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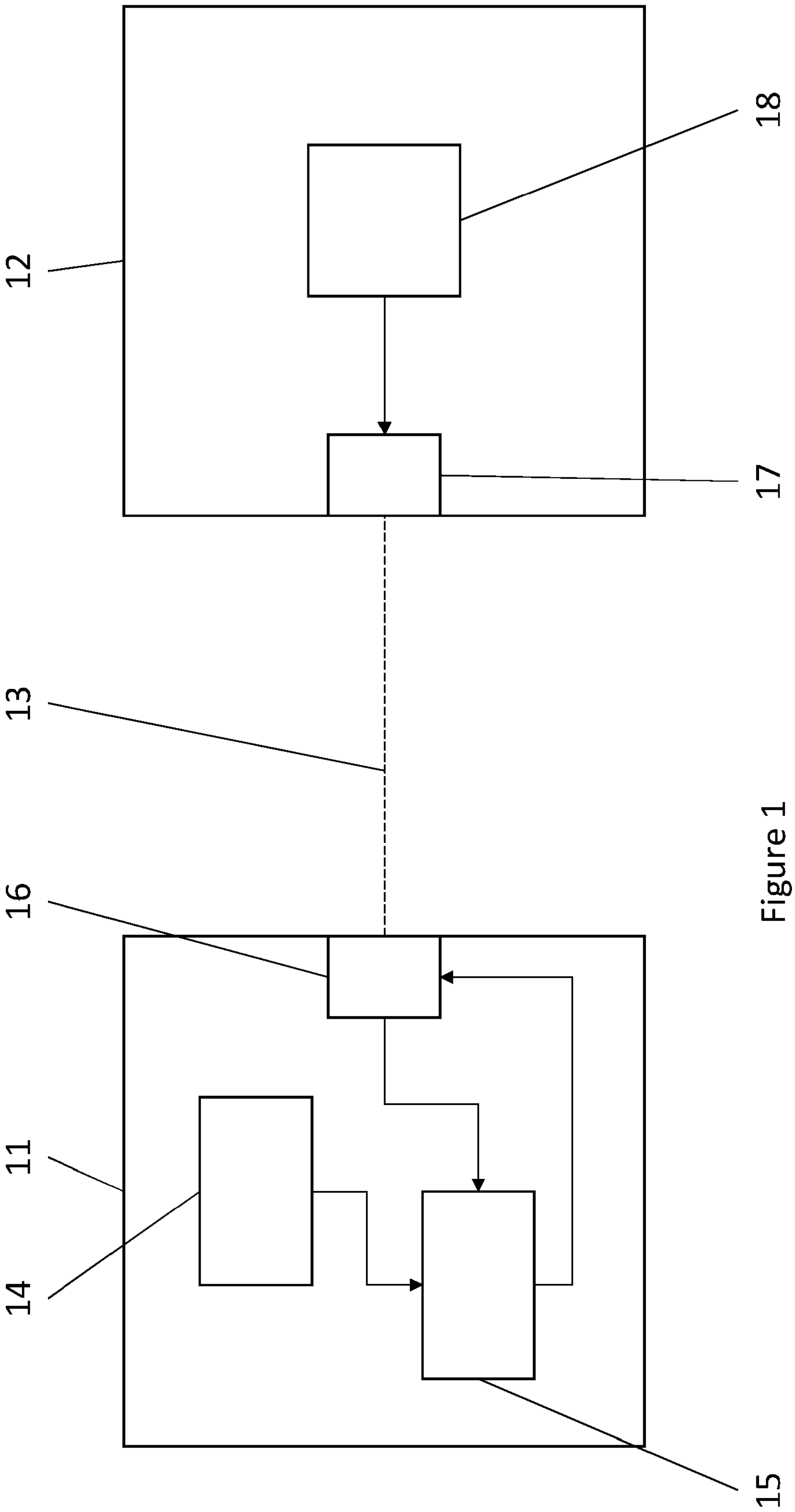

Figure 1

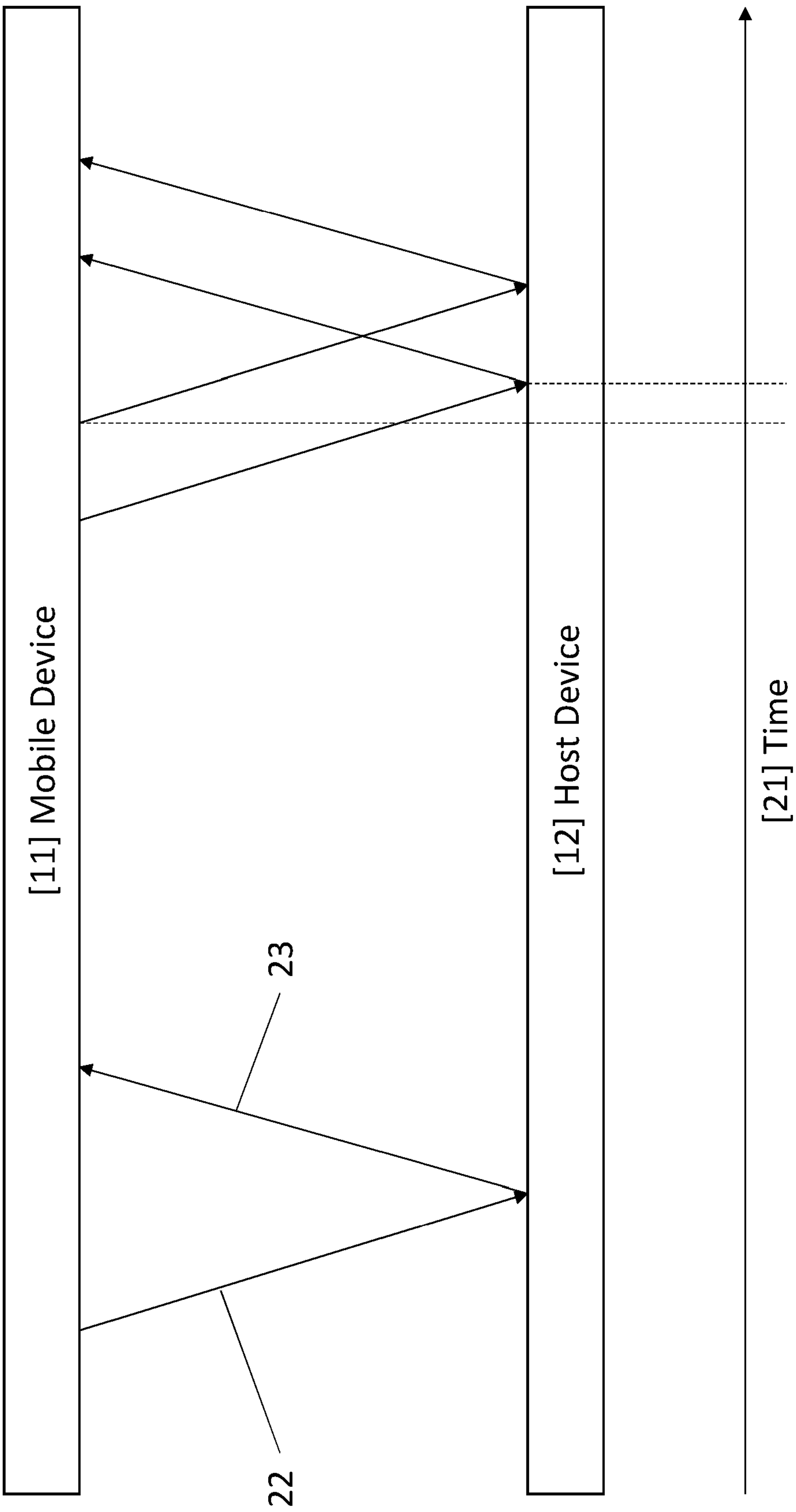

Figure 2

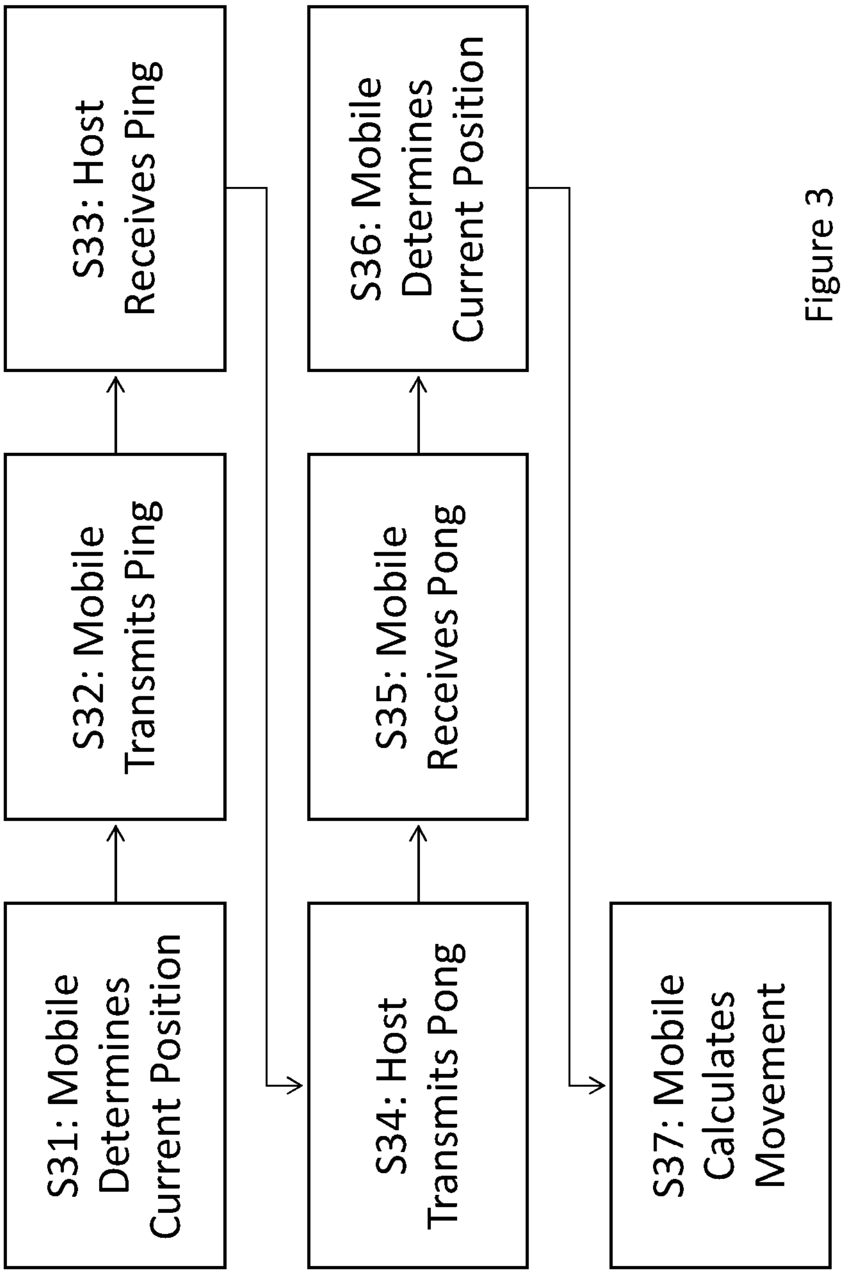
S31: Mobile Determines Current Position
S32: Mobile Transmits Ping
S33: Host Receives Ping
S34: Host Transmits Pong
S35: Mobile Receives Pong
S36: Mobile Determines Current Position
S37: Mobile Calculates Movement

Figure 3

Position Error Measurement in an Extended Reality Mobile Display Device

Background

When a host computing device transmits display data to a mobile display device such as a virtual-reality headset, a delay is introduced between the production of the display data and its actual display by or in the headset. This delay may be increased where the connection between the two devices is wireless.

Especially in the case of a virtual-reality headset worn by a user, the mobile device may be in constant motion relative to the host device and the user will expect this motion to be reflected in the images shown by the headset. The increased latency in the time between the generation of the display data by the host device and its display may cause delay in the apparent movement of the images displayed, which may result in a poor user experience. This delay and the resulting visual artefacts are known as position error.

The method of the invention provides a relatively low-cost method of determining position error to try to mitigate this problem.

Summary

Accordingly, in a first aspect, the invention provides a method of determining relative position of an extended reality mobile display device connected to receive display data from a host device, the method comprising:

determining, by the extended reality mobile display device and using one or more sensors of the extended reality mobile display device, a position and an orientation of the extended reality mobile display device at a transmit time;

transmitting, by the extended reality mobile display device, a plurality of first signals to the host device at different transmit times, wherein the plurality of first signals are transmitted to the host device with an adjustable frequency;

receiving, by the extended reality mobile display device, a plurality of second signals at different receive times, each of the second signals being transmitted from the host device upon receipt of a corresponding first signal thereat;

determining, by the extended reality mobile display device and using the one or more sensors, a position and an orientation of the extended reality mobile display device at the different receive times;

determining, by the extended reality mobile display device, a difference between the position and the orientation of the extended reality mobile display device at corresponding transmit and receive times;

correcting, by the extended reality mobile display device, display data received from the host device based on the determined difference between the position and the orientation of the extended reality mobile display device at corresponding transmit and receive times; and

displaying the corrected display data at the extended reality mobile display device,

wherein the adjustable frequency of transmission of the plurality of first signals is adjusted based on at least the determined difference between the respective position and the orientation of the extended reality mobile display device at the corresponding transmit and receive times, such that, if the difference is high, the frequency is increased, or if the difference is low, the frequency is decreased.

In one embodiment, the position and the orientation of the extended reality mobile display device at the transmit times are transmitted in the first signal to the host device and are returned to the extended reality mobile display device in the second signals.

Preferably, a position and an orientation of the extended reality mobile display device is determined at each transmit time and at each receive time and the respective difference between the respective position and the orientation of the extended reality mobile display device are determined for a corresponding transmit time and a corresponding receive time.

The display data is preferably received in a frame and the correction of the display data is based on the difference between the respective position and the orientation of the extended reality mobile display device between the transmit time and the receive time closest in time to a predetermined point of the received frame.

The respective position and the orientation of the extended reality mobile display device may be transmitted in the corresponding first signal to the host device and may be returned to the extended reality mobile display device in the corresponding second signal.

A list of the plurality of first signals may be stored at the extended reality mobile display device together with the corresponding position and orientation of the extended reality mobile display device. Preferably, the transmit times of the plurality of first signals are stored with the list.

Preferably, each of the plurality of first signals includes a corresponding identification and the identification is included in the second signal corresponding to the first signal.

The position and the orientation of the extended reality mobile display device at the transmit time and/or at the receive time may be determined from sensor data obtained from the one or more sensors of the extended reality mobile display device.

Alternatively, the position and the orientation of the extended reality mobile display device at the transmit time may be determined as a reference value, and the position and the orientation of the extended reality mobile display device at the receive time may be determined from movement data of the extended reality mobile display device between the transmit time and the receive time. Preferably, the one or more sensors include an accelerometer, and the movement data is received from the accelerometer and the position and the orientation of the extended reality mobile display device at the receive time are determined by double integrating acceleration data between the transmit time and the receive time.

The position and the orientation of the extended reality mobile display device may be determined using an x, y, and z axis location in space, roll rotation, pitch rotation and yaw rotation.

According to a second aspect, the invention provides an extended reality mobile display device configured to perform a method as described above.

In a third aspect, the invention provides an extended reality system comprising an extended reality mobile display device as described above and a host device connected thereto. Preferably, the connection is a wireless connection.

In a fourth aspect, the invention provides a computer readable medium comprising instructions executable by a processing module, which when executed by the processing module, cause the processing module to perform the method as described above.

In an embodiment, there is disclosed a method for determining the position error – i.e. the distance moved by a mobile device in the time required for a signal and its response to travel between the mobile device and a connected host – comprising:

1. The mobile device determining its current position (Pn);
2. The mobile device transmitting a “Ping” message to the host;
3. The host receiving the “Ping” message;

4. The host transmitting a “Pong” message to the mobile device;
5. The mobile device receiving the “Pong” message;
6. The mobile device determining its new position (Pn`);
7. The mobile device calculating the movement between Pn and Pn`.

This method allows position error to be determined with minimal processing, sensing or bandwidth requirements, meaning that it has very little effect on the normal operation of the mobile device and its connection to the host.

Brief Description of the Drawings

Embodiments of the invention will now be more fully described, by way of example, with reference to the drawings, of which:

Figure 1 shows an embodiment of a mobile device connected to a host device;

Figure 2 shows signals sent between the devices over time; and

Figure 3 shows a flowchart illustrating the method used by the devices in an embodiment of the invention.

Detailed Description of the Drawings

Figure 1 shows two wirelessly connected devices: an extended reality device [11] such as a VR or AR headset and a host device [12]. The host device [12] provides display and other data to the extended reality device [11].

The host device [12] includes, among other components, a processing module [18] which produces data to be transmitted to the extended reality device [11]. The processing module [18] is connected to a radio controller [17] which controls a wireless connection [13] between the host device [12] and the extended reality device [11]. The radio controller [17] is capable of determining when it has received signals and data from the extended reality device [11] and can direct them appropriately or react to them itself as appropriate. This may include sending messages to the extended reality device [11] independently of the operation of the processing module [18].

The extended reality device [11] includes, among other components, a radio controller [16] which controls the wireless connection [13] with the host device [12]. The wireless connection [13] is between this radio controller [16] and the corresponding radio controller [17] on the host device [12]. The radio controller [16] is connected to a processing module [15] on the extended reality device [11] which processes data received from the host device [12] and also produces data and signals to be transmitted to the host device [12]. The processing module [15] is in turn connected to one or more position sensors [14] which determines the position and orientation of the extended reality device [11], either as an absolute value or relative to a starting point. For this purpose, the term 'position' refers to a combination of attributes which may include location in space, roll rotation, pitch rotation, and yaw rotation, depending on the circumstances.

For example, the position sensors [14] may include a combination of an accelerometer which determines the exact location of the extended reality device [11] by detecting motion in various planes, and a gyroscope, which detects rotation. Alternatively, the position sensor [14] may determine the position of the extended reality device [11] within a space by triangulating between signals from multiple acoustic, radio, or magnetic antennae, or it may determine the movements of the extended reality device [11] from a starting point in order to determine the position of the extended reality device [11] relative to that starting point, irrespective of its absolute position, or it may use a combination of methods.

The use of an accelerometer as a sensor [14] is preferable because the method only requires the amount of movement and its direction, not its exact starting and ending points. In the example of a virtual-reality headset, head-tracking data from a variety of position sensors [14] is gathered as part of the normal operation of the extended reality device [11] and this may be used. Often, it is not available on the extended reality device [11] as it is usually only sent to the host device [12] for production of display data. An accelerometer is low-cost and relatively low-latency while allowing the relative position of the extended reality device [11] to be determined.

In any case, the processing module [15] can receive position data from the sensor [14] and use it in calculations and/or transmit it to the radio controller [16].

Figure 2 shows the signals transmitted over time between the extended reality device [11] and the host device [12] in two possible embodiments. The extended reality device [11] is represented by a bar at the top of the Figure while the host device [12] is represented by a similar bar at the bottom of the Figure. The passage of time [21] is represented by the arrow at the bottom of the Figure, showing that time has passed between the left side of the Figure and the right side of the Figure. Accordingly, the positions of the arrows representing the signals [22, 23] exchanged between the devices [11, 12] represent points in time, not components of the devices [11, 12].

The first case, on the left, is the most straightforward though the practical benefits may be limited. In this case one signal [22, 23] is "in flight" at a time. In this case, a first "ping" signal [22] is sent from the radio controller [16] on the extended reality device [11] to the radio controller [17] on the host device [12]. The radio controller [17] on the host device [12] then responds with a "pong" signal [23]. In this case, because there is only one signal in flight at a time, there is no need for the extended reality device [11] to keep a record of the signals, as the "pong" signals [23] will not arrive out of order.

In the second case, on the right, a stream of "ping" signals [22] is transmitted at intervals, regardless of whether the corresponding responding "pong" signals [23] have been received. This can mean that, as indicated in the Figure by vertical dashed lines, a “ping” signal [22] may be transmitted before the previous “ping” signal [22] has been received by the host device [12]. This means that the extended reality device [11] may need to keep a record of the “ping” signals [22] transmitted and their times of transmission, as well as ensuring that the “ping” signals [22] and their corresponding responding “pong” signals [23] can be identified.

The determination of how frequently and regularly “ping” signals [22] should be transmitted may be determined by a number of heuristics. For example, the extended reality device [11] may dynamically adjust the rate at which the “ping” signals are sent according to the current latency – i.e. the time between the generation of a frame of display data and its display on a display device – such that if latency is high, position is measured less frequently and therefore the “ping” signals [22] are transmitted less frequently. Alternatively, latency may be an indicator of how accurately the radio controller [17] on the host device [12] is transmitting a directional signal and the rate of sending the “ping” signals may be determined via the current position error such that “ping” signals are transmitted more frequently if the position error is high, allowing it to be corrected more accurately. The rate at which “ping” signals are transmitted may be affected by the frame rate, but is not dependent on it.

Overall, more frequent “ping” signals allow the extended reality device [11] to measure the current position error due to latency in real time, which means that it can immediately adapt to changes in transport latency. Thus, variation in one of these measures or another measure of wireless connection performance may be similarly used such that at times of high variability “ping” signals [22] are transmitted more frequently.

These cases will be further described with reference to Figure 3, which describes the process of for an embodiment of the invention.

At Step S31, the extended reality device [11] detects its current position. Depending on the position sensor(s) [14] in use, this may involve calculating movement from a previous reference point according to an accelerometer, or according to changes in image processing of data from an external camera attached to the extended reality device [11], or any other method appropriate to the type of position sensor(s) [14]. This position is passed from the position sensor(s) [14] to the processing module [15] on the extended reality device [11] and stored.

Alternatively, the radio controller [16] on the extended reality device [11] may be connected directly to the position sensor(s) [14] such that when it receives a command to transmit a “ping” signal [22] it is able to fetch the current position of the extended reality device [11] directly.

At Step S32, the processing module [15] on the extended reality device [11] instructs the radio controller [16] to send a "ping" signal [22] to the host device [12]. In the case where there are many "ping" signals [22] in flight, the processing module [15] may store a list of the "ping" signals [22] currently in flight, together with the associated position data and, optionally, their times of transmission. This list may be stored on a first-in-first-out ("FIFO") basis, if it can be assumed that the corresponding responding "pong" signals [23] will arrive in the order in which the "ping" signals [22] were transmitted, or it may be stored in a keyed format such that each "ping" signal [22] has a unique reference which is then carried by its corresponding "pong" signal [23]. Finally, instead of storing the initial position on the mobile device [11], it could be sent as payload data of the "ping" signal [22].

At Step S33, the radio controller [17] on the host device [12] receives the transmitted "ping" signal [22]. It then immediately responds by transmitting a "pong" signal [23] to the radio controller [16] on the extended reality device [11] at Step S34. If the received "ping" signal [22] includes a unique reference and/or initial position data, this might be included in the "pong" signal [23] in order to indicate which "ping" signal [22] it is responding to, in case the "ping" signals [22] and "pong" signals [23] arrive out of order. Alternatively, the radio controller [17] on the host device [12] might signal the processing module [18] to indicate that a "ping" signal [22] has been received and the processing module [18] might then instruct the radio controller [16] to command it to transmit the "pong" signal [23].

At Step S35, the radio controller [16] on the extended reality device [11] transmits a signal to the processing module [15] to indicate that a "pong" signal [23] has been received. This may include the reference number and/or initial position data associated with the original "ping" signal [22] if it is available. The processing module [15] then determines the extended reality device's [11] new position at Step S36. This will again involve an operation appropriate to the position sensor(s) [14], for example subtracting the current location from the original location or double-integrating acceleration data between the time at which the "ping" signal [22] was sent and the time at which the "pong" signal [12] was received in order to provide the distance that the extended reality device [11] has moved in that time. Similar methods might be used for other relative positions, or if the position sensor(s) [14] determines an absolute position relative to an external space, the position sensor(s) [14] may be able to provide that position.

At Step S37, the processing module [15] uses the original and current positions of the extended reality device [11] to calculate the distance that the extended reality device [11] has moved between the transmission of the "ping" signal [22] and receipt of the corresponding "pong" signal [23]. This can then be used to adjust position-dependent data received from the host device [12] to take into account movement that may occur in the time between position data being transmitted to the host device [12] and data that may have been generated based on that sensor data being received from the host device [12]. For example, the processing module [15] may carry out asynchronous reprojection, a technique in which a previous frame is warped using new tracking data. In this case, the processing module [15] would use the position error to calculate a continuation of the sensor data used to create the frame and transform the image data contained in the frame as appropriate.

An example application is a virtual-reality headset receiving data from a local host device such as a gaming console or across a network, including the internet, in which the location and pose of the headset are used to determine what display data will be displayed on its internal display device. If the user, and therefore the headset, have moved in between the transmission of position data and the receipt of appropriate display data, the display data may be slightly out of date, which may mean lag between when the user expects a movement to affect the display data and the actual change in the display data. This leads to a poor user experience. If the headset is able to determine this error, it may be able to amend the received display data accordingly.

These methods may be carried out at any point in the generation and display of a frame. It may be most convenient to perform them at the beginning of every frame, but the position error may be determined at the end of the frame or at a consistent point between the beginning and end of the frame. Alternatively, several “ping” signals could be transmitted during the frame and the average measurement from the received “pong” signals could be used.

Although only a few particular embodiments have been described in detail above, it will be appreciated that various changes, modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention as defined in the claims. For example, hardware aspects may be implemented as software where appropriate and vice versa.

Claims

1. A method of determining a relative position of an extended reality mobile display device connected to receive display data from a host device, the method comprising:

determining, by the extended reality mobile display device and using one or more sensors of the extended reality mobile display device, a position and an orientation of the extended reality mobile display device at a transmit time;

transmitting, by the extended reality mobile display device, a plurality of first signals to the host device at different transmit times, wherein the plurality of first signals are transmitted to the host device with an adjustable frequency;

receiving, by the extended reality mobile display device, a plurality of second signals at different receive times, each of the second signals being transmitted from the host device upon receipt of a corresponding first signal thereat;

determining, by the extended reality mobile display device and using the one or more sensors, a position and an orientation of the extended reality mobile display device at the receive time;

determining, by the extended reality mobile display device, a difference between the position and the orientation of the extended reality mobile display device at corresponding transmit and receive times;

correcting, by the extended reality mobile display device, display data received from the host device based on the determined difference between the position and the orientation of the extended reality mobile display device at corresponding transmit and receive times; and

displaying the corrected display data at the extended reality mobile display device,

wherein the adjustable frequency of transmission of the plurality of first signals is adjusted based on at least the determined difference between the respective position and the orientation of the extended reality mobile display device at the corresponding transmit and receive times, such that, if the difference is high, the frequency is increased, or if the difference is low, the frequency is decreased.

2. A method of determining relative position of an extended reality mobile display device according to claim 1, wherein the position and the orientation of the extended reality mobile display

device at the transmit times are transmitted in the first signals to the host device and are returned to the extended reality mobile display device in the second signals.

3. A method of determining relative position of an extended reality mobile display device according to claim 1, wherein a position and an orientation of the extended reality mobile display device is determined at each transmit time and at each receive time and the respective differences between the respective position and the orientation of the extended reality mobile display device are determined for a corresponding transmit time and a corresponding receive time.

4. A method of determining relative position of an extended reality mobile display device according to claim 3, wherein the display data is received in a frame and the correction of the display data is based on the difference between the respective position and the orientation of the extended reality mobile display device between the transmit time and the receive time closest in time to a predetermined point of the received frame.

5. A method of determining relative position of an extended reality mobile display device according to either claim 3 or claim 4, wherein the respective position and the orientation of the extended reality mobile display device are transmitted in the corresponding first signal to the host device and are returned to the extended reality mobile display device in the corresponding second signal.

6. A method of determining relative position of an extended reality mobile display device according to either claim 3 or claim 4, wherein a list of the plurality of first signals is stored at the extended reality mobile display device together with the corresponding position and orientation of the extended reality mobile display device.

7. A method of determining relative position of an extended reality mobile display device according to claim 6, wherein the transmit times of the plurality of first signals are stored with the list.

8. A method of determining relative position of an extended reality mobile display device according to any preceding claim, wherein each of the plurality of first signals includes a corresponding identification and the identification is included in the second signal corresponding to the first signal.

9. A method of determining relative position of an extended reality mobile display device according to any preceding claim, wherein the position and the orientation of the extended reality mobile display device at the transmit time are determined from sensor data obtained from the one or more sensors of the extended reality mobile display device.

10. A method of determining relative position of an extended reality mobile display device according to any preceding claim, wherein the position and the orientation of the extended reality mobile display device at the receive time are determined from sensor data obtained from the one or more sensors of the extended reality mobile display device.

11. A method of determining relative position of an extended reality mobile display device according to any one of claims 1 to 8, wherein the position and the orientation of the extended reality mobile display device at the transmit time is determined as a reference value, and wherein the position and the orientation of the extended reality mobile display device at the receive time are determined from movement data of the extended reality mobile display device between the transmit time and the receive time.

12. A method of determining relative position of an extended reality mobile display device according to claim 11, wherein the one or more sensors includes an accelerometer, wherein the movement data is received from the accelerometer, and wherein the position and the orientation of the extended reality mobile display device at the receive time are determined by double integrating acceleration data between the transmit time and the receive time.

13. A method of determining relative position of an extended reality mobile display device according to any preceding claim, wherein the position and the orientation of the extended reality mobile display device are determined using an x, y, and z axis location in space, roll rotation, pitch rotation and yaw rotation.

14. An extended reality mobile display device configured to perform a method according to any preceding claim.

15. An extended reality system comprising an extended reality mobile display device according to claim 14 and a host device connected thereto.

16. An extended reality system according to claim 15, wherein the connection is a wireless connection.

17. A computer readable medium comprising instructions executable by a processing module, which when executed by the processing module, cause the processing module to perform the method of any one of claims 1 to 13.