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(54) **SYSTEMS AND METHODS FOR VIEWPORT-BASED AUGMENTED REALITY HAPTIC EFFECTS**

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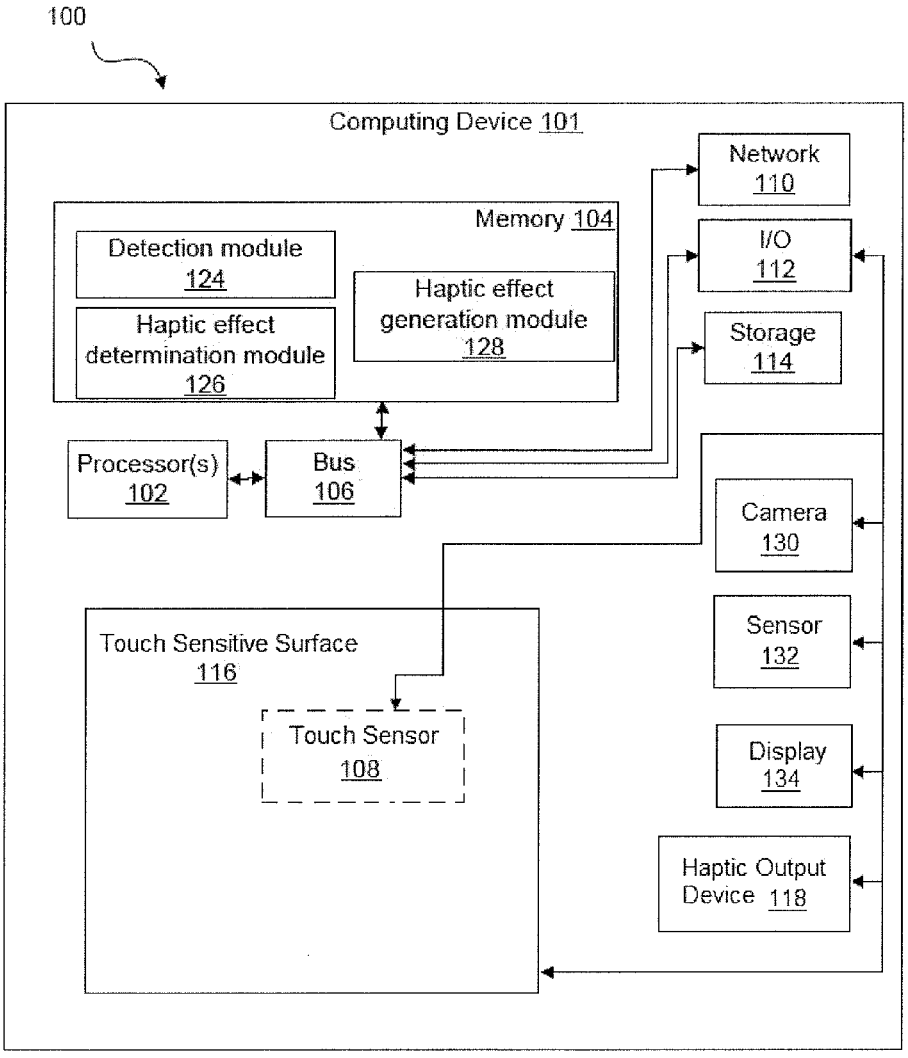
(57) **ABSTRACT**

One illustrative system disclosed herein includes a display configured to receive a display signal and output an image, and an image capture device configured to capture an area image and transmit an image signal. The illustrative system also includes a processor in communication with the image capture device and the display, the processor configured to: receive the image signal; determine a virtual object based in part on the image signal; determine the display signal based in part on the image signal, wherein the display signal includes data associated with the virtual object; determine a haptic effect based at least in part on the virtual object; and transmit a haptic signal associated with the haptic effect. The illustrative system further includes a haptic output device configured to receive the haptic signal and output the haptic effect.



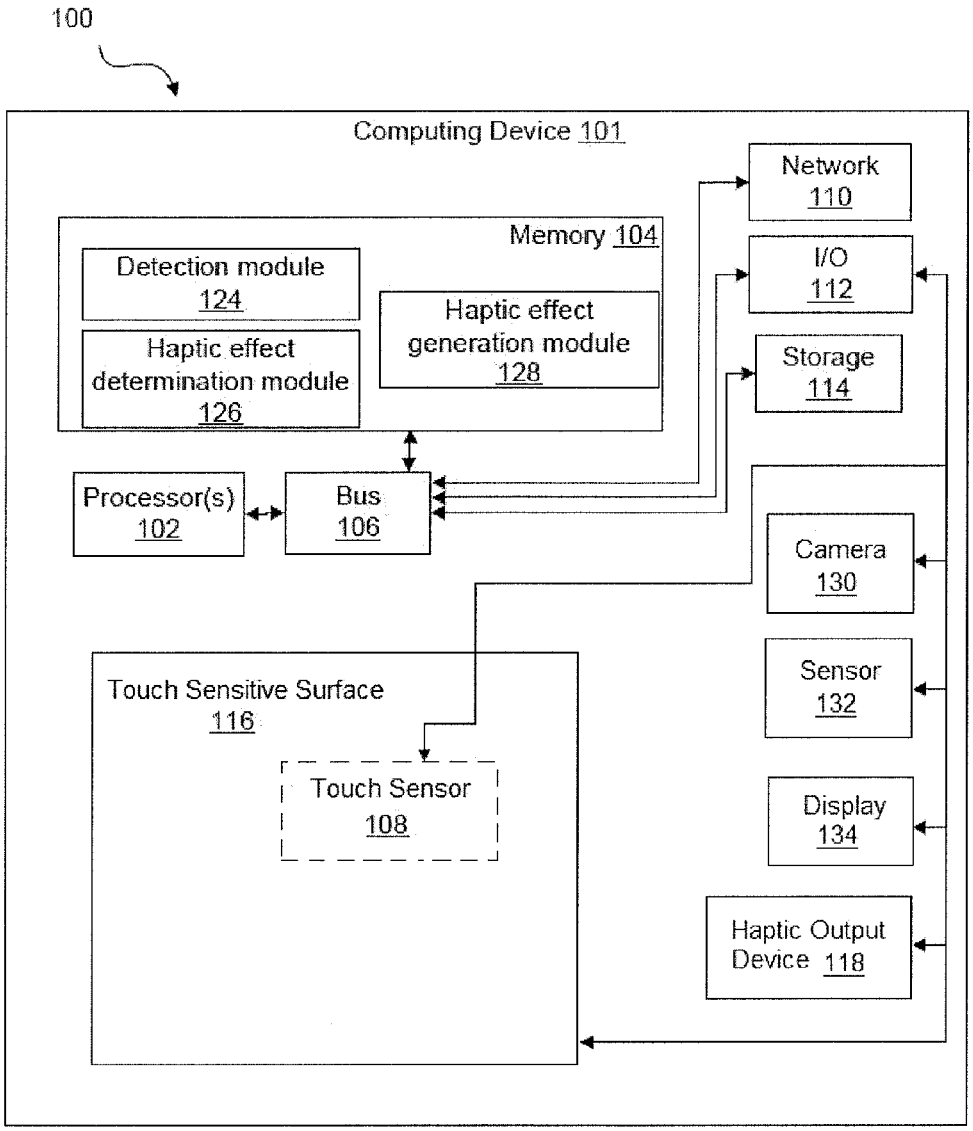

100
Computing Device 101
Network 110
Memory 104
Detection module 124
Haptic effect determination module 126
Haptic effect generation module 128
I/O 112
Storage 114
Processor(s) 102
Bus 106
Camera 130
Touch Sensitive Surface 116
Touch Sensor 108
Sensor 132
Display 134
Haptic Output Device 118

Figure 1

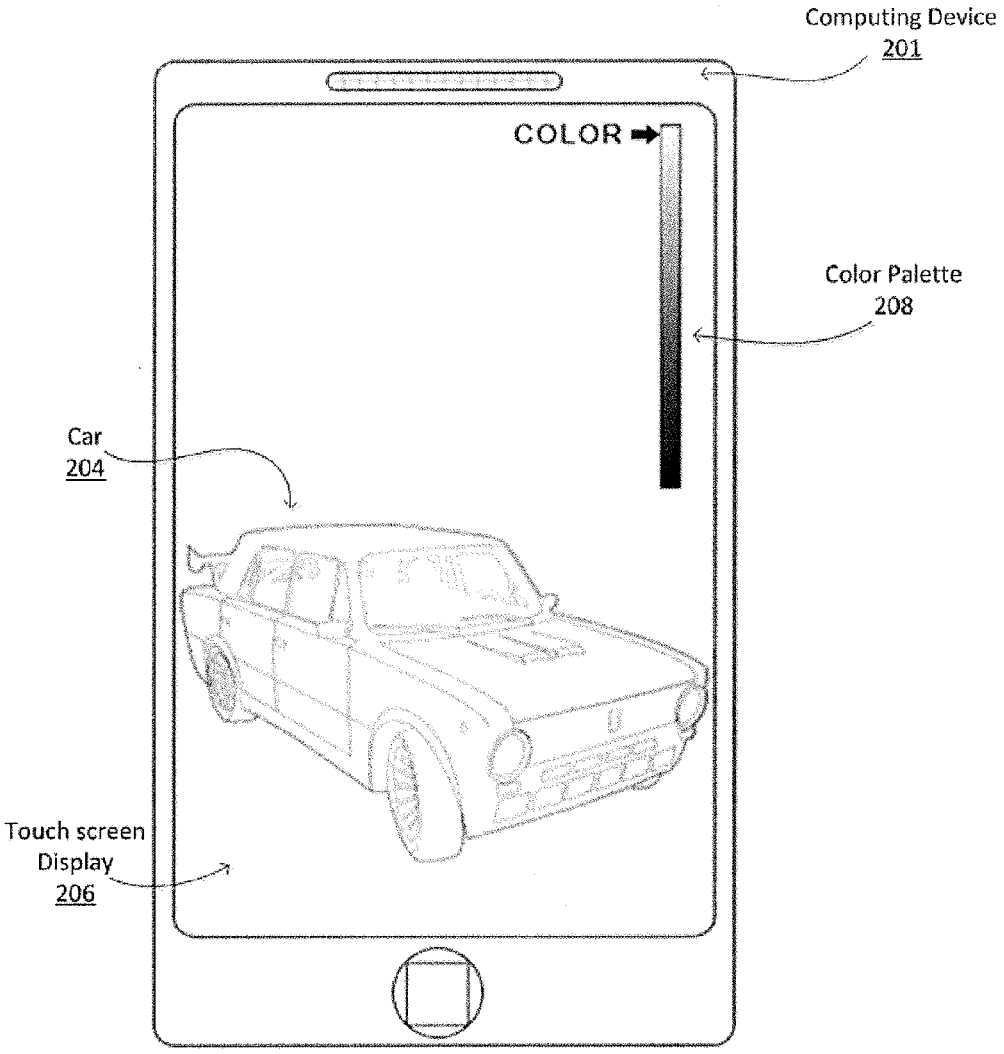

Computing Device
201
COLOR
Color Palette
208
Car
204
Touch screen
Display
206

Figure 2

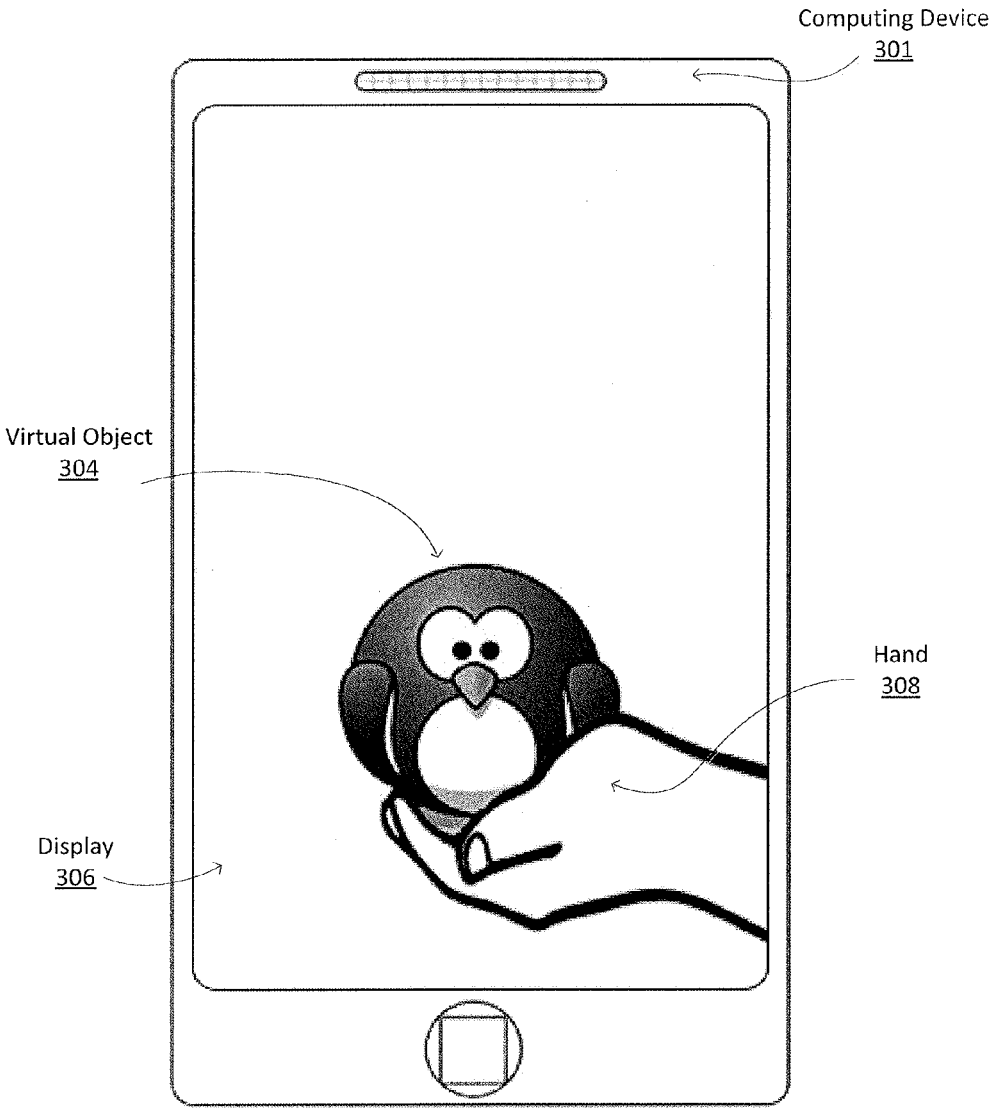

Computing Device
301
Virtual Object
304
Hand
308
Display
306

Figure 3

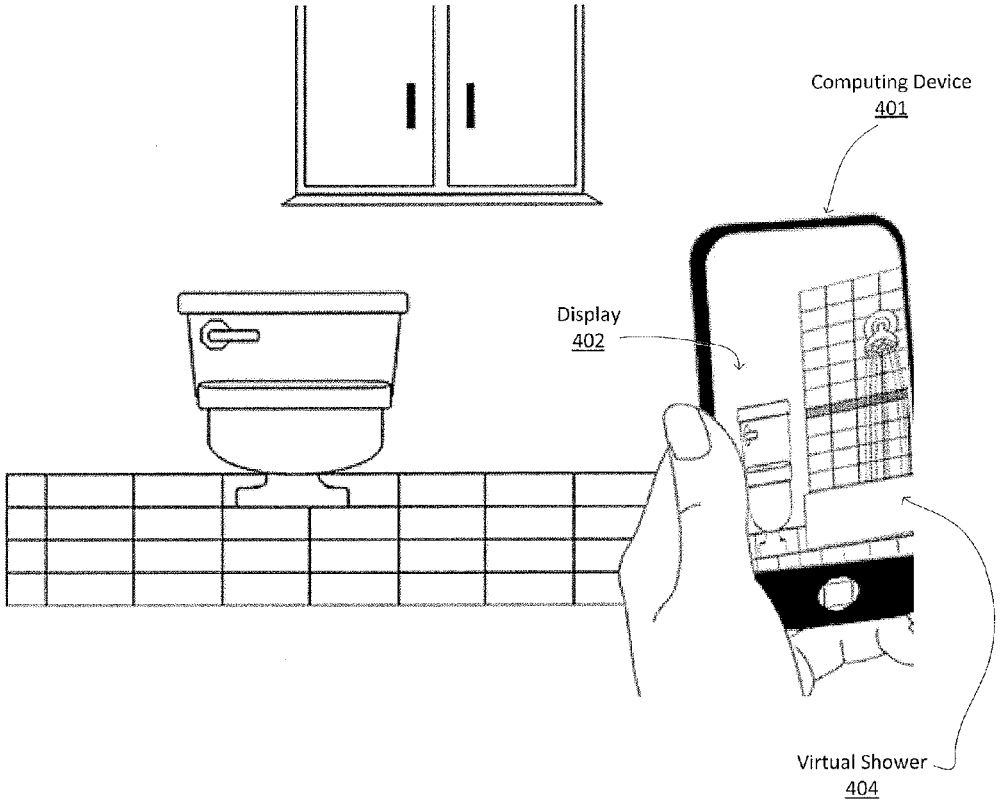


Figure 4

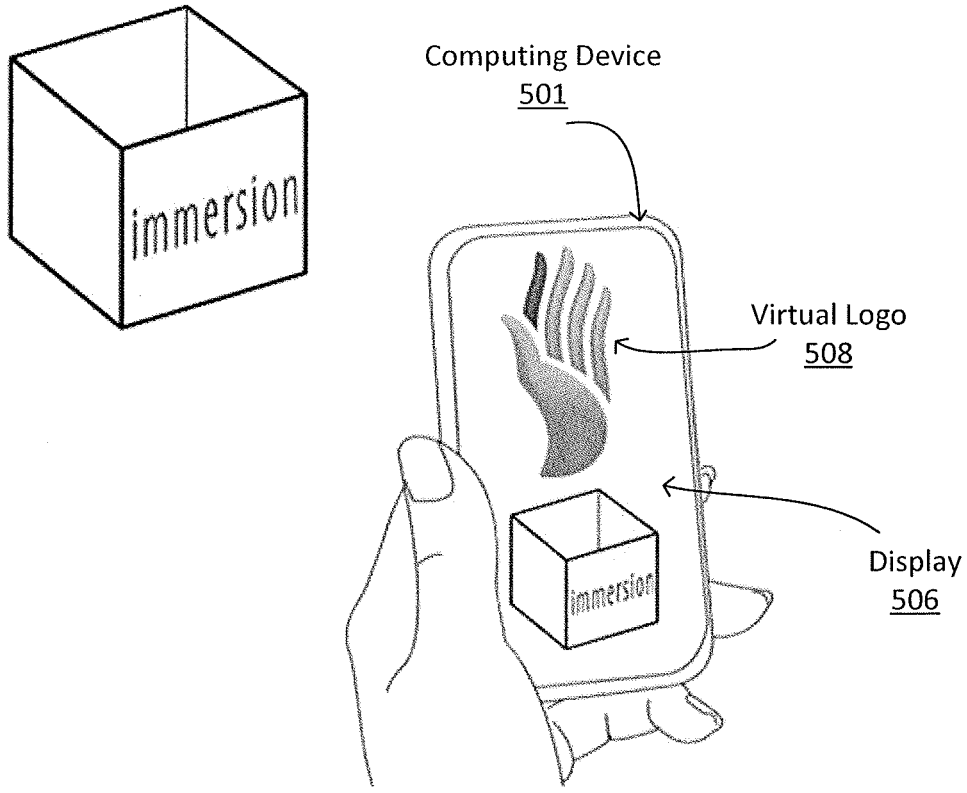

immersion
Computing Device
501
Virtual Logo
508
Display
506
immersion

Figure 5

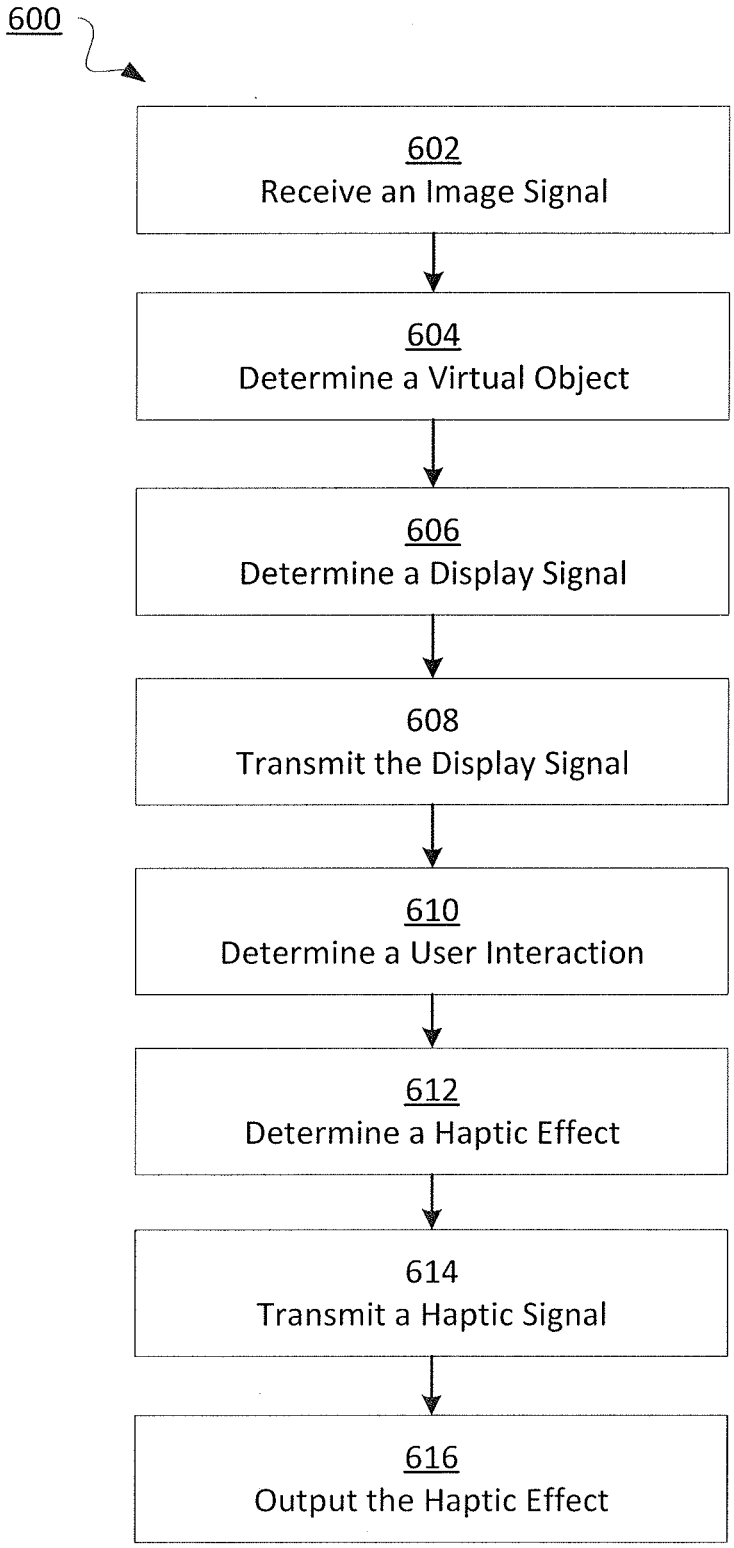

600
602
Receive an Image Signal
604
Determine a Virtual Object
606
Determine a Display Signal
608
Transmit the Display Signal
610
Determine a User Interaction
612
Determine a Haptic Effect
614
Transmit a Haptic Signal
616
Output the Haptic Effect

Figure 6

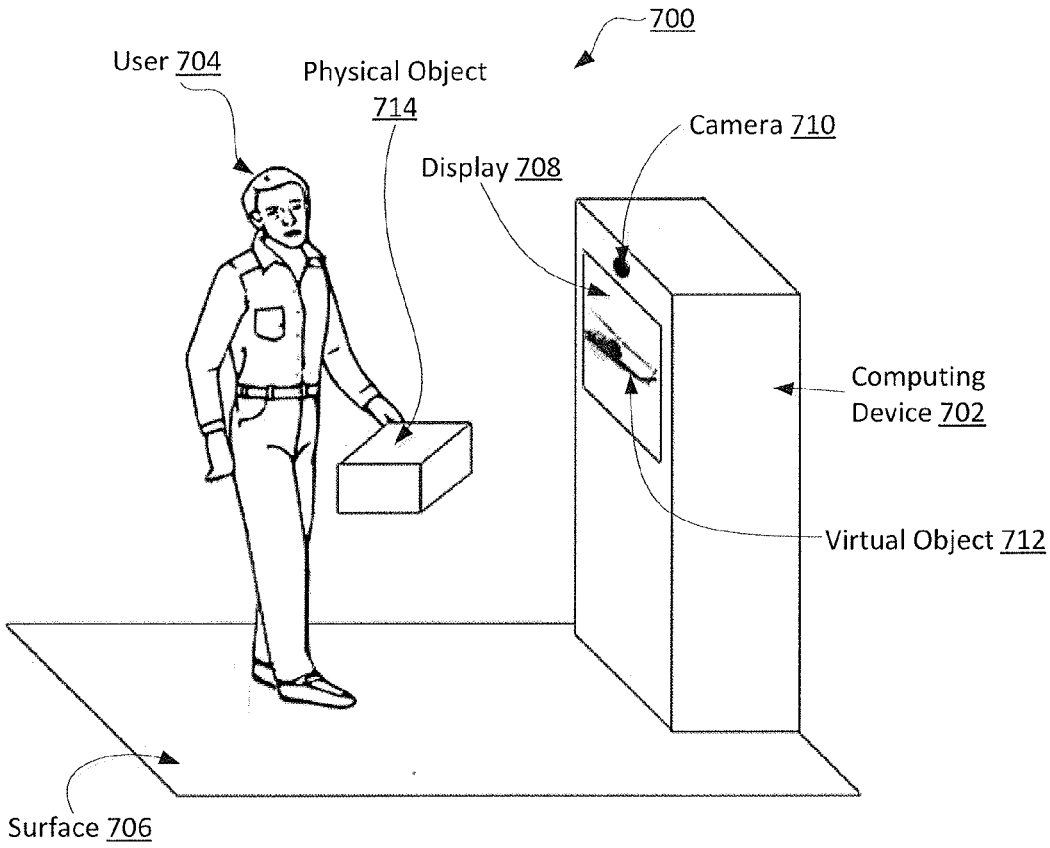

700
User 704
Physical Object 714
Camera 710
Display 708
Computing Device 702
Virtual Object 712
Surface 706

Figure 7

SYSTEMS AND METHODS FOR VIEWPORT-BASED AUGMENTED REALITY HAPTIC EFFECTS

FIELD OF THE INVENTION

[0001] The present invention relates to the field of user interface devices. More specifically, the present invention relates to viewport-based augmented reality haptic effects.

BACKGROUND

[0002] As computer-based systems become more prevalent, the quality of the interfaces through which humans interact with these systems is becoming increasingly important. One common type of user interface is an augmented reality user interface. Augmented reality interfaces typically allow users to view, via a display, camera data that has been supplemented ("augmented") with virtual content. This virtual content may include text, images, or sounds, which may provide a user with additional information about aspects of the scene associated with the camera data. Augmented reality interfaces may be improved by including haptic capability.

SUMMARY

[0003] Embodiments of the present disclosure comprise computing devices comprising viewport-based augmented reality haptic effects. In one embodiment, a system of the present disclosure may comprise a display configured to receive a display signal and output an image, and an image capture device (e.g., a camera) configured to capture an area image and transmit an image signal. The system may also comprise a processor in communication with the image capture device and the display, the processor configured to: receive the image signal; determine a virtual object based in part on the image signal; determine the display signal based in part on the image signal, wherein the display signal comprises data associated with the virtual object; determine a haptic effect based at least in part on the virtual object; and transmit a haptic signal associated with the haptic effect. The system may further comprise a haptic output device configured to receive the haptic signal and output the haptic effect.

[0004] In another embodiment, a method of the present disclosure may comprise: receiving an image signal, wherein the image signal comprises an area image; determining a virtual object based in part on the image signal; determining a display signal based in part on the image signal, wherein the display signal comprises data associated with the virtual object; and transmitting the display signal to a display, wherein the display is configured to output an image. The method may further comprise determining a haptic effect based at least in part on the virtual object; transmitting a haptic signal associated with the haptic effect to a haptic output device; and outputting the haptic effect. Yet another embodiment comprises a computer-readable medium for implementing such a method.

[0005] These illustrative embodiments are mentioned not to limit or define the limits of the present subject matter, but to provide examples to aid understanding thereof. Illustrative embodiments are discussed in the Detailed Description, and further description is provided there. Advantages offered by various embodiments may be further understood by examining this specification and/or by practicing one or more embodiments of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] A full and enabling disclosure is set forth more particularly in the remainder of the specification. The specification makes reference to the following appended figures.

[0007] FIG. **1** is a block diagram showing a system for viewport-based augmented reality haptic effects according to one embodiment;

[0008] FIG. **2** shows an embodiment of a system for viewport-based augmented reality haptic effects;

[0009] FIG. **3** shows another embodiment of a system for viewport-based augmented reality haptic effects;

[0010] FIG. **4** shows a system for viewport-based augmented reality haptic effects according to one embodiment;

[0011] FIG. **5** shows a system for viewport-based augmented reality haptic effects according to another embodiment;

[0012] FIG. **6** is a flow chart of steps for performing a method for providing viewport-based augmented reality haptic effects according to one embodiment; and

[0013] FIG. **7** shows a system for viewport-based augmented reality haptic effects according to another embodiment.

DETAILED DESCRIPTION

[0014] Reference will now be made in detail to various and alternative illustrative embodiments and to the accompanying drawings. Each example is provided by way of explanation and not as a limitation. It will be apparent to those skilled in the art that modifications and variations can be made. For instance, features illustrated or described as part of one embodiment may be used in another embodiment to yield a still further embodiment. Thus, it is intended that this disclosure include modifications and variations as come within the scope of the appended claims and their equivalents.

Illustrative Examples of Viewport-Based Augmented Reality Haptic Effects

[0015] One illustrative embodiment of the present disclosure comprises a mobile device, such as a smartphone. The mobile device comprises a touch screen display, a memory, a camera, and a processor in communication with each of these elements. The touch screen display comprises a viewport. A viewport comprises a region of a screen where data (e.g., text or images) is displayed. In some embodiments, the viewport may comprise the entire area of the screen.

[0016] In the illustrative embodiment, the mobile device also comprises an augmented reality application. Augmented reality applications output, via a display, camera data that has been supplemented ("augmented") with virtual content, such as text or images. The virtual content may either be static or animated. In the illustrative embodiment, a user may execute the augmented reality application and use a camera of the mobile device to capture an image with the mobile device. For example, the user may orient the mobile device so that the camera captures an image of a room of a house. In such an embodiment, the augmented reality application receives image data from the camera and outputs this data to the touch-screen display. In some embodiments, this image data may be updated in real time, e.g., the augmented reality application may continue to receive updated image data from the camera. In some embodiments, the user may perceive the camera data as if the user is looking through the display.

[0017] In the illustrative embodiment, the user may select a virtual object to include in the augmented reality application. For example, the user may select a virtual object associated with a piece of furniture from a catalogue associated with the augmented reality application. In such an embodiment, the augmented reality application generates a graphical representation of the furniture in the touch screen display. For example, the augmented reality application may generate a three-dimensional (3D) virtual representation of the furniture allowing the user to view, via the touch-screen display, the furniture in a room. Further, in the illustrative embodiment, the user may use the application to view virtual object (e.g., the image of the furniture) in different locations and with different orientations, scales, and colors. Thus, in the illustrative embodiment, a designer, distributor, retailer, or other seller may provide an augmented reality application and catalog to allow users to select and view items prior to purchase. In other embodiments, augmented reality applications may be used to provide users with additional information (e.g., address, pricing information, historical information, educational information, or reviews) about, for example, a company, product, or location; and/or add, modify, or remove objects (e.g., people, animals, buildings, landscape features, automobiles) from a scene captured by a camera.

[0018] In the illustrative embodiment, the user may make changes to the image or the virtual object by making gestures on the touch screen (e.g., a finger swipe or contacting an object displayed on the touch-screen). As discussed above, in the illustrative embodiment, the augmented reality application layers the virtual object over the camera's data. In the illustrative embodiment, by changing the orientation of the device or by making gestures on the touch-screen display, the user may alter the location, orientation, scale, color, or other factors associated with the virtual object. This may allow the user to perceive the virtual object in place in various locations (e.g., how a piece of furniture may look in various rooms).

[0019] In the illustrative embodiment, the mobile device further comprises a haptic output device. The haptic output device receives a signal from the mobile device and outputs a haptic effect to the user. In the illustrative embodiment, the haptic effect may comprise a simulated texture, a vibration, or a perceived change in a coefficient of friction. Further, in the illustrative embodiment, the haptic output device outputs haptic effects that are remote from the mobile device (hereinafter "remote haptic effects"). For example, the haptic output device may output a remote haptic effect by emitting a concentrated pressure wave in the direction of the user, or by emitting a solid, liquid, or gas from a jet at the user. Alternatively, in some embodiments the haptic output device may be separate from the mobile device. For example, the haptic output device may be associated with a wearable article, (e.g., a sleeve, a watch, a bracelet, an article of clothing, a jacket, glasses, a glove, a ring, a headband, a hat, or a shoe) and communicatively coupled to the mobile device (e.g., via a network connection, Bluetooth connection, or some other wired or wireless connection).

[0020] In the illustrative embodiment, the mobile device is configured to output a haptic effect, via the haptic output device, upon the occurrence of an event. An event, as used herein, is any interaction, action, collision, or other event which occurs during operation of the device which can potentially comprise an associated haptic effect. In the illustrative embodiment, an event comprises the presence of a virtual object (e.g., the presence of a virtual furniture piece), an interaction with the mobile device (e.g., tilting or moving the mobile device, interacting with the touch screen display), a change in status in the mobile device, receiving data, sending data, program activity (e.g., game activity), interacting with a virtual object, movement of a virtual object (e.g., moving or bouncing of a virtual object), and/or a change in scale, location, orientation, color, or other characteristic of a virtual object.

[0021] For example, in the illustrative embodiment, the mobile device outputs an effect when the user interacts with a virtual object (e.g., by touching the location associated with a virtual piece of furniture or touching an area in real space associated with the virtual object), or makes a gesture on the surface of the touch screen display (e.g., to change the color, size, or orientation of the virtual furniture piece). Further, the haptic effect may be associated with the virtual object. For example, in the illustrative embodiment, when the user interacts with the location of the touch screen associated with the virtual furniture, the mobile device determines a haptic effect associated with a material associated with the virtual furniture (e.g., wood, glass, metal, or plastic) and outputs a haptic effect associated with one or more of those materials (e.g., a haptic effect configured to simulate the texture of the material to the user). As another example, in the illustrative embodiment, if the user touches an area in real space associated with a piece of virtual furniture, the mobile device outputs a remote haptic effect comprising, for example, a puff of air emitted to the back of the user's hand. The user may perceive the remote haptic effect as if the user is interacting with the virtual object in real space.

[0022] The description of the illustrative embodiment above is provided merely as an example. Various other embodiments of the present invention are described herein and variations of such embodiments would be understood by one of skill in the art. Advantages offered by various embodiments may be further understood by examining this specification and/or by practicing one or more embodiments of the claimed subject matter.

Illustrative Systems for Viewport-Based Augmented Reality Haptic Effects

[0023] FIG. **1** is a block diagram showing a system **100** for viewport-based augmented reality haptic effects according to one embodiment. In the embodiment shown, system **100** comprises a computing device **101** having a processor **102** in communication with other hardware via bus **106**. Computing device **101** may comprise, for example, a smartphone, tablet, e-reader, laptop computer, portable gaming device, a head-mounted display, or glasses.

[0024] A memory **104**, which can comprise any suitable tangible (and non-transitory) computer-readable medium such as RAM, ROM, EEPROM, or the like, embodies program components that configure operation of the computing device **101**. In the embodiment shown, computing device **101** further includes one or more network interface devices **110**, input/output (I/O) interface components **112**, and storage **114**.

[0025] Network device **110** can represent one or more of any components that facilitate a network connection. Examples include, but are not limited to, wired interfaces such as Ethernet, USB, IEEE 1394, and/or wireless interfaces such as IEEE 802.11, Bluetooth, or radio interfaces for

accessing cellular telephone networks (e.g., transceiver/antenna for accessing a CDMA, GSM, UMTS, or other mobile communications network).

[0026] I/O components **112** may be used to facilitate wired or wireless connection to devices such as one or more displays **134**, game controllers, keyboards, mice, joysticks, cameras, buttons, speakers, microphones, and/or other hardware used to input data or output data. Storage **114** represents nonvolatile storage such as magnetic, optical, or other storage media included in device **101** or coupled to processor **102**.

[0027] System **100** further includes a touch sensitive surface **116**, which, in this example, is integrated into computing device **101**. Touch sensitive surface **116** represents any surface that is configured to sense tactile input of a user. One or more touch sensors **108** are configured to detect a touch in a touch area when an object contacts a touch sensitive surface **116** and provide appropriate data for use by processor **102**. Any suitable number, type, or arrangement of sensors can be used. For example, resistive and/or capacitive sensors may be embedded in touch sensitive surface **116** and used to determine the location of a touch and other information, such as pressure, speed, and/or direction. As another example, optical sensors with a view of the touch sensitive surface **116** may be used to determine the touch position.

[0028] In other embodiments, the touch sensor **108** may comprise a LED detector. For example, in one embodiment, touch sensitive surface **116** may comprise a LED finger detector mounted on the side of a display **134**. In some embodiments, the processor **102** is in communication with a single touch sensor **108**, in other embodiments, the processor **102** is in communication with a plurality of touch sensors **108**, for example, a first touch-screen and a second touch screen. The touch sensor **108** is configured to detect user interaction, and based on the user interaction, transmit signals to processor **102**. In some embodiments, touch sensor **108** may be configured to detect multiple aspects of the user interaction. For example, touch sensor **108** may detect the speed and pressure of a user interaction, and incorporate this information into the interface signal.

[0029] Touch sensitive surface **116** may or may not comprise (or otherwise correspond to) a display **134**, depending on the particular configuration of the system **100**. Some embodiments include a touch enabled display that combines a touch sensitive surface **116** and a display **134** of the device. The touch sensitive surface **116** may correspond to the display **134** exterior or one or more layers of material above the actual display **134** components. In other embodiments, the computing device **101** comprises a touch sensitive surface **116** which may be mapped to a graphical user interface provided in a display **134** that is included in system **100** interfaced to computing device **101**.

[0030] Further, system **100** comprises a camera **130**. Although the camera **130** is depicted in FIG. **1** as being internal to computing device **101**, in some embodiments, the camera **130** may be external to and in communication with computing device **101**. For example, camera **130** may be external to and in communication with computing device **101** via wired interfaces such as Ethernet, USB, IEEE 1394, and/or wireless interfaces such as IEEE1 802.11, Bluetooth, or radio interfaces. Camera **130** is configured to capture one or more images of an area (hereinafter be referred to as an "area image"). An area image comprises an image of a space and/or one or more objects within the space, e.g., an indoor area such as a room in a house or the inside of a store, or an outdoor area such as a park or street. Camera **130** is further configured to transmit a camera **130** signal associated with the images to the processor **102**. Further, in some embodiments, the system **100** may comprise a plurality of cameras **130**. In some embodiments, the processor **102** may determine an image and/or display signal to output to the display **134** based on signals from one or more cameras **130**. For example, in some embodiments, the processor **102** may determine an image to output to the display **134** comprising a 3D representation of a scene based on signals from a plurality of cameras **130**.

[0031] In the embodiment shown, computing device **101** comprises one or more additional sensors **132**. In some embodiments, the sensor **132** may comprise, for example, a gyroscope, an accelerometer, a global positioning system (GPS) unit, a range sensor, or a depth sensor. In some embodiments, the gyroscope, accelerometer, and GPS unit may detect an orientation, acceleration, and location of computing device **101**, respectively. In some embodiments, the camera, range sensor, and/or depth sensor may detect a distance between computing device **101** and an external object (e.g., a user's hand, head, arm, foot, or leg; another person; an automobile; a tree; a building; or a piece of furniture). In some embodiments, computing device **301** may generate a virtual object with properties based on this distance (e.g., the orientation, color, scale, or location). In some embodiments, the processor **102** may be in communication with a single sensor **132** and, in other embodiments, the processor **102** may be in communication with a plurality of sensors **132**, for example, a gyroscope and an accelerometer. The sensor **132** is configured to transmit a sensor **132** signals to processor **102**.

[0032] System **100** further includes haptic output device **118** in communication with processor **102**. Haptic output device **118** is configured to output an effect in response to a haptic signal. In some embodiments, haptic output device **118** is configured to output a haptic effect comprising, for example, a vibration, a change in a perceived coefficient of friction, a simulated texture, a surface deformation, and/or a puff of a solid, liquid, or gas.

[0033] In some embodiments, haptic output device **118** may output a haptic effect by vibrating the computing device **101** or a component of computing device **101**, e.g., touch sensitive surface **116** or display **134**. In such embodiments, haptic output device **118** may comprise a haptic output device configured to output a vibration, e.g., one or more of a piezo-electric actuator, an electric motor, an electro-magnetic actuator, a voice coil, a shape memory alloy, an electro-active polymer, a solenoid, an eccentric rotating mass motor (ERM), or a linear resonant actuator (LRA).

[0034] In some embodiments, haptic output device **118** may be configured to output remote haptic effects. In some embodiments, haptic output device **118** may comprise, for example, speakers or jets that emit materials such as solids, liquids, gasses, or plasmas from the computing device **101** to the user. In some embodiments, haptic output device **118** may use a plurality of ultrasonic transducers to emit a concentrated pressure wave toward the user.

[0035] In some embodiments, haptic output device **118** may output a haptic effect via a surface that a user may be contacting. For example, in some embodiments, the computing device **101** may be positioned on surface (e.g., a floor, desk, chair, or table) that a user may be contacting. The haptic output device **118** may output a haptic effect by vibrating, moving, tilting, or deforming the surface. For example, in some embodiments, the computing device **101** may be posi-

tioned on a table the user may be contacting. In some embodiments, the haptic output device **118** may output a haptic effect by vibrating the table. In some embodiments, the user may be able to perceive the haptic effect via the table.

[0036] In the embodiment shown in FIG. **1**, haptic output device **118** is in communication with processor **102** and internal to computing device **101**. In other embodiments, haptic output device **118** may be remote from computing device **101**, but communicatively coupled to processor **102**. For example, haptic output device **118** may be external to and in communication with computing device **101** via wired interfaces such as Ethernet, USB, IEEE 1394, and/or wireless interfaces such as IEEE 802.11, Bluetooth, or radio interfaces. In some embodiments, haptic output device **118** may be coupled to a wearable device that may be remote from the computing device **101**. In some embodiments, the wearable device may comprise shoes, a sleeve, a jacket, glasses, a glove, a ring, a watch, a wristband, a bracelet, an article of clothing, a hat, a headband, and/or jewelry. The wearable device may be associated with a part of a user's body, for example, a user's finger, arm, hand, foot, leg, head, or other body part.

[0037] In some embodiments, the haptic output device **118** may be disposed within an object (not shown) external to computing device **101**, for example, a box, wand, book, or smartphone. In some embodiments, the haptic output device **118** may output a haptic effect via the external object. For example, in some embodiments, the external object may determine (e.g., via Bluetooth or GPS) if the external object is within a certain distance (e.g., 1 m) from the computing device **101**. In some embodiments, the external object may output a haptic effect via the haptic output device **118** if the external device is a certain distance (e.g., 1 m) from the computing device **101**.

[0038] In some embodiments, haptic output device **118** may be configured to output a haptic effect simulating a texture or modulating the perceived coefficient of friction on the touch sensitive surface **116** in response to a haptic signal. In one such embodiment, haptic output device **118** may comprise an ultrasonic actuator. An ultrasonic actuator may vibrate at an ultrasonic frequency, for example 20 kHz, increasing or reducing the perceived coefficient at the surface of touch sensitive surface **116**. Further, an ultrasonic actuator may comprise a piezo-electric material.

[0039] In other such embodiments, haptic output device **118** may use electrostatic attraction, for example by use of an electrostatic surface actuator, to output a haptic effect simulating a texture or modulating the perceived coefficient of friction on the touch sensitive surface **116**. In such an embodiment, the electrostatic actuator may comprise a conducting layer and an insulating layer. The conducting layer may be any semiconductor or other conductive material, such as copper, aluminum, gold, or silver. The insulating layer may be glass, plastic, polymer, or any other insulating material. Furthermore, the processor **102** may operate the electrostatic actuator by applying an electric signal, for example, an AC signal generated by a high-voltage amplifier, to the conducting layer. The electric signal may, in some embodiments, capacitively couple the conducting layer with an object (e.g., a user's finger, head, foot, arm, shoulder, leg, or other body part, or a stylus) near or touching the touch sensitive surface **116**. In some embodiments, varying the levels of attraction between the object and the conducting layer can vary the simulated texture on an object moving across the surface of the touch sensitive surface **116**.

[0040] In some embodiments, haptic output device **118** may comprise a deformation device configured to output a haptic effect by deforming the surface of the touch sensitive surface **116** or another surface of computing device **101**. In such an embodiment, haptic output device **118** may comprise a smart gel that responds to stimulus or stimuli by changing in stiffness, volume, transparency, and/or color. In some embodiments, stiffness may comprise the resistance of the touch sensitive surface **116** against deformation. In one such embodiment, one or more wires may be embedded in or coupled to the smart gel. As current runs through the wires, heat is emitted, causing the smart gel to expand or contract, deforming haptic output device **118**. In other embodiments, haptic output device **118** may comprise an actuator coupled to an arm that rotates a deformation component. The actuator may comprise a piezo-electric actuator, rotating/linear actuator, solenoid, an electroactive polymer actuator, macro fiber composite (MFC) actuator, shape memory alloy (SMA) actuator, and/or other actuator. As the actuator rotates the deformation component, the deformation component may move the surface of haptic output device **118**, causing it to deform. In some embodiments, haptic output device **118** may be a portion of the housing of touch sensitive surface **116**. In other embodiments, haptic output device **118** may be housed inside a flexible housing overlaying touch sensitive surface **116**.

[0041] Although a single haptic output device **118** is shown here, some embodiments may use multiple haptic output devices of the same or different type to provide haptic feedback. Some haptic effects may utilize an actuator coupled to a housing of the device, and some haptic effects may use multiple actuators in sequence and/or in concert. For example, in some embodiments, multiple vibrating actuators and gas jets can be used alone or in concert to provide different haptic effects.

[0042] Turning to memory **104**, program components **124**, **126**, and **128** are depicted to show how a device can be configured in some embodiments to provide viewport-based augmented reality haptic effects. In this example, a detection module **124** configures processor **102** to monitor touch sensitive surface **116** via touch sensor **108** to determine a position of a touch. For example, module **124** may sample touch sensor **108** in order to track the presence or absence of a touch and, if a touch is present, to track one or more of the location, path, velocity, acceleration, pressure and/or other characteristics of the touch over time.

[0043] Haptic effect determination module **126** represents a program component that analyzes data to determine a haptic effect to generate. Particularly, haptic effect determination module **126** may comprise code that determines, based on the location of the touch on the touch sensitive surface **116**, a haptic effect to output and code that selects one or more haptic effects to provide in order to simulate the effect. For example, different haptic effects may be selected based on the location of a touch in order to simulate the presence of a virtual object (e.g., a virtual piece of furniture, automobile, animal, cartoon character, button, lever, logo, or person) on the display **134**. Further, in some embodiments, haptic effect determination module **126** may comprise code that determines, based on the size, color, location, movement, and/or other characteristics of a virtual object, a haptic effect to output and code that selects one or more haptic effects to provide in order to simulate the effect. For example, haptic effects may be

selected based on the color of a virtual object (e.g., a strong vibration if the virtual object is red, and a weaker vibration if the virtual object is green).

[0044] In some embodiments, haptic effect determination module **126** may determine a haptic effect based on events. An event, as used herein, is any interaction, action, collision, or other event which occurs during operation of the device which can potentially comprise an associated haptic effect. In some embodiments, an event may comprise the presence of a virtual object (e.g., the presence of a virtual furniture piece), an interaction with the mobile device (e.g., tilting or moving the mobile device, or interaction with a touch sensitive surface **116**), a change in status in the mobile device, receiving data, sending data, program activity (e.g., game activity), interacting with a virtual object, movement of a virtual object (e.g., moving or bouncing of a virtual object), and/or a change in scale, location, orientation, color, or other characteristic of a virtual object. For example, in some embodiments, the augmented reality application may comprise a game in which a user navigates a virtual avatar through a virtual space. In some embodiments, if the user's virtual avatar strikes an object in the virtual space (e.g., a furniture piece in a virtual representation of the user's home), the augmented reality application may determine a haptic effect configured to simulate a collision. For example, haptic effect determination module **126** may determine a haptic effect comprising a vibration with a magnitude proportional to the speed of impact between the avatar and the virtual object. That is, the higher the impact speed between the avatar and the virtual object, the higher the magnitude of the vibration.

[0045] In other embodiments, haptic effect determination module **126** may determine a haptic effect based at least in part on sensor signals received from sensor **132**. Sensor **132** may comprise, for example, a camera or depth sensor. In some embodiments, processor **102** may receive sensor signals from sensor **132** and determine a distance between the computing device **101** and the user or a part of the user's body (e.g., hand or finger). Based on this determination, haptic effect determination module **132** may determine a remote haptic effect. For example, in one such embodiment, the processor **102** may determine a haptic effect that is output to the user's foot using a haptic output device configured to output a puff of air. In such an embodiment, processor **102** may receive sensor signals from sensor **132** and based on those signals determine the distance (e.g., 1 m) between the computing device **101** and the user's foot. The haptic effect determination module **126** may determine the haptic effect based at least in part on the determined distance.

[0046] Haptic effect generation module **128** represents programming that causes processor **102** to transmit a haptic signal to haptic output device **118** to generate the selected haptic effect. For example, haptic effect generation module **128** may access stored waveforms or commands to send to haptic output device **118**. As another example, haptic effect generation module **128** may comprise algorithms to determine the haptic signal. Haptic effect generation module **128** may comprise algorithms to determine target coordinates for the haptic effect. These target coordinates may comprise, for example, a location on the touch sensitive surface **116**.

[0047] FIG. **2** shows an embodiment of a system for viewport-based augmented reality haptic effects. In this example, the system comprises a computing device **201**. In some embodiments, the computing device **201** may comprise a tablet, kiosk, smartphone, e-reader, laptop computer, desktop computer, portable gaming device, glasses, a head-mounted display, and/or other electronic devices. In the embodiment shown in FIG. **2**, the computing device **201** comprises a touch screen display **206**.

[0048] The computing device **201** further comprises a camera (not shown). In some embodiments, the camera may be internal to computing device **201**. For example, the camera may be positioned on the front, back, or sides of computing device **201**. In other embodiments, the camera may be external to computing device **201** and in wired or wireless communication with computing device **201**. In still other embodiments, computing device **201** may comprise a plurality of cameras, which me be internal and/or external to computing device **201**.

[0049] The computing device **201** comprises an augmented reality application. In the embodiment shown in FIG. **2**, the augmented reality application allows a user to capture camera data and change the color of the objects associated with the camera data. For example, as shown in FIG. **2**, the user may adjust the color of an object using the color palette **208**.

[0050] As shown in FIG. **2**, the user has oriented the computing device **201** to capture camera data associated with a car. The user may interact with the color palette **208** by, for example, sliding the user's finger or a stylus across the surface of the touch screen display **206** (e.g., with a swipe or two finger pinch). Further, in some embodiments, the user may interact with the color palette **208** by shaking, tilting, or otherwise moving computing device **201**. In such embodiments, an accelerometer or gyroscope may detect the user interaction and transmit sensor signals associated with the user interaction to a processor.

[0051] Computing device **201** may determine and output a haptic effect based on the occurrence of an event. The event may comprise a passage of time; a change in color, scale, orientation, or location of a virtual object; or a user interaction with the computing device **201** (e.g., tilting or moving the computing device **201**, interacting with the touch screen display **206**, or interacting with other user interface devices such as buttons or joysticks). The haptic effect may comprise a vibration, a perceived change in a coefficient of friction, or a simulated texture. In some embodiments, the simulated texture may comprise metal, glass, plastic, wood, rubber, canvas, sand, gravel, cement, grass, and/or other textures. For example, in one embodiment, as a user places a finger over the location on the display **206** comprising the car **204**, the computing device **201** outputs a haptic effect comprising a simulated metal texture. In another embodiment, the haptic effect may comprise a surface deformation, for example, raising or lowering a portion of the touch screen display **206**. For example, in one embodiment, as a user places a finger over the location on the display **206** comprising the car **204**, the computing device **201** outputs a haptic effect comprising a surface deformation in which the portion of the touch screen display **206** comprising the perimeter of the car is raised.

[0052] In some embodiments, computing device **201** may determine a haptic effect based at least in part on camera data (e.g., real-time or near real-time camera data). For example, in some embodiments, the computing device **201** may determine a haptic effect based on the data in the image captured by the camera. In one such embodiment, the computing device determines that the camera data comprises an image of a car and outputs an associated haptic effect. For example, the computing device may output a haptic effect (e.g., a vibration) configured to mimic the rumbling of a car engine. In

some embodiments, this haptic effect may be output on a periodic basis (e.g., every two minutes).

[0053] In some embodiments, the computing device **201** may output haptic feedback based at least in part on data from other sensors (e.g., a GPS device, an accelerometer, a gyroscope, an inclinometer, a depth sensor, or a range detector). For example, in some embodiments, the processor may determine the haptic effect based in part on the user's location. In some embodiments, the user may capture an image of a car on the street. In such an embodiment, the computing device **201** may determine, via a GPS device, the user's location and display data associated with the car and the location. For example, the computing device **201** may provide a notification with the nearest car dealership carrying the car, as well as other information about the car (e.g., year, model, or price). In some embodiments, the computing device **201** may output a haptic effect associated with the car. For example, in one embodiment, the haptic effect comprises a vibration with a magnitude that is inversely proportional to the distance between the user and the car dealership.

[0054] As another example, in some embodiments, the user may capture an image of a restaurant. In such an embodiment, the computing device **201** may determine, via a GPS device, the user's location and display data associated with the restaurant. For example, the computing device may provide a notification with information about the restaurant (e.g., the owners, the menu, reservation options, restaurant hours, the website, the style of cuisine, or reviews). In some embodiments, the computing device **201** may output a haptic effect associated with the restaurant. For example, in one embodiment, the haptic effect comprises a vibration with a magnitude that is proportional to the review rating (out of five stars) of the restaurant.

[0055] In some embodiments, computing device **201** may analyze the camera's data and, based on this analysis, add virtual objects (e.g., people, animals, furniture, streets, gravel, sand, plants, buildings, carpets, insects, or vehicles) to the scene captured by the camera. For example, in some embodiments, computing device **201** may analyze the camera's data and determine that the scene captured by the camera includes a car **204**. Based on this analysis, the computing device **201** may add a virtual object to the scene comprising, for example, a road underneath the car **206**. In some embodiments, as a user moves a finger across the surface of the touch screen display **206** on the areas comprising the road, the computing device **201** may output a haptic effect comprising an increase in the perceived coefficient of friction on the surface of display **206**. In other embodiments, the computing device **201** may add a virtual car to the scene, for example, so that the user may compare the car captured by the camera with other automobile makes or models. In some embodiments, as a user switches between virtual car models, for example by swiping a finger across the surface of the touch screen display **206**, the computing device **201** may output a haptic effect comprising a vibration to confirm receipt of the user input. In some embodiments, the computing device **201** may add a virtual tree to the scene. In some embodiments, as a user moves a finger across the surface of the touch screen display **206** on the areas comprising the tree, the computing device **201** may output a haptic effect comprising a simulated texture associated with bark or leaves.

[0056] In some embodiments, computing device **201** may output sound, text, and/or video in addition to haptic effects based on the occurrence of an event and/or camera data. In some embodiments, the sound, text, and/or video may be associated with a virtual object. For example, upon the occurrence of an event (e.g., a user interacting with the virtual car), the computing device **201** may output a haptic effect and a sound (e.g., a horn honk).

[0057] FIG. **3** shows another embodiment of a system for viewport-based augmented reality haptic effects. In this example, the system comprises a computing device **301**, which comprises a smartphone or tablet with a display **306**.

[0058] Computing device **301** comprises a camera (not shown) positioned on the back of the computing device **301**. Further, computing device **301** comprises an augmented reality application. The augmented reality application may output on the display **306** a virtual object **304**, for example, a virtual hat, glasses, cartoon characters, automobiles, furniture, buttons, levers, buildings, plants, and/or animals. In some embodiments, the augmented reality application may place the virtual object **304** in one of various locations on the display **306**, for example, in the corners or middle of the display, or in locations associated with the camera data (e.g., on top of a bookshelf, a car, a house, an animal, or person captured by the camera). Further, in some embodiments, the augmented reality application may alter the orientation, scale, color, and/or other characteristics of the virtual object **304** based on where the virtual object's **304** location in the display **306**.

[0059] In the embodiment shown in FIG. **3**, the augmented reality application generates a virtual object **304** on an object captured by the camera. For example, in the embodiment shown in FIG. **3**, a user has placed a hand **308** within the view of the camera and the augmented reality application has generated a virtual object **304** comprising a virtual penguin on the user's hand.

[0060] In some embodiments, computing device **301** may output a haptic effect based on the virtual object **304** and/or the occurrence of an event. In some embodiments, the haptic effect may be based on the movement, color, location, orientation, scale, or presence of the virtual object **304**. For example, in the embodiment shown in FIG. **3**, the computing device **301** may output a haptic effect associated with movement of the virtual penguin, e.g., walking on the user's hand **308**. In such an embodiment, as the virtual penguin takes steps, the computing device **301** may output a haptic effect, for example, vibrations through the housing of computing device **301**.

[0061] Further, in some embodiments, computing device **301** may output a remote haptic effect. As discussed above, the remote haptic effect may comprise a haptic effect output remotely from the computing device **301**, for example, by a puff of a solid, liquid, gas, or plasma from a jet, by a concentrated pressure wave from an array of ultrasonic transducers, or by a haptic output device coupled to a wearable device associated with a user's body part. For example, in some embodiments, the haptic effect may be associated with interactions between the virtual object **304** and the user. For example, in the embodiment shown in FIG. **3**, as the virtual penguin moves on the user's right hand **308**, computing device **301** may output a remote haptic effect directed at the user's hand **308**. This remote haptic effect may comprise, e.g., an air puff or a concentrated pressure wave emitted toward the location on the user's hand **308** where the virtual object has "stepped." In such an embodiment, the user may perceive the puff of gas or concentrated pressure wave as if the virtual object **308** was actually contacting the user's hand **308**. As

another example, in some embodiments, the computing device **301** may comprise a front-facing camera. In some embodiments, the user may be able to use an augmented reality application to put a virtual object **304** (e.g., a superhero mask) on the user's body, for example, on the user's face. As a user manipulates a virtual object **304**, the computing device **301** may output a remote haptic effect directed at the user's face. This remote haptic effect may comprise, for example, a gas puff or a concentrated pressure wave emitted toward the user's face. In such an embodiment, the user may perceive the puff of gas or concentrated pressure wave as if the virtual object **308** was actually contacting and/or moving across the user's face.

[0062] In some embodiments, the system may comprise a haptic output device remote from, but in communication with, computing device **301**. For example, the haptic device may be coupled to a wearable device (e.g., shoes, a sleeve, a jacket, glasses, a glove, a ring, a watch, a bracelet, wristband, a headband, an article of clothing, a hat, and/or jewelry) associated with a part of a user's body (e.g., a user's finger, arm, hand, foot, leg, or head). The computing device **301** may output a remote haptic effect (e.g., a vibration) to the user via the remote haptic output device.

[0063] For example, in some embodiments, the user may wear a wearable device comprising one or more haptic output devices in communication with computing device **301**. As a user manipulates a virtual object **304**, the computing device **301** may output a remote haptic effect via the wearable device. For example, in some embodiments, the user may be wearing a headband comprising one or more haptic output devices. In some embodiments, the computing device **301** may comprise a front-facing camera, and the user may be able to use an augmented reality application to "try on" virtual articles of clothing. For example, in one such embodiment, the user may add a hat to the camera data associated with the user's head. As the user manipulates the virtual hat via the augmented reality application, the computing device **301** may output a remote haptic effect through headband (e.g., a vibration) in order to simulate the feeling of manipulating a hat on the user's head. In another embodiment, the user may be playing an augmented reality application comprising a video game. For example, the user may be playing a video game in which the user can shoot a wrist-mounted, futuristic virtual laser gun. The augmented reality application may add the virtual laser gun to the camera data associated with the user's wrist. In some embodiments, the user may perceive the virtual laser gun as if it is on the user's wrist. Further, the user may be wearing a wristband comprising one or more haptic output devices. As the user fires the virtual laser gun, the computing device **301** may output a remote haptic effect (e.g., a vibration) via the wristband. In some embodiments, the remote haptic effect may simulate the feeling of firing a laser gun.

[0064] FIG. **4** shows a system for viewport-based augmented reality haptic effects according to one embodiment. In this example, the system comprises a computing device **401**, which comprises a smartphone with a display **402**. Computing device **401** further comprises a camera (not shown) positioned on the back of the computing device **401** and an augmented reality application. In the embodiment shown in FIG. **4**, the augmented reality application is related to decorating or renovating. In some embodiments, such an application may allow a user to virtually add or remove walls from a room, change a room's wall color, and/or add or remove furniture to the room.

[0065] In the embodiment shown in FIG. **4**, the user has pointed the camera toward a bathroom, and computing device **401** is outputting data from the camera associated with the bathroom on the display **402**. In the embodiment shown in FIG. **4**, an augmented reality application allows a user to add virtual furniture or fixtures to the bathroom. In this example, the user has chosen to add a virtual shower **404** to the user's bathroom.

[0066] In some embodiments, computing device **401** may output a different types of haptic effects based on the virtual object (e.g., the virtual shower **404**) and/or in response to different events. For example, in one embodiment, a user may choose different tile for the virtual shower. Thereafter, if the user moves a finger across the display **402**, computing device **401** outputs textures or changes in a perceived coefficient of friction associated with the tile on the surface of the display **402**.

[0067] In some embodiments, the computing device **401** may detect the user's gestures in the area captured by the camera via one or more of a camera, depth sensor, and/or range sensor. In some embodiments, based on this data, the computing device may enable the user to interact with the area associated with a virtual object, e.g., the user may interact with the virtual shower's faucet. In such an embodiment, computing device **401** may output a remote haptic effect associated with the user interaction. For example, the computing device **401** may output a remote haptic effect comprising a puff of air at the back of the user's finger or by vibrating a haptically-enabled wearable device (e.g., a ring or watch). In some embodiments, this haptic feedback may confirm receipt of the input gesture or simulate an interaction with the virtual object. For example, in the embodiment shown in FIG. **4**, interacting with the virtual shower's faucet may turn the virtual shower "on." In such an embodiment, when the virtual shower is on the computing device **401** may display virtual water running from the virtual shower head and output an associated haptic effect. For example, the computing device **401** may output a haptic effect comprising a light vibration via the housing of the computing device **401** to simulate the feel of running water.

[0068] In some embodiments, the computing device **401** may be configured to be worn on the user's head or face, for example, as a helmet or glasses. In some embodiments, the computing device **401** may comprise a display **402**, for example, a head-mounted display (HMD). In some embodiments, the display **402** may be transparent. Further, the computing device **401** comprises an augmented reality application. The augmented reality application may output a virtual object on the display **402**. In some embodiments, upon the occurrence of an event, the computing device **401** may output a haptic effect, for example, a vibration or a remote haptic effect (e.g., via a wearable device or a puff of gas). For example, in some embodiments, the computing device **401** may comprise a helmet. The helmet may comprise a camera positioned to capture images in front of or behind the user. The computing device **401** may output the camera images to a display **402**. Further, in some embodiments, the computing device **401** may output a virtual object (e.g., a virtual shower **404**) overlaying the camera images. In some embodiments, upon the user interacting with the area in real space associated with the virtual object, the computing device **401** may output a haptic effect associated with the interaction. For example, upon the user touching an area in real space associated with the virtual object, the computing device **401** may output a

haptic effect comprising, for example, a puff of gas toward the user's finger. Additional examples of a head-mounted display may be found in U.S. patent application Ser. No. 14/106275, which claims priority to U.S. Provisional Patent Application No. 61/909797, the entirety of both of which is hereby incorporated by reference herein.

[0069] FIG. **5** shows a system for viewport-based augmented reality haptic effects according to another embodiment. In this example, the system comprises a computing device **501**, which comprises a smartphone with a display **506**.

[0070] Computing device **501** comprises a camera (not shown) positioned on the back of the computing device **501**. In this example, the user has pointed the camera toward a box with a company name on it, and computing device **501** is outputting data from the camera associated with the box on the display **506**. Computing device **501** further comprises an augmented reality application. In the embodiment shown in FIG. **5**, the augmented reality application analyzes the camera data and determines if data associated with a company, e.g., the company's logo, name or products, is present. If data associated with the company is present, the augmented reality application outputs a virtual object associated with the company. For example, the augmented reality application may output a virtual logo associated with the company. A virtual logo may comprise a 2D or 3D representation of the company's logo.

[0071] In the embodiment shown in FIG. **5**, the augmented reality application has analyzed the data associated with the box, determined the Immersion company name is present, and is outputting a virtual logo **508** comprising the Immersion logo. In other embodiments, the augmented reality application may analyze a product (e.g., a car, hat, phone, computer, tablet, furniture, or clothing), determine a company associated with a product (e.g., Maserati®), and output a virtual logo **508** associated with the company. For example, in some embodiments, the application may detect certain product features (e.g., the size, shape, color, and/or material of the product) and/or a logo on the product to determine a company associated with the product.

[0072] In some embodiments, computing device **501** may output different types of haptic effects based on the virtual object and/or in response to different events. In some embodiments, computing device **508** may output the haptic effects immediately upon the display of the virtual logo **508** or after a certain time delay (e.g., after two minutes, or repeatedly every two minutes). In other embodiments, computing device **501** may output a haptic effect (e.g., a vibration, a texture, or a change in a perceived coefficient of friction) when a user touches the location on the display **506** comprising the virtual logo **508**.

[0073] In some embodiments, a user may be able to reach out and touch the location in real space associated with the location of the virtual logo **508**. In response, computing device **501** may output a remote haptic effect, for example, a puff of gas, a concentrated pressure wave, or by activating a haptic output device coupled to a wearable device. In some embodiments, computing device **501** may additionally or alternatively output a local haptic effect, for example, by vibrating the housing of the computing device **501**. In some embodiments, haptic effects may provide confirmation of a user input or provide greater interactivity with the virtual logo **508**.

[0074] In some embodiments, computing device **501** may output a haptic effect associated with the company's product or brand. For example, a company may associate a certain haptic effect or series of haptic effects with a particular product or brand. In some embodiments, upon a user interacting with a company's virtual logo **508**, the computing device **501** may output a haptic effect associated with the company. For example, in some embodiments, Immersion may associate with its brand a haptic effect comprising three short pulsed vibrations. Upon a user interacting with Immersion's virtual logo **508**, computing device **501** may determine and output this haptic effect. In some embodiments, determining the haptic effect may comprise accessing a local and/or remote database of haptic effects associated with logos.

Illustrative Methods for Providing a Viewport-Based Augmented Reality Haptic Effect

[0075] FIG. **6** is a flow chart of steps for performing a method for providing viewport-based augmented reality haptic effects according to one embodiment. In some embodiments, the steps in FIG. **6** may be implemented in program code that is executed by a processor, for example, the processor in a general purpose computer, a mobile device, or a server. In some embodiments, these steps may be implemented by a group of processors. In some embodiments one or more steps shown in FIG. **6** may be omitted or performed in a different order. Similarly, in some embodiments, additional steps not shown in FIG. **6** may also be performed. The steps below are described with reference to components described above with regard to system **100** shown in FIG. **1**.

[0076] The method **600** begins at step **602** when processor **102** receives an image signal. The image signal may be associated with data from a camera **130** (e.g., an area image of the field of view of the camera **130**). For example, in some embodiments, the image may comprise an image of a city street. In such an embodiment, the image may comprise features commonly found on a city street (e.g., building, cars, street signs, or people).

[0077] The method **600** continues at step **604** when processor **102** determines a virtual object (e.g., a virtual automobile, avatar, or piece of furniture) based in part on the image signal. In some embodiments, the virtual object may comprise data associated with the image captured by the camera **130**. For example, in some embodiments, the virtual object may comprise data associated with a store or restaurant in the image. In such an embodiment, the virtual object may comprise the menu of a restaurant in the image.

[0078] The method **600** continues at step **606** when processor **102** determines a display signal based in part on the image signal. The display signal comprises data associated with a virtual object. In some embodiments, the display signal comprises virtual object data overlaying the image captured by the camera **130**. For example, in some embodiments, the display signal may comprise menu data overlaying the restaurant in the image captured by the camera **130**.

[0079] The method **600** continues at step **608** when processor **102** transmits the display signal to a display. The display is configured to output an image associated with the display signal. For example, the display may output an image comprising menu data overlaying the image of a restaurant.

[0080] The method **600** continues at step **610** when the processor **102** determines a user interaction with a virtual object. In some embodiments, the processor **102** may determine, via signals from sensor **108**, a user interaction on the

surface of touch sensitive surface **116** at a location associated with a virtual object. For example, in some embodiments, the processor **102** may determine a user interaction with a virtual object (e.g., a virtual menu) if the user taps a finger on the touch sensitive surface **116** at a location associated with the virtual object. In some embodiments, the processor **102** may determine a user interaction (e.g., tilting or moving the computing device) via signals from sensors **132**. For example, in some embodiments, processor **102** may determine a user interaction upon the user touching a point in real space associated with a virtual object (e.g., a point in real space associate with a virtual car).

[0081] The method **600** continues at step **612** when processor **102** determines a haptic effect. In some embodiments, the processor **102** may determine the haptic effect based at least in part on one or more of: the virtual object, the image signal from the camera **130**, an event, or a haptic profile. In some embodiments, the processor **102** may rely on programming contained in haptic effect determination module **126** to determine the haptic effect. In some embodiments, haptic effect determination module **126** may comprise a lookup table. In some embodiments, processor **102** may use the lookup table to associate events with particular haptic effects (e.g., textures).

[0082] For example, in one embodiment, the event is based on game activity (e.g., a gunshot, a level completion, or an explosion). In such an embodiment, the augmented reality application may output a virtual object (e.g., a virtual car) that the user can control to complete certain objectives (e.g., successfully navigating the car around a pedestrian). As the user completes objectives, the computing device **101** may determine associated haptic effects.

[0083] In some embodiments, users may have "haptic profiles" wherein a user can determine and save in memory **104** a "profile" of the haptic effects the user would like associated with particular events. For example, in one embodiment, a user can select from a list of available haptic effects and associate one of these haptic effects with a virtual object output by the augmented reality application. In some embodiments, the list may comprise, for example, haptic effects such as a puff of air, an intense vibration, a light vibration, or textures such as bumpy, rubbery, or smooth. In some embodiments, the processor **102** may consult with the user's haptic profile to determine which haptic effect to generate. For example, if the user's haptic profile associates interaction with a virtual object with an intense vibration, in response to the user placing a finger on a touch screen display over the virtual object, the processor **102** may determine a haptic effect comprising an intense vibration.

[0084] The method **600** continues at step **614** when processor **102** transmits a haptic signal to the haptic output device **118**. The haptic signal is based at least in part on the haptic effect. In some embodiments, the processor **102** may access drive signals stored in memory **104** and associated with particular haptic effects. In one embodiment, a signal is generated by accessing a stored algorithm and inputting parameters associated with an effect. For example, in such an embodiment, an algorithm may output data for use in generating a drive signal based on amplitude and frequency parameters. As another example, a second haptic signal may comprise data sent to an actuator to be decoded by the actuator. For instance, the actuator may itself respond to commands specifying parameters such as amplitude and frequency.

[0085] The method **600** continues at step **614** when haptic output device **118** outputs the haptic effect. Haptic output device **118** receives the haptic signal and outputs the haptic effect. In some embodiments, the haptic effect comprises a vibration, a change in a perceived coefficient of friction, a simulated texture, a surface deformation, a concentrated pressure wave, and/or a puff of a solid, liquid, gas, or plasma.

Additional Embodiments of Systems for Viewport-Based Augmented Reality Haptic Effects

[0086] FIG. **7** shows a system for viewport-based augmented reality haptic effects according to another embodiment. In this example, the system **700** comprises a computing device **702** positioned on a surface **706** (e.g., the floor). The computing device **702** comprises a display **708** and a camera **710**. In this example, the computing device **702** comprises a kiosk.

[0087] The computing device **702** further comprises an augmented reality application. In some embodiments, the augmented reality application may be configured to generate a virtual object **712** associated with a user **704**. In some embodiments, the augmented reality application may be configured to generate a virtual object **712** associated with a physical object **714** (e.g., a box, book, wand, card, block, cube, smartphone, chair, or pen) external to the computing device **702**. For example, in some embodiments, a user **704** may be holding the physical object **714**. The computing device **702** may detect the physical object **714** (e.g., via the camera **710**) and/or determine a characteristic of the physical object **714**. In some embodiments, the computing device **702** may generate a virtual object **712** based on the determined characteristic.

[0088] In some embodiments, the physical object **708** may comprise a haptic output device in communication with the computing device **702**. Upon the occurrence of an event, the computing device **702** may output a haptic effect to the user **704** via the physical object **714**. For example, in some embodiments, the user may be holding the physical object **714** (e.g., a wand) in front of the camera **710**. The physical object **714** may comprise a haptic output device. The computing device **702** may comprise an augmented reality application configured to generate a virtual object (e.g., sparkles emitted from the end of the wand) associated with the physical object **714**. In some embodiments, upon the occurrence of an event (e.g., the user shaking the wand) the computing device **702** may further output a haptic effect (e.g., a vibration) via the physical object **714**.

[0089] For example, in some embodiments, the user **704** may be holding a physical object **714** comprising, for example, a card. The card may comprise a haptic output device in communication with the computing device **702**. Upon the occurrence of an event, the computing device **702** may output a haptic effect via the card. For example, the user **704** may position the card in front of the camera **710**. The computing device **702** may comprise an augmented reality application configured to generate a virtual object **712** positioned on top of the card. For example, in some embodiments, the augmented reality application may generate a virtual car positioned on top of the card. As the user **704** interacts with the virtual car (e.g., by opening or closing the car's virtual doors or turning on the car's virtual engine), the computing device **702** may output a haptic effect to the user via the haptic output device in the card. For example, the haptic effect may

be configured to simulate the opening or closing of a car door, or the rumbling of a car's engine.

[0090] Further, in some embodiments, a user **704** may contact a surface **706** (e.g., a floor, desk, chair, or table) that is external to computing device **702**. In some embodiments, upon the occurrence of an event, the computing device **702** may output a haptic effect to the user **704** via the surface **706**. For example, in some embodiments, the computing device **702** may output a haptic effect configured to vibrate, tilt, or move the surface **706** that the user **704** is contacting (e.g., on which the user **704** is standing or sitting). In some embodiments, the surface **706** may comprise a haptic output device in communication with the computing device **702**. The computing device **702** may output haptic effects via the haptic output device. In other embodiments, the computing device **702** may output haptic effects (e.g., vibrations) that propagate through the surface **706** such that the user **704** may perceive the haptic effect. For example, in some embodiments, the physical object **714** may comprise a book and the computing device **702** may comprise, for example, a kiosk, television, computer, or game system. The user **704** may be holding the book in front of a camera **710**. In some embodiments, the computing device **702** may comprise an augmented reality application configured to generate a virtual object **712** associated with the book, for example, a virtual character associated with the book. In some embodiments, upon the user **704** interacting with the virtual character, the computing device **702** may output a haptic effect via a surface **706**, for example, the floor on which the user **704** is standing. For example, in some embodiments, the computing device **702** may vibrate the floor such that the user **704** may perceive the haptic effect.

[0091] Further, in some embodiments, the computing device **702** may analyze camera data and determine information associated with the physical object **714** (e.g., its manufacturer, size, shape, contents, color, or orientation). In some embodiments, the computing device **702** may output a haptic effect based on the determined information. For example, in some embodiments, a user **704** may hold a physical object **714** comprising for example, a toy box in front of a camera **710** associated with the computing device **702**. The computing device **702** may determine information associated with the toy box, for example, that the toy box contains a toy helicopter. In some embodiments, the computing device **702** may comprise an augmented reality application configured to generate a virtual object **712** associated with the physical object **714**, for example, a 3D model of the toy within the toy box (e.g., the toy helicopter). Further, in some embodiments, the computing device **702** may output a haptic effect based on the determined information. For example, in the embodiment above in which the physical object comprises a toy helicopter, the computing device **702** may output a haptic effect comprising a low rumbling vibration configured to simulate a helicopter in flight. In some embodiments, the computing device **702** may output the haptic effect via the surface **706** on which the user **704** is standing. In other embodiments, the computing device **702** may output the haptic effect via a haptic output device within the toy box.

Advantages of a Viewport-Based Augmented Reality Haptic Effect

[0092] There are numerous advantages of having viewport-based augmented reality haptic effects. Providing haptic feedback as users interact with a virtual object via an augmented reality application may allow the user to more realistically perceive aspects of the virtual object, thereby increasing overall user satisfaction. For example, in some embodiments, an augmented reality application may output a virtual tiger overlaying camera data. Upon the occurrence of an event, such as the user moving a finger across a touch screen display area associated with the virtual tiger, the computing device may output a texture simulating fur. As a result, the user may perceive the virtual tiger as more realistic.

[0093] Further, adding haptic feedback to viewport-based augmented reality may lead to improved marketing for brands. For example, in some embodiments, an augmented reality application may output a virtual object comprising, for example, a company logo and, upon the occurrence of an event, output haptic feedback associated with the logo. This may cause the user to identify a haptic effect with a brand, strengthening the brand. Further, such embodiments may provide a more immersive and enhanced marketing experience.

[0094] In some embodiments, viewport-based augmented reality haptic effects may provide a confirmation to a user. For example, in some embodiments, an augmented reality application may output a virtual object comprising a button. As a user interacts with a location in real space associated with the button, the computing device may output a haptic effect (e.g., a concentrated pressure wave) to the back of the user's finger, thereby confirming a button press. In some embodiments, confirmatory haptic feedback may provide an enhanced user experience.

[0095] In some embodiments, adding haptic feedback to viewport-based augmented reality may provide additional information to a user. For example, in some embodiments, an augmented reality application may output a virtual object comprising a motorcycle. The user may be able to switch motorcycle models by swiping a finger across the display screen. Upon switching motorcycle models, in some embodiments, the augmented reality application may output a vibration with a magnitude and/or duration based on the horsepower of the engine in the presently-displayed motorcycle model. Thus, a user may perceive additional information about the virtual object (e.g., virtual motorcycle) as a result of the haptic effects.

General Considerations

[0096] The methods, systems, and devices discussed above are examples. Various configurations may omit, substitute, or add various procedures or components as appropriate. For instance, in alternative configurations, the methods may be performed in an order different from that described, and/or various stages may be added, omitted, and/or combined. Also, features described with respect to certain configurations may be combined in various other configurations. Different aspects and elements of the configurations may be combined in a similar manner. Also, technology evolves and, thus, many of the elements are examples and do not limit the scope of the disclosure or claims.

[0097] Specific details are given in the description to provide a thorough understanding of example configurations (including implementations). However, configurations may be practiced without these specific details. For example, well-known circuits, processes, algorithms, structures, and techniques have been shown without unnecessary detail in order to avoid obscuring the configurations. This description provides example configurations only, and does not limit the scope, applicability, or configurations of the claims. Rather,

the preceding description of the configurations will provide those skilled in the art with an enabling description for implementing described techniques. Various changes may be made in the function and arrangement of elements without departing from the spirit or scope of the disclosure.

[0098] Also, configurations may be described as a process that is depicted as a flow diagram or block diagram. Although each may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be rearranged. A process may have additional steps not included in the figure. Furthermore, examples of the methods may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware, or microcode, the program code or code segments to perform the necessary tasks may be stored in a non-transitory computer-readable medium such as a storage medium. Processors may perform the described tasks.

[0099] Having described several example configurations, various modifications, alternative constructions, and equivalents may be used without departing from the spirit of the disclosure. For example, the above elements may be components of a larger system, wherein other rules may take precedence over or otherwise modify the application of the invention. Also, a number of steps may be undertaken before, during, or after the above elements are considered. Accordingly, the above description does not bound the scope of the claims.

[0100] The use of "adapted to" or "configured to" herein is meant as open and inclusive language that does not foreclose devices adapted to or configured to perform additional tasks or steps. Additionally, the use of "based on" is meant to be open and inclusive, in that a process, step, calculation, or other action "based on" one or more recited conditions or values may, in practice, be based on additional conditions or values beyond those recited. Headings, lists, and numbering included herein are for ease of explanation only and are not meant to be limiting.

[0101] Embodiments in accordance with aspects of the present subject matter can be implemented in digital electronic circuitry, in computer hardware, firmware, software, or in combinations of the preceding. In one embodiment, a computer may comprise a processor or processors. The processor comprises or has access to a computer-readable medium, such as a random access memory (RAM) coupled to the processor. The processor executes computer-executable program instructions stored in memory, such as executing one or more computer programs including a sensor sampling routine, selection routines, and other routines to perform the methods described above.

[0102] Such processors may comprise a microprocessor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), field programmable gate arrays (FPGAs), and state machines. Such processors may further comprise programmable electronic devices such as PLCs, programmable interrupt controllers (PICs), programmable logic devices (PLDs), programmable read-only memories (PROMs), electronically programmable read-only memories (EPROMs or EEPROMs), or other similar devices.

[0103] Such processors may comprise, or may be in communication with, media, for example tangible computer-readable media, that may store instructions that, when executed by the processor, can cause the processor to perform the steps described herein as carried out, or assisted, by a processor. Embodiments of computer-readable media may comprise, but are not limited to, all electronic, optical, magnetic, or other storage devices capable of providing a processor, such as the processor in a web server, with computer-readable instructions. Other examples of media comprise, but are not limited to, a floppy disk, CD-ROM, magnetic disk, memory chip, ROM, RAM, ASIC, configured processor, all optical media, all magnetic tape or other magnetic media, or any other medium from which a computer processor can read. Also, various other devices may comprise computer-readable media, such as a router, private or public network, or other transmission device. The processor, and the processing, described may be in one or more structures, and may be dispersed through one or more structures. The processor may comprise code for carrying out one or more of the methods (or parts of methods) described herein.

[0104] While the present subject matter has been described in detail with respect to specific embodiments thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing may readily produce alterations to, variations of, and equivalents to such embodiments. Accordingly, it should be understood that the present disclosure has been presented for purposes of example rather than limitation, and does not preclude inclusion of such modifications, variations and/or additions to the present subject matter as would be readily apparent to one of ordinary skill in the art.

What is claimed:

1. A system comprising:

a display configured to receive a display signal and output an image;

an image capture device configured to capture an area image and transmit an image signal;

a processor in communication with the image capture device and the display, the processor configured to:

receive the image signal;

determine a virtual object based in part on the image signal;

determine the display signal based in part on the image signal, wherein the display signal comprises data associated with the virtual object;

determine a haptic effect based at least in part on the virtual object;

transmit a haptic signal associated with the haptic effect; and

a haptic output device configured to receive the haptic signal and output the haptic effect.

2. The system of claim **1**, wherein the display comprises a touch screen display.

3. The system of claim **1**, wherein the display signal comprises the virtual object overlaid over the area image.

4. The system of claim **1**, wherein the virtual object comprises: an automobile, a bike, a piece of furniture, an insect, a building, a house, an animal, a person, a computing device, a cartoon character, a logo, or a plant.

5. The system of claim **1**, wherein the haptic output device is coupled to an article configured to be worn by a user.

6. The system of claim **5**, wherein the article comprises: a sleeve, a watch, a bracelet, a wristband, an article of clothing, a jacket, glasses, a glove, a ring, a headband, a hat, or a shoe.

7. The system of claim **1**, wherein the haptic effect comprises one or more of: a vibration, a simulated texture, a

change in a perceived coefficient of friction, or an emission of one or more of solids, liquids, gasses, plasmas, or concentrated pressure waves.

8. The system of claim **1**, wherein determining the haptic effect further comprises:

determining a user interaction with the virtual object and wherein the haptic effect is based at least in part on the user interaction.

9. A method comprising:

receiving an image signal, wherein the image signal comprises an area image;

determining a virtual object based in part on the image signal;

determining a display signal based in part on the image signal, wherein the display signal comprises data associated with the virtual object;

transmitting the display signal to a display, wherein the display is configured to output an image;

determining a haptic effect based at least in part on the virtual object;

transmitting a haptic signal associated with the haptic effect to a haptic output device; and

outputting the haptic effect.

10. The method of claim **9**, wherein the display comprises a touch screen display.

11. The method of claim **9**, wherein display signal comprises the virtual object overlaid over the area image.

12. The method of claim **9**, wherein the virtual object comprises: an automobile, a bike, a piece of furniture, an insect, a building, a house, an animal, a person, a computing device, a cartoon character, a logo, or a plant.

13. The method of claim **9**, wherein the haptic output device is coupled to an article configured to be worn by a user.

14. The method of claim **13**, wherein the article comprises: a sleeve, a watch, a bracelet, a wristband, an article of clothing, a jacket, glasses, a glove, a ring, a headband, a hat, or a shoe.

15. The method of claim **9**, wherein the haptic effect comprises one or more of: a vibration, a simulated texture, a change in a perceived coefficient of friction, or an emission of one or more of solids, liquids, gasses, plasmas, or concentrated pressure waves.

16. The method of claim **9**, wherein determining the haptic effect further comprises:

determining a user interaction with the virtual object and wherein the haptic effect is based at least in part on the user interaction.

17. A non-transient computer readable medium comprising program code, which when executed by a processor is configured to cause the processor to:

receive an image signal, wherein the image signal comprises an area image;

determine a virtual object based in part on the image signal;

determine a display signal based in part on the image signal, wherein the display signal comprises data associated with the virtual object;

transmit the display signal to a display, wherein the display is configured to output an image;

determine a haptic effect based at least in part on the virtual object;

transmit a haptic signal associated with the haptic effect to a haptic output device; and

output the haptic effect.

18. The non-transient computer readable medium of claim **17**, wherein the virtual object comprises: an automobile, a bike, a piece of furniture, an insect, a building, a house, an animal, a person, a computing device, a cartoon character, a logo, or a plant.

19. The non-transient computer readable medium of claim **17**, wherein the haptic output device is coupled to an article configured to be worn by a user.

20. The non-transient computer readable medium of claim **17**, wherein determining the haptic effect further comprises: determining a user interaction with the virtual object and wherein the haptic effect is based at least in part on the user interaction.

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