a magnitude in the coordinate space.

[0020] A computing device can maintain, for example in a memory associated with the device, a

representation of a virtual environment. As used herein, a virtual environment is a computational representation of a three-dimensional space. A virtual environment can include representations of any object, action, signal, parameter, coordinate, vector, or other characteristic associated with that space. In some examples, circuitry (e.g., a processor) of a computing device can maintain and update a state of a virtual environment; that is, a processor can determine at a first time t_0, based on data associated with the virtual environment and/or input provided by a user, a state of the virtual environment at a second time t_1. For instance, if an object in the virtual environment is located at a first coordinate at time t_0, and has certain programmed physical parameters (e.g., mass, coefficient of friction); and an input received from user indicates that a force should be applied to the object in a direction vector; the processor can apply laws of kinematics to determine a location of the object at time t_1 using basic mechanics. The processor can use any suitable information known about the virtual environment, and/or any suitable input, to determine a state of the virtual environment at a time t_1. In maintaining and updating a state of a virtual environment, the processor can execute any suitable software, including software relating to the creation and deletion of virtual objects in the virtual environment; software (e.g., scripts) for defining behavior of virtual objects or characters in the virtual environment; software for defining the behavior of signals (e.g., audio signals) in the virtual environment; software for creating and updating parameters associated with the virtual environment; software for generating audio signals in the virtual environment; software for handling input and output; software for implementing network operations; software for applying asset data (e.g., animation data to move a virtual object over time); or many other possibilities.
[0021] Output devices, such as a display or a speaker, can present any or all aspects of a virtual environment to a user. For example, a virtual environment may include virtual objects (which may include representations of inanimate objects; people; animals; lights; etc.) that may be presented to a user. A processor can determine a view of the virtual environment (for example, corresponding to a "camera" with an origin coordinate, a view axis, and a frustum); and render, to a display, a viewable scene of the virtual environment corresponding to that view. Any suitable rendering technology may be used for this purpose. In some examples, the viewable scene may include only some virtual objects in the virtual environment, and exclude certain other virtual objects. Similarly, a virtual environment may include audio aspects that may be presented to a user as one or more audio signals. For instance, a virtual object in the virtual environment may generate a sound originating from a location coordinate of the object (e.g., a virtual character may speak or cause a sound effect); or the virtual environment may be associated with musical cues or ambient sounds that may or may not be associated with a particular location. A processor can determine an audio signal corresponding to a "listener" coordinate—for instance, an audio signal corresponding to a composite of sounds in the virtual environment, and mixed and processed to simulate an audio signal that would be heard by a listener at the listener coordinate—and present the audio signal to a user via one or more speakers.
[0022] Because a virtual environment exists only as a computational structure, a user cannot directly perceive a virtual environment using one's ordinary senses. Instead, a user can perceive a virtual environment only indirectly, as presented to the user, for example by a display, speakers, haptic output devices, etc. Similarly, a user cannot directly touch, manipulate, or otherwise interact with a virtual environment; but can provide input data, via input devices or sensors, to a processor that can use the device or sensor data to update the virtual environment. For example, a camera sensor can provide optical data indicating that a user is trying to move an object in a virtual environment, and a processor can use that data to cause the object to respond accordingly in the virtual environment.
[0023] A mixed reality system can present to the user, for example using a transmissive display and/or one or more speakers (which may, for example, be incorporated into a wearable head device), a mixed reality environment ("MRE") that combines aspects of a real environment and a virtual environment. In some embodiments, the one or more speakers may be external to the head-

mounted wearable unit. As used herein, an MRE is a simultaneous representation of a real environment and a corresponding virtual environment. In some examples, the corresponding real and virtual environments share a single coordinate space; in some examples, a real coordinate space and a corresponding virtual coordinate space are related to each other by a transformation matrix (or other suitable representation). Accordingly, a single coordinate (along with, in some examples, a transformation matrix) can define a first location in the real environment, and also a second, corresponding, location in the virtual environment; and vice versa.

[0024] In an MRE, a virtual object (e.g., in a virtual environment associated with the MRE) can correspond to a real object (e.g., in a real environment associated with the MRE). For instance, if the real environment of an MRE includes a real lamp post (a real object) at a location coordinate, the virtual environment of the MRE may include a virtual lamp post (a virtual object) at a corresponding location coordinate. As used herein, the real object in combination with its corresponding virtual object together constitute a "mixed reality object." It is not necessary for a virtual object to perfectly match or align with a corresponding real object. In some examples, a virtual object can be a simplified version of a corresponding real object. For instance, if a real environment includes a real lamp post, a corresponding virtual object may include a cylinder of roughly the same height and radius as the real lamp post (reflecting that lamp posts may be roughly cylindrical in shape). Simplifying virtual objects in this manner can allow computational efficiencies, and can simplify calculations to be performed on such virtual objects. Further, in some examples of an MRE, not all real objects in a real environment may be associated with a corresponding virtual object. Likewise, in some examples of an MRE, not all virtual objects in a virtual environment may be associated with a corresponding real object. That is, some virtual objects may solely in a virtual environment of an MRE, without any real-world counterpart.

[0025] In some examples, virtual objects may have characteristics that differ, sometimes drastically, from those of corresponding real objects. For instance, while a real environment in an MRE may include a green, two-armed cactus—a prickly inanimate object—a corresponding virtual object in the MRE may have the characteristics of a green, two-armed virtual character with human facial features and a surly demeanor. In this example, the virtual object resembles its corresponding real object in certain characteristics (color, number of arms); but differs from the real object in other characteristics (facial features, personality). In this way, virtual objects have the potential to represent real objects in a creative, abstract, exaggerated, or fanciful manner; or to impart behaviors (e.g., human personalities) to otherwise inanimate real objects. In some examples, virtual objects may be purely fanciful creations with no real-world counterpart (e.g., a virtual monster in a virtual environment, perhaps at a location corresponding to an empty space in a real environment).

[0026] Compared to VR systems, which present the user with a virtual environment while obscuring the real environment, a mixed reality system presenting an MRE affords the advantage that the real environment remains perceptible while the virtual environment is presented. Accordingly, the user of the mixed reality system is able to use visual and audio cues associated with the real environment to experience and interact with the corresponding virtual environment. As an example, while a user of VR systems may struggle to perceive or interact with a virtual object displayed in a virtual environment—because, as noted above, a user cannot directly perceive or interact with a virtual environment—a user of an MR system may find it intuitive and natural to interact with a virtual object by seeing, hearing, and touching a corresponding real object in his or her own real environment. This level of interactivity can heighten a user's feelings of immersion, connection, and engagement with a virtual environment. Similarly, by simultaneously presenting a real environment and a virtual environment, mixed reality systems can reduce negative psychological feelings (e.g., cognitive dissonance) and negative physical feelings (e.g., motion sickness) associated with VR systems. Mixed reality systems further offer many possibilities for applications that may augment or alter our experiences of the real world.

[0027] FIG. **1**A illustrates an example real environment **100** in which a user **110** uses a mixed

reality system **112**. Mixed reality system **112** may include a display (e.g., a transmissive display) and one or more speakers, and one or more sensors (e.g., a camera), for example as described below. The real environment **100** shown includes a rectangular room **104**A, in which user **110** is standing; and real objects **122**A (a lamp), **124**A (a table), **126**A (a sofa), and **128**A (a painting). Room **104**A further includes a location coordinate **106**, which may be considered an origin of the real environment **100**. As shown in FIG. **1**A, an environment/world coordinate system **108** (comprising an x-axis **108**X, a y-axis **108**Y, and a z-axis **108**Z) with its origin at point **106** (a world coordinate), can define a coordinate space for real environment **100**. In some embodiments, the origin point **106** of the environment/world coordinate system **108** may correspond to where the mixed reality system **112** was powered on. In some embodiments, the origin point **106** of the environment/world coordinate system **108** may be reset during operation. In some examples, user **110** may be considered a real object in real environment **100**; similarly, user **110**'s body parts (e.g., hands, feet) may be considered real objects in real environment **100**. In some examples, a user/listener/head coordinate system **114** (comprising an x-axis **114**X, a y-axis **114**Y, and a z-axis **114**Z) with its origin at point **115** (e.g., user/listener/head coordinate) can define a coordinate space for the user/listener/head on which the mixed reality system **112** is located. The origin point **115** of the user/listener/head coordinate system **114** may be defined relative to one or more components of the mixed reality system **112**. For example, the origin point **115** of the user/listener/head coordinate system **114** may be defined relative to the display of the mixed reality system **112** such as during initial calibration of the mixed reality system **112**. A matrix (which may include a translation matrix and a Quaternion matrix or other rotation matrix), or other suitable representation can characterize a transformation between the user/listener/head coordinate system **114** space and the environment/world coordinate system **108** space. In some embodiments, a left ear coordinate **116** and a right ear coordinate **117** may be defined relative to the origin point **115** of the user/listener/head coordinate system **114**. A matrix (which may include a translation matrix and a Quaternion matrix or other rotation matrix), or other suitable representation can characterize a transformation between the left ear coordinate **116** and the right ear coordinate **117**, and user/listener/head coordinate system **114** space. The user/listener/head coordinate system **114** can simplify the representation of locations relative to the user's head, or to a head-mounted device, for example, relative to the environment/world coordinate system **108**. Using Simultaneous Localization and Mapping (SLAM), visual odometry, or other techniques, a transformation between user coordinate system **114** and environment coordinate system **108** can be determined and updated in real-time.

[0028] FIG. **1**B illustrates an example virtual environment **130** that corresponds to real environment **100**. The virtual environment **130** shown includes a virtual rectangular room **104**B corresponding to real rectangular room **104**A; a virtual object **122**B corresponding to real object **122**A; a virtual object **124**B corresponding to real object **124**A; and a virtual object **126**B corresponding to real object **126**A. Metadata associated with the virtual objects **122**B, **124**B, **126**B can include information derived from the corresponding real objects **122**A, **124**A, **126**A. Virtual environment **130** additionally includes a virtual monster **132**, which does not correspond to any real object in real environment **100**. Real object **128**A in real environment **100** does not correspond to any virtual object in virtual environment **130**. A persistent coordinate system **133** (comprising an x-axis **133**X, a y-axis **133**Y, and a z-axis **133**Z) with its origin at point **134** (persistent coordinate), can define a coordinate space for virtual content. The origin point **134** of the persistent coordinate system **133** may be defined relative/with respect to one or more real objects, such as the real object **126**A. A matrix (which may include a translation matrix and a Quaternion matrix or other rotation matrix), or other suitable representation can characterize a transformation between the persistent coordinate system **133** space and the environment/world coordinate system **108** space. In some embodiments, each of the virtual objects **122**B, **124**B, **126**B, and **132** may have their own persistent coordinate point relative to the origin point **134** of the persistent coordinate system **133**. In some

embodiments, there may be multiple persistent coordinate systems and each of the virtual objects **122**B, **124**B, **126**B, and **132** may have their own persistent coordinate point relative to one or more persistent coordinate systems.

[0029] Persistent coordinate data may be coordinate data that persists relative to a physical environment. Persistent coordinate data may be used by MR systems (e.g., MR system **112**, **200**) to place persistent virtual content, which may not be tied to movement of a display on which the virtual object is being displayed. For example, a two-dimensional screen may only display virtual objects relative to a position on the screen. As the two-dimensional screen moves, the virtual content may move with the screen. In some embodiments, persistent virtual content may be displayed in a corner of a room. An MR user may look at the corner, see the virtual content, look away from the corner (where the virtual content may no longer be visible because the virtual content may have moved from within the user's field of view to a location outside the user's field of view due to motion of the user's head), and look back to see the virtual content in the corner (similar to how a real object may behave).

[0030] In some embodiments, persistent coordinate data (e.g., a persistent coordinate system and/or a persistent coordinate frame) can include an origin point and three axes. For example, a persistent coordinate system may be assigned to a center of a room by an MR system. In some embodiments, a user may move around the room, out of the room, re-enter the room, etc., and the persistent coordinate system may remain at the center of the room (e.g., because it persists relative to the physical environment). In some embodiments, a virtual object may be displayed using a transform to persistent coordinate data, which may enable displaying persistent virtual content. In some embodiments, an MR system may use simultaneous localization and mapping to generate persistent coordinate data (e.g., the MR system may assign a persistent coordinate system to a point in space). In some embodiments, an MR system may map an environment by generating persistent coordinate data at regular intervals (e.g., an MR system may assign persistent coordinate systems in a grid where persistent coordinate systems may be at least within five feet of another persistent coordinate system).

[0031] In some embodiments, persistent coordinate data may be generated by an MR system and transmitted to a remote server. In some embodiments, a remote server may be configured to receive persistent coordinate data. In some embodiments, a remote server may be configured to synchronize persistent coordinate data from multiple observation instances. For example, multiple MR systems may map the same room with persistent coordinate data and transmit that data to a remote server. In some embodiments, the remote server may use this observation data to generate canonical persistent coordinate data, which may be based on the one or more observations. In some embodiments, canonical persistent coordinate data may be more accurate and/or reliable than a single observation of persistent coordinate data. In some embodiments, canonical persistent coordinate data may be transmitted to one or more MR systems. For example, an MR system may use image recognition and/or location data to recognize that it is located in a room that has corresponding canonical persistent coordinate data (e.g., because other MR systems have previously mapped the room). In some embodiments, the MR system may receive canonical persistent coordinate data corresponding to its location from a remote server.

[0032] With respect to FIGS. **1**A and **1**B, environment/world coordinate system **108** defines a shared coordinate space for both real environment **100** and virtual environment **130**. In the example shown, the coordinate space has its origin at point **106**. Further, the coordinate space is defined by the same three orthogonal axes (**108**X, **108**Y, **108**Z). Accordingly, a first location in real environment **100**, and a second, corresponding location in virtual environment **130**, can be described with respect to the same coordinate space. This simplifies identifying and displaying corresponding locations in real and virtual environments, because the same coordinates can be used to identify both locations. However, in some examples, corresponding real and virtual environments need not use a shared coordinate space. For instance, in some examples (not shown),

a matrix (which may include a translation matrix and a Quaternion matrix or other rotation matrix), or other suitable representation can characterize a transformation between a real environment coordinate space and a virtual environment coordinate space.

[0033] FIG. **1**C illustrates an example MRE **150** that simultaneously presents aspects of real environment **100** and virtual environment **130** to user **110** via mixed reality system **112**. In the example shown, MRE **150** simultaneously presents user **110** with real objects **122**A, **124**A, **126**A, and **128**A from real environment **100** (e.g., via a transmissive portion of a display of mixed reality system **112**); and virtual objects **122**B, **124**B, **126**B, and **132** from virtual environment **130** (e.g., via an active display portion of the display of mixed reality system **112**). As above, origin point **106** acts as an origin for a coordinate space corresponding to MRE **150**, and coordinate system **108** defines an x-axis, y-axis, and z-axis for the coordinate space.

[0034] In the example shown, mixed reality objects include corresponding pairs of real objects and virtual objects (i.e., **122**A/**122**B, **124**A/**124**B, **126**A/**126**B) that occupy corresponding locations in coordinate space **108**. In some examples, both the real objects and the virtual objects may be simultaneously visible to user **110**. This may be desirable in, for example, instances where the virtual object presents information designed to augment a view of the corresponding real object (such as in a museum application where a virtual object presents the missing pieces of an ancient damaged sculpture). In some examples, the virtual objects (**122**B, **124**B, and/or **126**B) may be displayed (e.g., via active pixelated occlusion using a pixelated occlusion shutter) so as to occlude the corresponding real objects (**122**A, **124**A, and/or **126**A). This may be desirable in, for example, instances where the virtual object acts as a visual replacement for the corresponding real object (such as in an interactive storytelling application where an inanimate real object becomes a "living" character).

[0035] In some examples, real objects (e.g., **122**A, **124**A, **126**A) may be associated with virtual content or helper data that may not necessarily constitute virtual objects. Virtual content or helper data can facilitate processing or handling of virtual objects in the mixed reality environment. For example, such virtual content could include two-dimensional representations of corresponding real objects; custom asset types associated with corresponding real objects; or statistical data associated with corresponding real objects. This information can enable or facilitate calculations involving a real object without incurring unnecessary computational overhead.

[0036] In some examples, the presentation described above may also incorporate audio aspects. For instance, in MRE **150**, virtual monster **132** could be associated with one or more audio signals, such as a footstep sound effect that is generated as the monster walks around MRE **150**. As described further below, a processor of mixed reality system **112** can compute an audio signal corresponding to a mixed and processed composite of all such sounds in MRE **150**, and present the audio signal to user **110** via one or more speakers included in mixed reality system **112** and/or one or more external speakers.

Example Mixed Reality System

[0037] Example mixed reality system **112** can include a wearable head device (e.g., a wearable augmented reality or mixed reality head device) comprising a display (which may include left and right transmissive displays, which may be near-eye displays, and associated components for coupling light from the displays to the user's eyes); left and right speakers (e.g., positioned adjacent to the user's left and right ears, respectively); an inertial measurement unit (IMU) (e.g., mounted to a temple arm of the head device); an orthogonal coil electromagnetic receiver (e.g., mounted to the left temple piece); left and right cameras (e.g., depth (time-of-flight) cameras) oriented away from the user; and left and right eye cameras oriented toward the user (e.g., for detecting the user's eye movements). However, a mixed reality system **112** can incorporate any suitable display technology, and any suitable sensors (e.g., optical, infrared, acoustic, LIDAR, EOG, GPS, magnetic). In addition, mixed reality system **112** may incorporate networking features (e.g., Wi-Fi capability) to communicate with other devices and systems, including other mixed reality systems. Mixed reality

system **112** may further include a battery (which may be mounted in an auxiliary unit, such as a belt pack designed to be worn around a user's waist), a processor, and a memory. The wearable head device of mixed reality system **112** may include tracking components, such as an IMU or other suitable sensors, configured to output a set of coordinates of the wearable head device relative to the user's environment. In some examples, tracking components may provide input to a processor performing a Simultaneous Localization and Mapping (SLAM) and/or visual odometry algorithm. In some examples, mixed reality system **112** may also include a handheld controller **300**, and/or an auxiliary unit **320**, which may be a wearable beltpack, as described further below.

[0038] FIGS. **2**A-**2**D illustrate components of an example mixed reality system **200** (which may correspond to mixed reality system **112**) that may be used to present an MRE (which may correspond to MRE **150**), or other virtual environment, to a user. FIG. **2**A illustrates a perspective view of a wearable head device **2102** included in example mixed reality system **200**. FIG. **2**B illustrates a top view of wearable head device **2102** worn on a user's head **2202**. FIG. **2**C illustrates a front view of wearable head device **2102**. FIG. **2**D illustrates an edge view of example eyepiece **2110** of wearable head device **2102**. As shown in FIGS. **2**A-**2**C, the example wearable head device **2102** includes an example left eyepiece (e.g., a left transparent waveguide set eyepiece) **2108** and an example right eyepiece (e.g., a right transparent waveguide set eyepiece) **2110**. Each eyepiece **2108** and **2110** can include transmissive elements through which a real environment can be visible, as well as display elements for presenting a display (e.g., via imagewise modulated light) overlapping the real environment. In some examples, such display elements can include surface diffractive optical elements for controlling the flow of imagewise modulated light. For instance, the left eyepiece **2108** can include a left incoupling grating set **2112**, a left orthogonal pupil expansion (OPE) grating set **2120**, and a left exit (output) pupil expansion (EPE) grating set **2122**. Similarly, the right eyepiece **2110** can include a right incoupling grating set **2118**, a right OPE grating set **2114** and a right EPE grating set **2116**. Imagewise modulated light can be transferred to a user's eye via the incoupling gratings **2112** and **2118**, OPEs **2114** and **2120**, and EPE **2116** and **2122**. Each incoupling grating set **2112**, **2118** can be configured to deflect light toward its corresponding OPE grating set **2120**, **2114**. Each OPE grating set **2120**, **2114** can be designed to incrementally deflect light down toward its associated EPE **2122**, **2116**, thereby horizontally extending an exit pupil being formed. Each EPE **2122**, **2116** can be configured to incrementally redirect at least a portion of light received from its corresponding OPE grating set **2120**, **2114** outward to a user eyebox position (not shown) defined behind the eyepieces **2108**, **2110**, vertically extending the exit pupil that is formed at the eyebox. Alternatively, in lieu of the incoupling grating sets **2112** and **2118**, OPE grating sets **2114** and **2120**, and EPE grating sets **2116** and **2122**, the eyepieces **2108** and **2110** can include other arrangements of gratings and/or refractive and reflective features for controlling the coupling of imagewise modulated light to the user's eyes.

[0039] In some examples, wearable head device **2102** can include a left temple arm **2130** and a right temple arm **2132**, where the left temple arm **2130** includes a left speaker **2134** and the right temple arm **2132** includes a right speaker **2136**. An orthogonal coil electromagnetic receiver **2138** can be located in the left temple piece, or in another suitable location in the wearable head unit **2102**. An Inertial Measurement Unit (IMU) **2140** can be located in the right temple arm **2132**, or in another suitable location in the wearable head device **2102**. The wearable head device **2102** can also include a left depth (e.g., time-of-flight) camera **2142** and a right depth camera **2144**. The depth cameras **2142**, **2144** can be suitably oriented in different directions so as to together cover a wider field of view.

[0040] In the example shown in FIGS. **2**A-**2**D, a left source of imagewise modulated light **2124** can be optically coupled into the left eyepiece **2108** through the left incoupling grating set **2112**, and a right source of imagewise modulated light **2126** can be optically coupled into the right eyepiece **2110** through the right incoupling grating set **2118**. Sources of imagewise modulated light **2124**, **2126** can include, for example, optical fiber scanners; projectors including electronic light

modulators such as Digital Light Processing (DLP) chips or Liquid Crystal on Silicon (LCoS) modulators; or emissive displays, such as micro Light Emitting Diode (μLED) or micro Organic Light Emitting Diode (μOLED) panels coupled into the incoupling grating sets **2112**, **2118** using one or more lenses per side. The input coupling grating sets **2112**, **2118** can deflect light from the sources of imagewise modulated light **2124**, **2126** to angles above the critical angle for Total Internal Reflection (TIR) for the eyepieces **2108**, **2110**. The OPE grating sets **2114**, **2120** incrementally deflect light propagating by TIR down toward the EPE grating sets **2116**, **2122**. The EPE grating sets **2116**, **2122** incrementally couple light toward the user's face, including the pupils of the user's eyes.

[0041] In some examples, as shown in FIG. **2**D, each of the left eyepiece **2108** and the right eyepiece **2110** includes a plurality of waveguides **2402**. For example, each eyepiece **2108**, **2110** can include multiple individual waveguides, each dedicated to a respective color channel (e.g., red, blue and green). In some examples, each eyepiece **2108**, **2110** can include multiple sets of such waveguides, with each set configured to impart different wavefront curvature to emitted light. The wavefront curvature may be convex with respect to the user's eyes, for example to present a virtual object positioned a distance in front of the user (e.g., by a distance corresponding to the reciprocal of wavefront curvature). In some examples, EPE grating sets **2116**, **2122** can include curved grating grooves to effect convex wavefront curvature by altering the Poynting vector of exiting light across each EPE.

[0042] In some examples, to create a perception that displayed content is three-dimensional, stereoscopically-adjusted left and right eye imagery can be presented to the user through the imagewise light modulators **2124**, **2126** and the eyepieces **2108**, **2110**. The perceived realism of a presentation of a three-dimensional virtual object can be enhanced by selecting waveguides (and thus corresponding the wavefront curvatures) such that the virtual object is displayed at a distance approximating a distance indicated by the stereoscopic left and right images. This technique may also reduce motion sickness experienced by some users, which may be caused by differences between the depth perception cues provided by stereoscopic left and right eye imagery, and the autonomic accommodation (e.g., object distance-dependent focus) of the human eye.

[0043] FIG. **2**D illustrates an edge-facing view from the top of the right eyepiece **2110** of example wearable head device **2102**. As shown in FIG. **2**D, the plurality of waveguides **2402** can include a first subset of three waveguides **2404** and a second subset of three waveguides **2406**. The two subsets of waveguides **2404**, **2406** can be differentiated by different EPE gratings featuring different grating line curvatures to impart different wavefront curvatures to exiting light. Within each of the subsets of waveguides **2404**, **2406** each waveguide can be used to couple a different spectral channel (e.g., one of red, green and blue spectral channels) to the user's right eye **2206**. (Although not shown in FIG. **2**D, the structure of the left eyepiece **2108** is analogous to the structure of the right eyepiece **2110**.)

[0044] FIG. **3**A illustrates an example handheld controller component **300** of a mixed reality system **200**. In some examples, handheld controller **300** includes a grip portion **346** and one or more buttons **350** disposed along a top surface **348**. In some examples, buttons **350** may be configured for use as an optical tracking target, e.g., for tracking six-degree-of-freedom (6DOF) motion of the handheld controller **300**, in conjunction with a camera or other optical sensor (which may be mounted in a head unit (e.g., wearable head device **2102**) of mixed reality system **200**). In some examples, handheld controller **300** includes tracking components (e.g., an IMU or other suitable sensors) for detecting position or orientation, such as position or orientation relative to wearable head device **2102**. In some examples, such tracking components may be positioned in a handle of handheld controller **300**, and/or may be mechanically coupled to the handheld controller. Handheld controller **300** can be configured to provide one or more output signals corresponding to one or more of a pressed state of the buttons; or a position, orientation, and/or motion of the handheld controller **300** (e.g., via an IMU). Such output signals may be used as input to a processor

of mixed reality system **200**. Such input may correspond to a position, orientation, and/or movement of the handheld controller (and, by extension, to a position, orientation, and/or movement of a hand of a user holding the controller). Such input may also correspond to a user pressing buttons **350**.

[0045] FIG. **3**B illustrates an example auxiliary unit **320** of a mixed reality system **200**. The auxiliary unit **320** can include a battery to provide energy to operate the system **200**, and can include a processor for executing programs to operate the system **200**. As shown, the example auxiliary unit **320** includes a clip **2128**, such as for attaching the auxiliary unit **320** to a user's belt. Other form factors are suitable for auxiliary unit **320** and will be apparent, including form factors that do not involve mounting the unit to a user's belt. In some examples, auxiliary unit **320** is coupled to the wearable head device **2102** through a multiconduit cable that can include, for example, electrical wires and fiber optics. Wireless connections between the auxiliary unit **320** and the wearable head device **2102** can also be used.

[0046] In some examples, mixed reality system **200** can include one or more microphones to detect sound and provide corresponding signals to the mixed reality system. In some examples, a microphone may be attached to, or integrated with, wearable head device **2102**, and may be configured to detect a user's voice. In some examples, a microphone may be attached to, or integrated with, handheld controller **300** and/or auxiliary unit **320**. Such a microphone may be configured to detect environmental sounds, ambient noise, voices of a user or a third party, or other sounds.

[0047] FIG. **4** shows an example functional block diagram that may correspond to an example mixed reality system, such as mixed reality system **200** described above (which may correspond to mixed reality system **112** with respect to FIG. **1**). As shown in FIG. **4**, example handheld controller **400**B (which may correspond to handheld controller **300** (a "totem")) includes a totem-to-wearable head device six degree of freedom (6DOF) totem subsystem **404**A and example wearable head device **400**A (which may correspond to wearable head device **2102**) includes a totem-to-wearable head device 6DOF subsystem **404**B. In the example, the 6DOF totem subsystem **404**A and the 6DOF subsystem **404**B cooperate to determine six coordinates (e.g., offsets in three translation directions and rotation along three axes) of the handheld controller **400**B relative to the wearable head device **400**A. The six degrees of freedom may be expressed relative to a coordinate system of the wearable head device **400**A. The three translation offsets may be expressed as X, Y, and Z offsets in such a coordinate system, as a translation matrix, or as some other representation. The rotation degrees of freedom may be expressed as sequence of yaw, pitch and roll rotations, as a rotation matrix, as a quaternion, or as some other representation. In some examples, the wearable head device **400**A; one or more depth cameras **444** (and/or one or more non-depth cameras) included in the wearable head device **400**A; and/or one or more optical targets (e.g., buttons **350** of handheld controller **400**B as described above, or dedicated optical targets included in the handheld controller **400**B) can be used for 6DOF tracking. In some examples, the handheld controller **400**B can include a camera, as described above; and the wearable head device **400**A can include an optical target for optical tracking in conjunction with the camera. In some examples, the wearable head device **400**A and the handheld controller **400**B each include a set of three orthogonally oriented solenoids which are used to wirelessly send and receive three distinguishable signals. By measuring the relative magnitude of the three distinguishable signals received in each of the coils used for receiving, the 6DOF of the wearable head device **400**A relative to the handheld controller **400**B may be determined. Additionally, 6DOF totem subsystem **404**A can include an Inertial Measurement Unit (IMU) that is useful to provide improved accuracy and/or more timely information on rapid movements of the handheld controller **400**B.

[0048] In some examples, it may become necessary to transform coordinates from a local coordinate space (e.g., a coordinate space fixed relative to the wearable head device **400**A) to an inertial coordinate space (e.g., a coordinate space fixed relative to the real environment), for

example in order to compensate for the movement of the wearable head device **400**A relative to the coordinate system **108**. For instance, such transformations may be necessary for a display of the wearable head device **400**A to present a virtual object at an expected position and orientation relative to the real environment (e.g., a virtual person sitting in a real chair, facing forward, regardless of the wearable head device's position and orientation), rather than at a fixed position and orientation on the display (e.g., at the same position in the right lower corner of the display), to preserve the illusion that the virtual object exists in the real environment (and does not, for example, appear positioned unnaturally in the real environment as the wearable head device **400**A shifts and rotates). In some examples, a compensatory transformation between coordinate spaces can be determined by processing imagery from the depth cameras **444** using a SLAM and/or visual odometry procedure in order to determine the transformation of the wearable head device **400**A relative to the coordinate system **108**. In the example shown in FIG. **4**, the depth cameras **444** are coupled to a SLAM/visual odometry block **406** and can provide imagery to block **406**. The SLAM/visual odometry block **406** implementation can include a processor configured to process this imagery and determine a position and orientation of the user's head, which can then be used to identify a transformation between a head coordinate space and another coordinate space (e.g., an inertial coordinate space). Similarly, in some examples, an additional source of information on the user's head pose and location is obtained from an IMU **409**. Information from the IMU **409** can be integrated with information from the SLAM/visual odometry block **406** to provide improved accuracy and/or more timely information on rapid adjustments of the user's head pose and position.

[0049] In some examples, the depth cameras **444** can supply 3D imagery to a hand gesture tracker **411**, which may be implemented in a processor of the wearable head device **400**A. The hand gesture tracker **411** can identify a user's hand gestures, for example by matching 3D imagery received from the depth cameras **444** to stored patterns representing hand gestures. Other suitable techniques of identifying a user's hand gestures will be apparent.

[0050] In some examples, one or more processors **416** may be configured to receive data from the wearable head device's 6DOF headgear subsystem **404**B, the IMU **409**, the SLAM/visual odometry block **406**, depth cameras **444**, and/or the hand gesture tracker **411**. The processor **416** can also send and receive control signals from the 6DOF totem system **404**A. The processor **416** may be coupled to the 6DOF totem system **404**A wirelessly, such as in examples where the handheld controller **400**B is untethered. Processor **416** may further communicate with additional components, such as an audio-visual content memory **418**, a Graphical Processing Unit (GPU) **420**, and/or a Digital Signal Processor (DSP) audio spatializer **422**. The DSP audio spatializer **422** may be coupled to a Head Related Transfer Function (HRTF) memory **425**. The GPU **420** can include a left channel output coupled to the left source of imagewise modulated light **424** and a right channel output coupled to the right source of imagewise modulated light **426**. GPU **420** can output stereoscopic image data to the sources of imagewise modulated light **424**, **426**, for example as described above with respect to FIGS. **2A-2D**. The DSP audio spatializer **422** can output audio to a left speaker **412** and/or a right speaker **414**. The DSP audio spatializer **422** can receive input from processor **419** indicating a direction vector from a user to a virtual sound source (which may be moved by the user, e.g., via the handheld controller **320**). Based on the direction vector, the DSP audio spatializer **422** can determine a corresponding HRTF (e.g., by accessing a HRTF, or by interpolating multiple HRTFs). The DSP audio spatializer **422** can then apply the determined HRTF to an audio signal, such as an audio signal corresponding to a virtual sound generated by a virtual object. This can enhance the believability and realism of the virtual sound, by incorporating the relative position and orientation of the user relative to the virtual sound in the mixed reality environment—that is, by presenting a virtual sound that matches a user's expectations of what that virtual sound would sound like if it were a real sound in a real environment.

[0051] In some examples, such as shown in FIG. **4**, one or more of processor **416**, GPU **420**, DSP audio spatializer **422**, HRTF memory **425**, and audio/visual content memory **418** may be included

in an auxiliary unit **400**C (which may correspond to auxiliary unit **320** described above). The auxiliary unit **400**C may include a battery **427** to power its components and/or to supply power to the wearable head device **400**A or handheld controller **400**B. Including such components in an auxiliary unit, which can be mounted to a user's waist, can limit the size and weight of the wearable head device **400**A, which can in turn reduce fatigue of a user's head and neck.

[0052] While FIG. **4** presents elements corresponding to various components of an example mixed reality system, various other suitable arrangements of these components will become apparent to those skilled in the art. For example, elements presented in FIG. **4** as being associated with auxiliary unit **400**C could instead be associated with the wearable head device **400**A or handheld controller **400**B. Furthermore, some mixed reality systems may forgo entirely a handheld controller **400**B or auxiliary unit **400**C. Such changes and modifications are to be understood as being included within the scope of the disclosed examples.

Session Manager

[0053] MR systems may be uniquely positioned to enable interactive virtual collaboration between users. Because MR systems may present virtual content three-dimensionally and in a user's physical environment, MR collaboration systems and methods may enable remote collaboration that can be at least as effective as local collaboration. In some embodiments, MR collaboration can allow users to see and/or manipulate virtual content in three-dimensional space. For example, a first user may launch an MR collaboration session and may see two virtual 3D models, a text document, and a messaging interface. A second user may join the session locally (e.g., the second user may walk into the same room as the first user), and the second user may see the same two virtual 3D models, text document, and messaging interface in the same location as the first user. In some embodiments, a third user may join the session remotely (e.g., the third user may not be in the same room as the first and the second users), and the third user may see the two virtual 3D models, text document, and messaging interface in the third user's environment. In some embodiments, the virtual content may share spatial relationships with each other (e.g., the virtual content may be arranged the same way) for all session users. In some embodiments, MR collaboration may allow users in the same physical space to leverage the shared physical context to enjoy more meaningful shared experiences involving virtual content.

[0054] In some embodiments, displaying and/or synchronizing virtual content across multiple MR systems may pose challenges. For example, it can be beneficial to develop systems and methods for ensuring each MR system displays shared virtual content in a manner that is consistent with other MR systems in a session. It can also be beneficial to develop systems and methods that may enable cross-application collaboration (e.g., virtual content that may be generated using applications created by different developers). In some embodiments, it can be beneficial to develop systems and methods that may allow users that are local to each other (e.g., users that are in the same room) to collaborate with each other as well as with users that are remote (e.g., in a different room). In some embodiments, it can be beneficial to develop systems and methods that may enable collaboration sessions to persist over time such that session users may continue collaborating at a later time. In some embodiments, it can be beneficial to develop systems and methods that may enable content persistence such that a session user to continue working on virtual content even without collaborating live with other users.

[0055] In some embodiments, a session may be broadly defined as a group of users (with identifiers) that can collaborate and share a series of experiences over time and space. In some embodiments, a session can include a communication and collaboration experience that provides network connectivity, common spatial references and a centralized user interface for chatting and sharing prisms with other MR users. Session participants can be remote or local in the same physical location. In some embodiments, a session manager can include a centralized backend service that manages some or all activity within a session. In some embodiments, session manager can include one or more user-facing, front-end controls and/or expressions representing session

manager and/or configured to receive user input (e.g., a menu and/or a session handle). In some embodiments, session manager can include a background service and/or daemon that orchestrates and manages various session events through various session states. Session manager may also drive the user experience by allowing users to be discovered and get connected with other users. In some embodiments, session manager may also manage various UI components such as a menu and/or session UI related states.

[0056] In some embodiments, collaboration can be facilitated by configuring virtual content in a collaboration session to behave similarly to real objects in collaboration sessions. For example, in a "real" collaboration session, users may sit around a table with documents and/or objects. Users may refer to "this" document and/or "that" document by pointing at a particular document. In some embodiments, users in a real collaboration session may refer to objects using relational terms (e.g., that object to the right). This behavior may occur naturally to users as a result of years of conditioning and working physically with other people. It can therefore be desirable to develop systems and methods for MR collaboration to enable natural interactions between users and the content on which they are collaborating on. In some embodiments, MR collaboration sessions can enable users to refer to colocated virtual content (e.g., virtual content that may appear in the same position in a real environment to multiple users) as if it were real content present in the user's physical environment. In some embodiments, MR collaboration sessions can persist. For example, all users may exit a session, and a user may launch the same session several weeks later. In some embodiments, the user may see all virtual content in the state at which it existed (e.g., in the same relative positions and/or with the same edits) when the users previously exited the session.

[0057] In some embodiments, a session can include a platform for presenting, synchronizing, managing, and/or storing virtual content used in a mixed reality collaboration session. For example, session users may have a recurring weekly meeting in which virtual content (e.g., word documents, 3D models, presentation slides, conversation history, etc.) are discussed and/or worked on. In some embodiments, users may leverage the platform of sessions to consolidate virtual content (which may be created by different developers) into a single virtual space that may persist over time. For example, loading a single session instance may present to a user a 3D model (generated using a first application created by a first developer), a text document describing goals and/or changes to the 3D model (generated using a second application created by a second developer), and a conversation history between session users related to this session. This virtual content may persist across time and across session users, such that the same user or a different session user may load the session and see the same session contents as any other session user. In some embodiments, a session may enable user presence flexibility (e.g., local users may share virtual content placement in their local space, but remote users may also see virtual content with the same spatial relationships in their remote space). In some embodiments, a session may enable capability flexibility. For example, capabilities (e.g., corresponding to third-party applications) can be interacted with/enabled/disabled without leaving a centralized session platform. In some embodiments, applications (e.g., third-party applications) may leverage the session platform to forgo building proprietary sharing platforms that may not be compatible with other apps. In some embodiments, a session may enable temporal flexibility. For example, users may access sessions at different times, and a live call with other users may not be necessary. In some embodiments, changes made by users can be synchronized such that the change may be reflected for other session users (whether they are currently in the session or enter the session at a later time).

[0058] In some embodiments, a session may include virtual content shared with one or more users over time. A session may have one or more owners, and in some embodiments, a user who created the session may be considered a session owner. A session may have one or more participants who may have access to the session. In some embodiments, a session owner may control what participants may join the session. In some embodiments, a session may have a session identifier. In some embodiments, each user (e.g., owner or participant) may have a user identifier. In some

embodiments, a session may include one or more user avatars, which may represent a remote user's positioning relative to other objects in a session. In some embodiments, a session may include location data (e.g., location data corresponding to each user, location data corresponding to locations the session has been opened in, etc.). Location data may include persistent coordinate data. In some embodiments, location data may include one or more transforms (e.g., one or more transformation matrices), which may relate a position to persistent coordinate data.

[0059] In some embodiments, a session can include one or more capabilities. A session capability may include one or more features that users can select and/or enable in a session. For example, virtual object sharing may be considered a session capability. In some embodiments, determining whether users are local to other users may be considered a session capability. In some embodiments, projecting a user avatar may be considered a session capability. In some embodiments, casting a user's screen to other users may be considered a session capability. In some embodiments, a capability can have one or more capability instances (e.g., a capability can have multiple instances running at the same time). For example, two virtual objects may be shared with users in a session, and each virtual object may be considered a separate capability instance.

[0060] In some embodiments, a session may be persistent. For example, a session may continue to exist even after all users have exited a session. In some embodiments, a session may continue to store session information such as session capabilities used (e.g., sharing a virtual object, what position the virtual object was in, etc.), user locations, user identifications, etc. Persistent sessions may facilitate long-term collaboration between users. For example, users may continue where they left off without having to rearrange their virtual workspace to their preference. In some embodiments, session persistence may enable a different user to enter the session at a later time and see virtual content arranged as it was when a previous user exited the session.

[0061] FIGS. **5**A-**5**C illustrate an exemplary MR collaboration session, according to some embodiments. FIG. **5**A illustrates an exemplary mixed reality collaboration session where users **508***a*, **508***b*, and **508***c* may be at a first location (e.g., a first room) together. FIG. **5**B illustrates an exemplary mixed reality collaboration session where users **508***d* and **508***e* may be at a second location (e.g., a second room) together. FIG. **5**C illustrates an exemplary mixed reality collaboration session where a session handle has been moved.

[0062] In some embodiments, users **508***a*, **508***b*, **508***c*, **508***d*, and **508***e* may all be part of the same mixed reality collaboration session **500**. In some embodiments, a collaboration session can include a session handle **502***a* (which may be a virtual object). Session handle **502***a* may serve as a local anchor for a session. For example, all session users in the same location (e.g., users **508***a*, **508***b*, and **508***c* may be considered in the same location if they share common persistent coordinate data) may be presented virtual content positioned relative to session handle **502***a*, which may give the virtual content the appearance of being located in a particular location and orientation in the real world, similar to a real/physical object. In some embodiments, session handle **502***a* may be positioned relative to persistent coordinate data (e.g., using a transform). In some embodiments, users **508***a*, **508***b*, and **508***c* may be using canonical persistent coordinate data, which may enable consistent placement of session handle **502***a* in each user's MR system. In some embodiments, users **508***a*, **508***b*, and **508***c* may all see session handle **502***a* at the same location (e.g., the users may all see session handle **502***a* on the floor at the same location).

[0063] In some embodiments, whether users can be considered local to each other may be determined using persistent coordinate data. For example, an MR system for user **508***a* may receive (e.g., from one or more remote servers) canonical persistent coordinate data based on an identified environment for user **508***a*. An MR system for user **508***a* may use location data (e.g., GPS, WiFi, and/or cellular data) and/or image recognition data (e.g., recognizing a known environment by comparing captured images with images of known environments) to identify an environment for user **508***a*. In some embodiments, an MR system for user **508***a* may transmit its received persistent coordinate data to other MR systems in a session (e.g., an MR system for user **508***b*). In some

embodiments, other MR systems in a session may receive canonical persistent coordinate data and compare the transmitted data received from other MR systems with canonical persistent coordinate already in use (and/or canonical persistent coordinate data received from one or more remote servers). If it is determined (e.g., using unique identifiers) that one or more instances of canonical persistent coordinate data is shared between MR systems in a session, it can be determined that the MR systems are local to each other. In some embodiments, if MR systems do not share instances of canonical persistent coordinate data, it may be determined that the MR systems are remote from each other. In some embodiments, a session handle (e.g., session handle **502***a*) may be displayed in relation to one or more shared instances of persistent canonical persistent coordinate data, which may enable session handle **502***a* to be presented in the same location to users **508***a*, **508***b*, and **508***c*.

[0064] In some embodiments, session **500** can include a shared virtual object **504***a*. Shared virtual object **504***a* may be considered a session capability instance. In some embodiments, users **508***a*, **508***b*, and **508***c* may all see virtual object **504***a* in the same location (e.g., the users may all see virtual object **504***a* at the end of a real table). In some embodiments, shared virtual object **504***a* may be positioned relative to session handle **502***a* (e.g., using a transform). In some embodiments, shared virtual object **504***a* may be positioned relative to persistent coordinate data (e.g., canonical persistent coordinate data). In some embodiments, a user (e.g., user **508***c*) may manipulate shared virtual object **504***a*. For example, user **508***c* may move object **504***a* from the edge of the table to the center of the table. In some embodiments, users **508***a* and **508***b* may also see object **504***a* move from the edge of the table to the center of the table. In some embodiments, if a user (e.g., user **508***b*) points to a portion of object **504***a* (e.g., the helmet), other users (e.g., **508***a* and **508***c*) may also see user **508***b* as pointing at the same portion of object **504***a*.

[0065] In some embodiments, session handle **502***a* may also be moved. For example, in FIG. **5**C, user **508***a* may move session handle **502***a* to the left. In some embodiments, any virtual content displayed as part of a session may also move, thereby maintaining the same relative positioning to session handle **502***a*. For example, as session handle **502***a* is moved to the left, object **504***a* may also be moved to the left by the same amount. In some embodiments, moving a session handle at one location (e.g., session handle **502***a*) may not move a session handle at a different location (e.g., session handle **502***b*). It can be beneficial to allow each group of local users to manage their own session handle placement. For example, because virtual content may be positioned relative to a session handle, each local group may determine an optimal location for their virtual content for their respective local physical environments.

[0066] Session **500** can involve users that may not share the same location. For example, in FIG. **5**B, users **508***d* and **508***e* may also be part of session **500**. In some embodiments, users **508***d* and **508***e* may be considered remote to users **508***a*, **508***b*, and **508***c* (e.g., because there may not be common persistent coordinate data between users **508***d*/**508***e* and **508***a*/**508***b*/**508***c*). In some embodiments, users **508***d* and **508***e* may see a second session handle **502***b*. In some embodiments, each user (or group of users) that does not have common persistent coordinate data with other users (or groups of users) may see their own session handle. Shared virtual content displayed to users **508***d* and **508***e* may be displayed relative to session handle **502***b*. For example, shared virtual object **504***b* may correspond to object **504***a*. In some embodiments, object **504***b* may be positioned in the same spot relative to session handle **502***b* as object **504***a* is positioned relative to session handle **502***a*. In some embodiments, if object **504***a* is moved relative to session handle **502***a*, object **504***b* may also move relative to session handle **502***b* (and vice versa). In some embodiments, session handle **502***b* may not move if session handle **502***a* is moved. This may enable local users to manage how session contents are presented to the local group of users.

[0067] In some embodiments, session **500** can include a user avatar **506***e*. In some embodiments, user avatar **506***e* can represent a user in session **500** that may be remote to other users in the session. For example, users **508***a*, **508***b*, and **508***c* may be considered local to each other (e.g.,

because they may share persistent coordinate data), and user **508***e* may be considered remote from users **508***a*, **508***b*, and **508***c* (e.g., because user **508***e* may not share persistent coordinate data with the other users). In some embodiments, user **508***e* (in FIG. 5B) may also be part of session **500**, and user avatar **506***e* may correspond to user **508***e*.

[0068] In some embodiments, user avatar **506***e* may enable user **508***e* to collaborate with users **508***a*, **508***b*, and **508***c*. In some embodiments, avatar **506***e* may mirror one or more movement of user **508***e*. For example, as user **508***e* approaches session handle **502***b*, user avatar **506***e* may approach session handle **502***a*, thereby maintaining the same relative positioning between user **508***e* and session handle **502***b*. In some embodiments, user **508***e* may point to object **504***b*, and avatar **506***e* may correspondingly point to object **504***a* at the same location. Similarly, avatar **506***b* may represent user **508***b*, and avatar **506***a* may represent user **508***a*. As user **508***a* approaches object **504***a*, avatar **506***a* may also approach object **504***b* accordingly. In some embodiments, a remote user may not broadcast an avatar to other users. For example, user **508***d* may be remote to users **508***a*, **508***b*, and **508***c*, but user **508***d* may not project a corresponding avatar for session handle **502***a*.

[0069] In some embodiments, session persistence may allow users to dynamically localize to different session locations. For example, users **508***a*, **508***b*, and **508***c* may be in a first room, and users **508***d* and **508***e* may be in a second room, which may be down the hall from the first room. In some embodiments, user **508***a* may leave the first room, walk down the hall and enter the second room, and virtual content may be displayed to user **508***a* relative to session handle **502***b*. In some embodiments, each MR system used by a user may periodically poll the user's location (e.g., using GPS data and/or image recognition). In some embodiments, an MR system may trigger a new location query (e.g., by using geofencing).

[0070] FIG. **6** illustrates an exemplary session manager architecture, according to some embodiments. In some embodiments, session manager **604** may run on MR system **602**, which may include one or more computer systems and can correspond to MR systems **112**, **200**. In some embodiments, session manager **604** can include a process, sub-process, thread, and/or service. In some embodiments, session manager **604** can include one or more data structures configured to store information. In some embodiments, session manager **604** can include a service (e.g., a background operating system service). In some embodiments, a process, sub-process, thread, and/or service of session manager **604** can be configured to continually run (e.g., in the background) while an operating system of a host system is running. In some embodiments, session manager **604** can include an instantiation of a parent background service, which may serve as a host process to one or more background processes and/or sub-processes. In some embodiments, session manager **604** can include a sub-process of a parent process. In some embodiments, session manager **604** can include a thread of a parent process.

[0071] Session manager **604** may include one or more session instances **606***a* and/or **606***b*. In some embodiments, a session instance can correspond to an MR collaboration session (e.g., session **500**). In some embodiments, a session instance may manage information used in an MR collaboration session. In some embodiments, a session instance may include one or more data structures configured to store information. In some embodiments, a session instance may include one or more processes, sub-processes, threads, and/or services. In some embodiments, one or more session instances may be stored at one or more remote servers. In some embodiments, session instances may be encrypted before it is stored (locally at an MR device or at one or more remote servers).

[0072] In some embodiments, a session instance may be configured to communicate with one or more capability instances. For example, session instance **606***b* may be configured to communicate with capability instances **608***b* and **608***c*. A capability instance may correspond to one or more session capabilities. For example, capability instance **608***b* may correspond to shared object **504***a*. In some embodiments, a capability instance may include one or more data structures configured to store information. In some embodiments, a capability instance may include one or more processes,

sub-processes, threads, and/or services.

[0073] In some embodiments, a capability instance can be configured to communicate with one or more connectivity services, such as application connectivity platform **610***a* and/or collaboration core **610***b*. In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* can include a process, sub-process, thread, and/or service. In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* can include one or more data structures configured to store information. In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* can include a service (e.g., a background operating system service). In some embodiments, a process, sub-process, thread, and/or service of application connectivity platform **610***a* and/or collaboration core **610***b* can be configured to continually run (e.g., in the background) while an operating system of a host system is running. In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* can include an instantiation of a parent background service, which may serve as a host process to one or more background processes and/or sub-processes. In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* can include a sub-process of a parent process. In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* can include a thread of a parent process.

[0074] In some embodiments, application connectivity platform **610***a* can provide a low-latency communication pathway between MR systems in a colocation session to enable real-time virtual object colocation. In some embodiments, application connectivity platform **610***a* can include one or more implementations of Web Real-Time Communication ("WebRTC"). For example, in some embodiments, data may be transmitted via one or more Twilio tracks for low-latency communication. In some embodiments, capability instances may utilize application connectivity platform **610***a* to send and/or receive low-latency data (e.g., relational transform data as a shared virtual object moves) from MR systems in a session. In some embodiments, application connectivity platform **610***a* can be configured to communicate with other application connectivity platforms running on other MR systems.

[0075] In some embodiments, collaboration core **610***b* can provide data synchronization services for simultaneous edits. In some embodiments, collaboration core **610***b* can be configured to receive edit data from one or more capability instances. In some embodiments, collaboration core **610***b* can be configured to communicate with external synchronization services (e.g., Firebase) to synchronize simultaneous edits to virtual content in a session.

[0076] In some embodiments, application connectivity platform **610***a* and/or collaboration core **610***b* may communicate with session manager **604**. In some embodiments, session manager **604** may provide privileged information directly to application connectivity platform **610***a* and/or collaboration core **610***b* (e.g., user identification data). It can be beneficial to shield privileged information from capability instances because a capability instance may be developed by an unknown developer, which may pose a security risk to the privileged data.

[0077] Although application connectivity platform **610***a* and collaboration core **610***b* are depicted as separate services, it is also contemplated that functions provided by each could be provided as a single service or as two or more services.

[0078] In some embodiments, session manager **604** may communicate with one or more remote servers and/or with one or more MR systems to synchronize session instances. For example, a second MR system may initiate a session and invite MR system **602** to participate in the session. In some embodiments, session manager **604** may create a new session instance corresponding to the newly joined session. In some embodiments, the new session instance may be a copy of a session instance on the second MR system. In some embodiments, a session instance may be received from one or more remote servers. In some embodiments, session instance data may be transmitted to one or more remote servers (e.g., if a capability instance has been updated, it can be desirable to transmit the update to other session users). In some embodiments, session instance data can be

transmitted to one or more remote servers at an end of a session (e.g., when the last user leaves a session), so that session data may be preserved and re-accessed at a later time. In some embodiments, session manager and/or a session instance may communicate with one or more services (e.g., one or more services provided by application connectivity platform **610***a*) to synchronize session instance data with other session instances (that may be stored at another MR system or a remote server). In some embodiments, session manager and/or a session instance may communicate with one or more services to establish a real-time and/or low-latency communication link with one or more remote end points (e.g., other MR systems in a session).

[0079] FIG. **7** illustrates an exemplary session instance architecture, according to some embodiments. In some embodiments, session instance **702** may correspond to session instance **604***a* and/or **604***b*. In some embodiments, session instance **702** can include one or more data structures, which can be configured to store one or more additional data structures (e.g., capabilities module **704**, participants module **708**, locations module **712**, and/or presence module **716**). Capabilities module **704** may manage data and/or data structures corresponding to one or more capability instances in a session. For example, instance **706***a* may correspond to a virtual object. In some embodiments, instance **706***a* may include transform data, which may relate the virtual object's position to persistent coordinate data and/or one or more session handle locations. In some embodiments, instance **706***a* may include one or more references to a collaboration core service. In some embodiments, references to a collaboration core service may enable instance **706***a* to be properly notified and/or updated if a change is made to instance **706***a* by a user. In some embodiments, instance **706***a* may include application connectivity platform data (e.g., where data should be sent to, what pipes should be used, etc.). In some embodiments, capabilities module **704** may be configured to communicate with one or more capability instances (e.g., capability instance **608***a*).

[0080] In some embodiments, session instance **702** may include participants module **708**. Participants module **708** may manage data and/or data structures corresponding to one or more users in a session. For example, user **710***a* may include an identifier for an MR system used by a user. In some embodiments, user **710***a* may include avatar data (e.g., appearance, size, color, etc.). In some embodiments, user **710***a* may include location data. In some embodiments, location data can include GPS data, WiFi data, cellular data, persistent coordinate data, etc.

[0081] In some embodiments, session instance **702** may include locations module **712**. Locations module **712** may manage data and/or data structures corresponding to one or more locations in a session. For example, location **714***a* may include persistent coordinate data, transformation data, data corresponding to a floor plane, etc. In some embodiments, location **714***a* may correspond to a user location. In some embodiments, location **714***a* may correspond to a session handle location.

[0082] In some embodiments, session instance **702** may include presence module **716**. Presence module **716** may manage data and/or data structures corresponding to local and/or remote status of one or more users. For example, instance **718***a* may indicate that a first user is remote from a second user, and a third user is local to the second user. In some embodiments, instance **718***a* may include data used for communication between users (e.g., using application connectivity platform **610***a*).

[0083] Systems, methods, and computer-readable media are disclosed. According to some examples, a system comprises: a wearable device comprising a transmissive display; and one or more processors configured to execute a method comprising: receiving persistent coordinate data; presenting a first virtual session handle to a first user at a first position via the transmissive display of a wearable device, wherein the first position is determined based on the persistent coordinate data; presenting a virtual object to the first user at a second position via the transmissive display, wherein the second position is determined based on the first position; receiving location data from a second user, wherein the location data relates a position of the second user to a position of a second virtual session handle; and presenting a virtual avatar to the first user at a third position via

the transmissive display, wherein the virtual avatar corresponds to the second user, wherein the third position is determined based on the location data, and wherein the third position is further determined based on the first position. In some examples, the method further comprises: receiving an input from the second user; and in response to receiving the input from the second user, presenting the virtual object to the first user at a fourth position via the transmissive display. In some examples, the virtual object is presented to the first user at the second position in response to an input from the first user, and the method further comprises transmitting the input from the first user to the second user. In some examples, the method further comprises: receiving an input from the first user; in response to receiving the input from the first user, presenting the first session handle to the first user at a fourth position; and presenting the virtual object to the first user at a fifth position via the transmissive display, the fifth position determined based on the fourth position. In some examples, the method further comprises transmitting the input from the first user to the second user. In some examples, the method further comprises: storing in a memory the first position, the second position, and the third position associated with a session instance at a first time; and receiving from the memory the first position, the second position, and the third position at a second time later than the first time.

[0084] According to some examples, a method comprises: receiving persistent coordinate data; presenting a first virtual session handle to a first user at a first position via a transmissive display of a wearable device, wherein the first position is determined based on the persistent coordinate data; presenting a virtual object to the first user at a second position via the transmissive display, wherein the second position is determined based on the first position; receiving location data from a second user, wherein the location data relates a position of the second user to a position of a second virtual session handle; and presenting a virtual avatar to the first user at a third position via the transmissive display, wherein the virtual avatar corresponds to the second user, wherein the third position is determined based on the location data, and wherein the third position is further determined based on the first position. In some examples, the method further comprises: receiving an input from the second user; and in response to receiving the input from the second user, presenting the virtual object to the first user at a fourth position via the transmissive display. In some examples, the virtual object is presented to the first user at the second position in response to an input from the first user, and the method further comprises transmitting the input from the first user to the second user. In some examples, the method further comprises: receiving an input from the first user; in response to receiving the input from the first user, presenting the first session handle to the first user at a fourth position; and presenting the virtual object to the first user at a fifth position via the transmissive display, the fifth position determined based on the fourth position. In some examples, the method further comprises transmitting the input from the first user to the second user. In some examples, the method further comprises: storing in a memory the first position, the second position, and the third position associated with a session instance at a first time; and receiving from the memory the first position, the second position, and the third position at a second time later than the first time.

[0085] According to some examples, a non-transitory computer-readable medium stores instructions that, when executed by one or more processors, cause the one or more processors to execute a method comprising: receiving persistent coordinate data; presenting a first virtual session handle to a first user at a first position via a transmissive display of a wearable device, wherein the first position is determined based on the persistent coordinate data; presenting a virtual object to the first user at a second position via the transmissive display, wherein the second position is determined based on the first position; receiving location data from a second user, wherein the location data relates a position of the second user to a position of a second virtual session handle; and presenting a virtual avatar to the first user at a third position via the transmissive display, wherein the virtual avatar corresponds to the second user, wherein the third position is determined based on the location data, and wherein the third position is further determined based on the first

position. In some examples, the method further comprises: receiving an input from the second user; and in response to receiving the input from the second user, presenting the virtual object to the first user at a fourth position via the transmissive display. In some examples, the virtual object is presented to the first user at the second position in response to an input from the first user, and the method further comprises transmitting the input from the first user to the second user. In some examples, the method further comprises: receiving an input from the first user; in response to receiving the input from the first user, presenting the first session handle to the first user at a fourth position; and presenting the virtual object to the first user at a fifth position via the transmissive display, the fifth position determined based on the fourth position. In some examples, the method further comprises transmitting the input from the first user to the second user. In some examples, the method further comprises: storing in a memory the first position, the second position, and the third position associated with a session instance at a first time; and receiving from the memory the first position, the second position, and the third position at a second time later than the first time.

[0086] According to some examples, a system comprises: a first wearable device comprising a first transmissive display and one or more sensors; and one or more processors configured to execute a method comprising: receiving a first input from a first session user associated with the first wearable device; in response to receiving the first input, generating a session instance, wherein the session instance is configured to store data corresponding to one or more capability instances, and wherein the session instance is further configured to store data corresponding to one or more session users; presenting a virtual session handle to the first session user at a first session handle position via the first transmissive display of the first wearable device; receiving a second input from the first session user; and in response to receiving the second input: generating a first capability instance associated with a process, the process comprising projecting a virtual object; presenting the virtual object to the first session user at a first object position via the first transmissive display; presenting the virtual object to a second session user at a second object position via a second transmissive display of a second wearable device; and storing data corresponding to the first session handle position, the first object position, the second object position, a first session user position, and a second session user position in the session instance, wherein the first session user position is determined via the one or more sensors of the first wearable device and the second session user position is determined via one or more sensors of the second wearable device. In some examples, the first object position is related to the first session handle position using transform data. In some examples, the transform data is stored in the session instance. In some examples, the method further comprises storing data corresponding to a localization status, wherein the localization status is based on the first session user position and the second session user position. In some examples, the second input is received at a first time, and the method further comprises: receiving a third input from the first session user at a second time later than the first time; and in response to receiving the third input: receiving data corresponding to the first object position and the first session user position; and presenting the virtual object to the first session user at the first object position. In some examples, the method further comprises: generating a second capability instance, the second capability instance associated with a second process, the second process comprising projecting a virtual avatar of the second session user; presenting the virtual avatar to the first session user via the first transmissive display; and storing data corresponding to the virtual avatar in the session instance. In some examples, the method further comprises generating a second capability instance, the second capability instance associated with a second process, the second process comprising casting a view associated with the first session user to the second session user.

[0087] According to some examples, a method comprises: receiving a first input from a first session user; in response to receiving the first input, generating a session instance, wherein the session instance is configured to store data corresponding to one or more capability instances, and wherein the session instance is further configured to store data corresponding to one or more

session users; presenting a virtual session handle to the first session user at a first session handle position via a first transmissive display of a first wearable device; receiving a second input from the first session user; and in response to receiving the second input: generating a first capability instance associated with a process, the process comprising projecting a virtual object; presenting the virtual object to the first session user at a first object position via the first transmissive display; presenting the virtual object to a second session user at a second object position via a second transmissive display of a second wearable device; and storing data corresponding to the first session handle position, the first object position, the second object position, a first session user position, and a second session user position in the session instance, wherein the first session user position is determined via one or more sensors of the first wearable device and the second session user position is determined via one or more sensors of the second wearable device. In some examples, the first object position is related to the first session handle position using transform data. In some examples, the transform data is stored in the session instance. In some examples, the method further comprises storing data corresponding to a localization status, wherein the localization status is based on the first session user position and the second session user position. In some examples, the second input is received at a first time, and the method further comprises: receiving a third input from the first session user at a second time later than the first time; and in response to receiving the third input: receiving data corresponding to the first object position and the first session user position; and presenting the virtual object to the first session user at the first object position. In some examples, the method further comprises: generating a second capability instance, the second capability instance associated with a second process, the second process comprising projecting a virtual avatar of the second session user; presenting the virtual avatar to the first session user via the first transmissive display; and storing data corresponding to the virtual avatar in the session instance. In some examples, the method further comprises generating a second capability instance, the second capability instance associated with a second process, the second process comprising casting a view associated with the first session user to the second session user.

[0088] According to some examples, a non-transitory computer-readable medium stores instructions that, when executed by one or more processors, cause the one or more processors to execute a method comprising: receiving a first input from a first session user; in response to receiving the first input, generating a session instance, wherein the session instance is configured to store data corresponding to one or more capability instances, and wherein the session instance is further configured to store data corresponding to one or more session users; presenting a virtual session handle to the first session user at a first session handle position via a first transmissive display of a first wearable device; receiving a second input from the first session user; in response to receiving the second input: generating a first capability instance associated with a process, the process comprising projecting a virtual object; presenting the virtual object to the first session user at a first object position via the first transmissive display; presenting the virtual object to a second session user at a second object position via a second transmissive display of a second wearable device; and storing data corresponding to the first session handle position, the first object position, the second object position, a first session user position, and a second session user position in the session instance, wherein the first session user position is determined via one or more sensors of the first wearable device and the second session user position is determined via one or more sensors of the second wearable device. In some examples, the first object position is related to the first session handle position using transform data. In some examples, the transform data is stored in the session instance. In some examples, the method further comprises storing data corresponding to a localization status, wherein the localization status is based on the first session user position and the second session user position. In some examples, the second input is received at a first time, and the method further comprises: receiving a third input from the first session user at a second time later than the first time; and in response to receiving the third input: receiving data corresponding to the first object position and the first session user position; and presenting the virtual object to the first

session user at the first object position. In some examples, the method further comprises: generating a second capability instance, the second capability instance associated with a second process, the second process comprising projecting a virtual avatar of the second session user; presenting the virtual avatar to the first session user via the first transmissive display; and storing data corresponding to the virtual avatar in the session instance. In some examples, the method further comprises generating a second capability instance, the second capability instance associated with a second process, the second process comprising casting a view associated with the first session user to the second session user.

[0089] Although the disclosed examples have been fully described with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. For example, elements of one or more implementations may be combined, deleted, modified, or supplemented to form further implementations. Such changes and modifications are to be understood as being included within the scope of the disclosed examples as defined by the appended claims.

Claims

1. A method comprising: receiving, at a first system comprising a first wearable head device, persistent coordinate data, the first wearable head device comprising a transmissive display, the first system having a first user; providing, from the first system, first location data, wherein the first location data relates a position of the first user to a position of a first virtual session handle of a session; and receiving, at the first system, first relational data, wherein the first relational data relates a first position of a virtual object to be presented on the transmissive display to the position of the first virtual session handle, wherein: the session comprises data associated with the first user and further comprises data associated with a second user of a second system, the second system comprising a second wearable head device, and the second system is configured to provide second location data, the second location data relating a position of the second user to a position of a second virtual session handle of the session.

2. The method of claim 1, further comprising receiving, at the first system, second relational data, wherein the second relational data relates a second position of the virtual object to the position of the first virtual session handle.

3. The method of claim 2, wherein the second relational data is provided in response to an input from the second user.

4. The method of claim 2, wherein the second relational data is provided in response to an input from the first user.

5. The method of claim 1, wherein: a session instance is stored in a memory at a first time, the session instance comprising the first position of the virtual object; and the session instance is retrievable from the memory at a second time later than the first time.

6. The method of claim 5, wherein a server remote to the first wearable head device comprises the memory.

7. The method of claim 5, wherein the session instance is encrypted prior to storing the session instance in the memory.

8. The method of claim 1, further comprising receiving, at the first system, user identification data.

9. The method of claim 1, wherein the virtual object is associated with a capability of the session.

10. The method of claim 1, wherein the first relational data is received via an application connectivity platform, the application connectivity platform in communication with the first system and the second system.

11. The method of claim 10, wherein the application connectivity platform provides a low-latency communication pathway between the first system and the second system.

12. The method of claim 1, wherein in response to an input from the first user, the position of the

first virtual session handle of the session is updated.

13. The method of claim 12, further comprising transmitting the input to the second system.

14. A system comprising: a first wearable device comprising a transmissive display; and one or more processors configured to perform a method comprising: receiving persistent coordinate data, wherein the system has a first user; providing first location data, wherein the first location data relates a position of the first user to a position of a first virtual session handle of a session; and receiving first relational data, wherein the first relational data relates a first position of a virtual object to be presented on the transmissive display to the position of the first virtual session handle, wherein: the session comprises data associated with the first user and further comprises data associated with a second user of a second system, the second system comprising a second wearable head device, and the second system is configured to provide second location data, the second location data relating a position of the second user to a position of a second virtual session handle of the session.

15. The system of claim 14, wherein the method further comprises receiving second relational data, wherein the second relational data relates a second position of the virtual object to the position of the first virtual session handle.

16. The system of claim 14, wherein: a session instance is stored in a memory at a first time, the session instance comprising the first position of the virtual object; and the session instance is retrievable from the memory at a second time later than the first time.

17. The system of claim 14, wherein the virtual object is associated with a capability of the session.

18. The system of claim 14, wherein the first relational data is received via an application connectivity platform, the application connectivity platform in communication with the first system and the second system.

19. The system of claim 14, wherein in response to an input from the first user, the position of the first virtual session handle of the session is updated.

20. A non-transitory computer-readable medium storing instructions that, when executed by one or more processors, cause the one or more processors to perform a method comprising: receiving, at a first system comprising a first wearable head device, persistent coordinate data, the first wearable head device comprising a transmissive display, the first system having a first user; providing, from the first system, first location data, wherein the first location data relates a position of the first user to a position of a first virtual session handle of a session; and receiving, at the first system, first relational data, wherein the first relational data relates a first position of a virtual object to be presented on the transmissive display to the position of the first virtual session handle, wherein: the session comprises data associated with the first user and further comprises data associated with a second user of a second system, the second system comprising a second wearable head device, and the second system is configured to provide second location data, the second location data relating a position of the second user to a position of a second virtual session handle of the session.