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(54) **SYSTEM FOR HAPTICALLY REPRESENTING SENSOR INPUT**

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| ***G08B 21/00*** | (2006.01) |
| ***H04B 3/36*** | (2006.01) |
| ***G06F 3/01*** | (2006.01) |
| ***G09B 21/00*** | (2006.01) |
| ***A61B 5/00*** | (2006.01) |

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CPC ..... ***G06F 3/016*** (2013.01); ***A61B 5/0002*** (2013.01); ***G08B 6/00*** (2013.01); ***G09B 21/003*** (2013.01)

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CPC ..... G06F 3/016; G06F 19/3418; G08B 6/00; G08B 25/10; G08B 21/22; G09B 21/003; A61B 5/0002

USPC ..... 340/4.12, 539.12, 407.1, 407.2, 475, 340/573.1, 573.3

See application file for complete search history.

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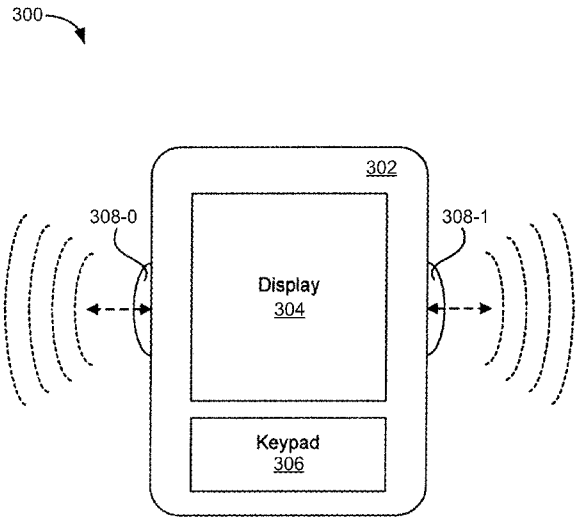
(57) **ABSTRACT**

A haptic representation system is provided that generates a haptic effect in response to sensor input. The sensor input is mapped to a haptic signal. The haptic signal is sent to an actuator configured to receive the haptic signal. The actuator utilizes the haptic signal to generate the haptic effect.

**30 Claims, 11 Drawing Sheets**



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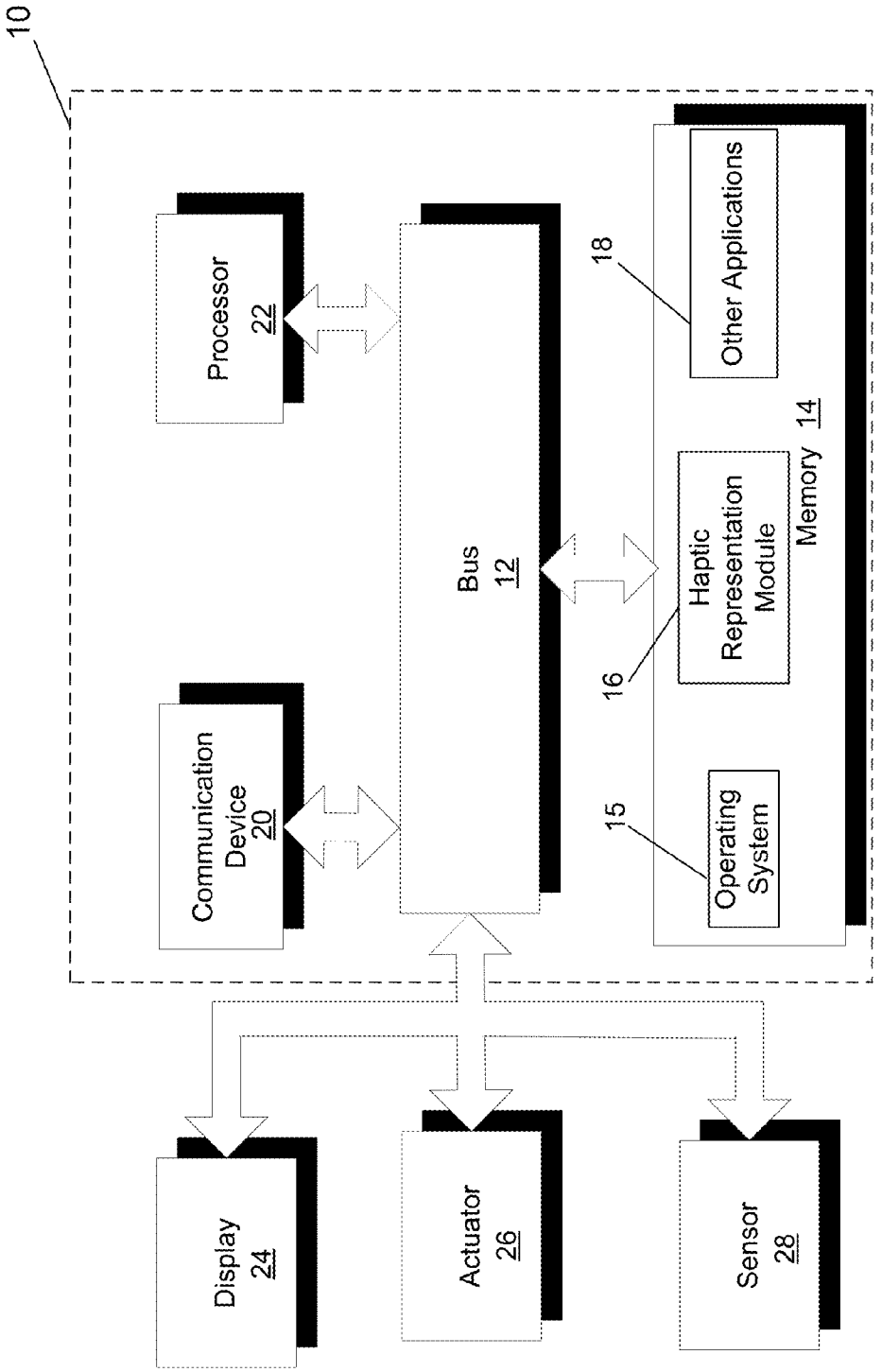
10
Processor
22
Bus
12
Communication
Device
20
Memory
14
Other Applications
18
Haptic
Representation
Module
16
Operating
System
15
Display
24
Actuator
26
Sensor
28

Fig. 1

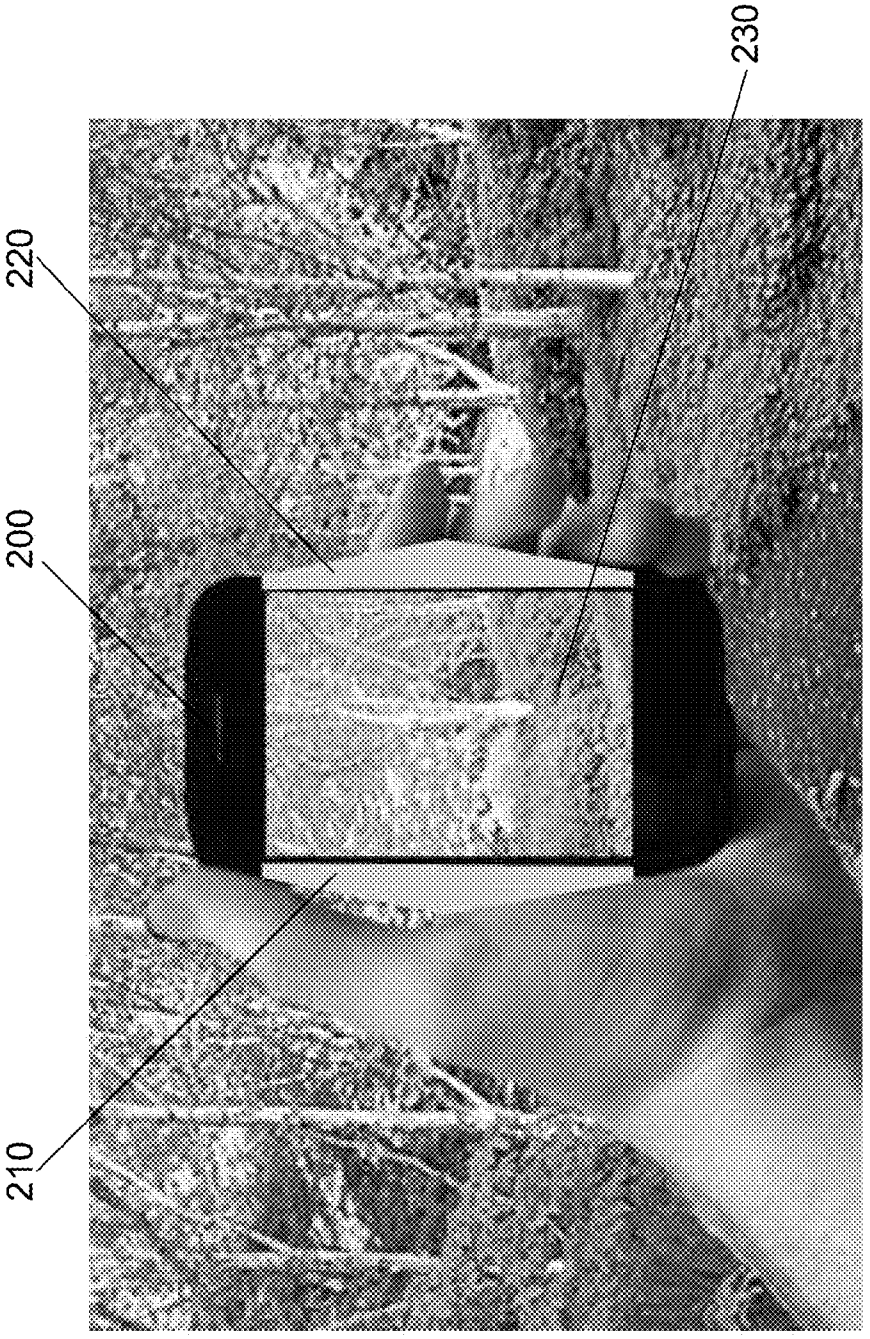


Fig. 2

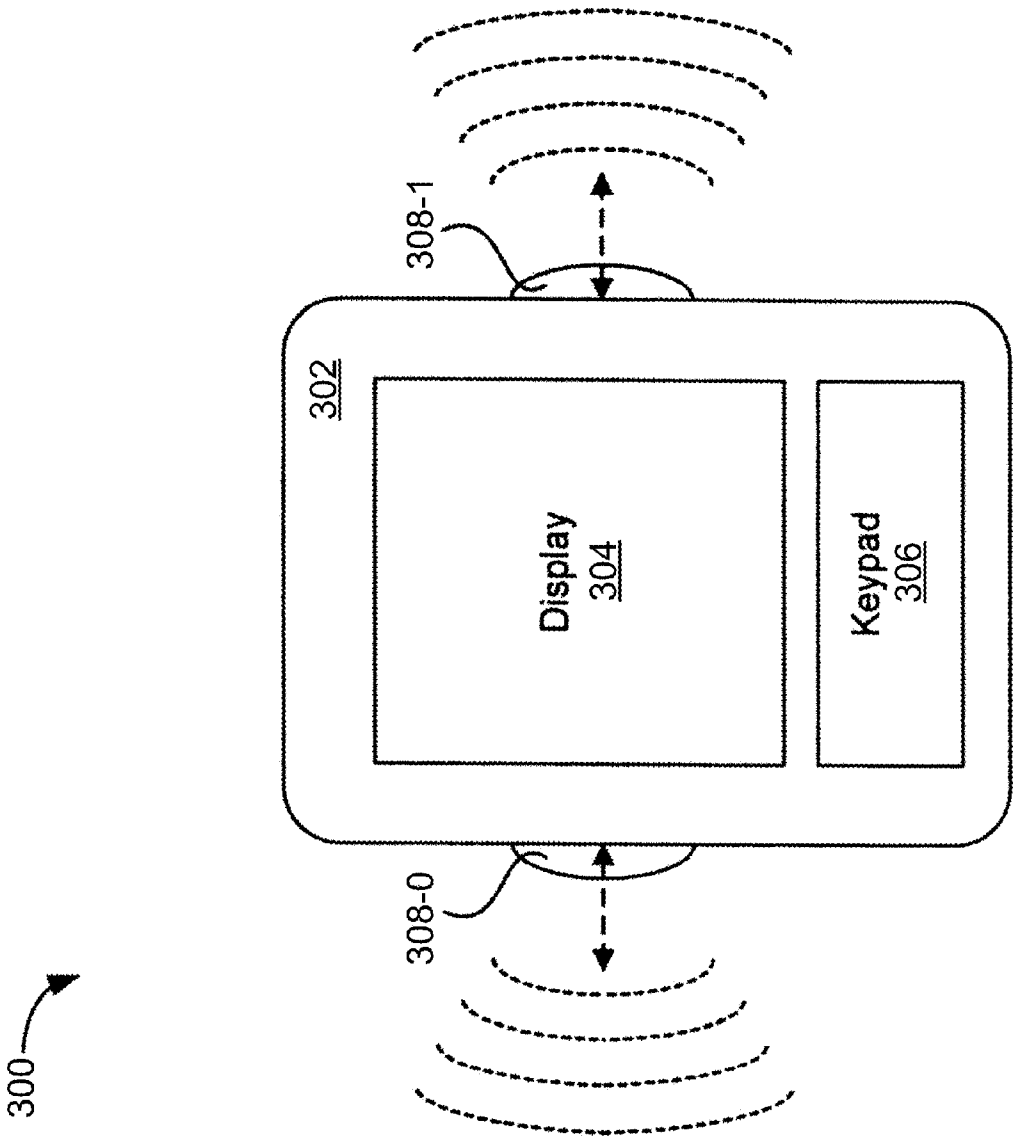


Fig. 3

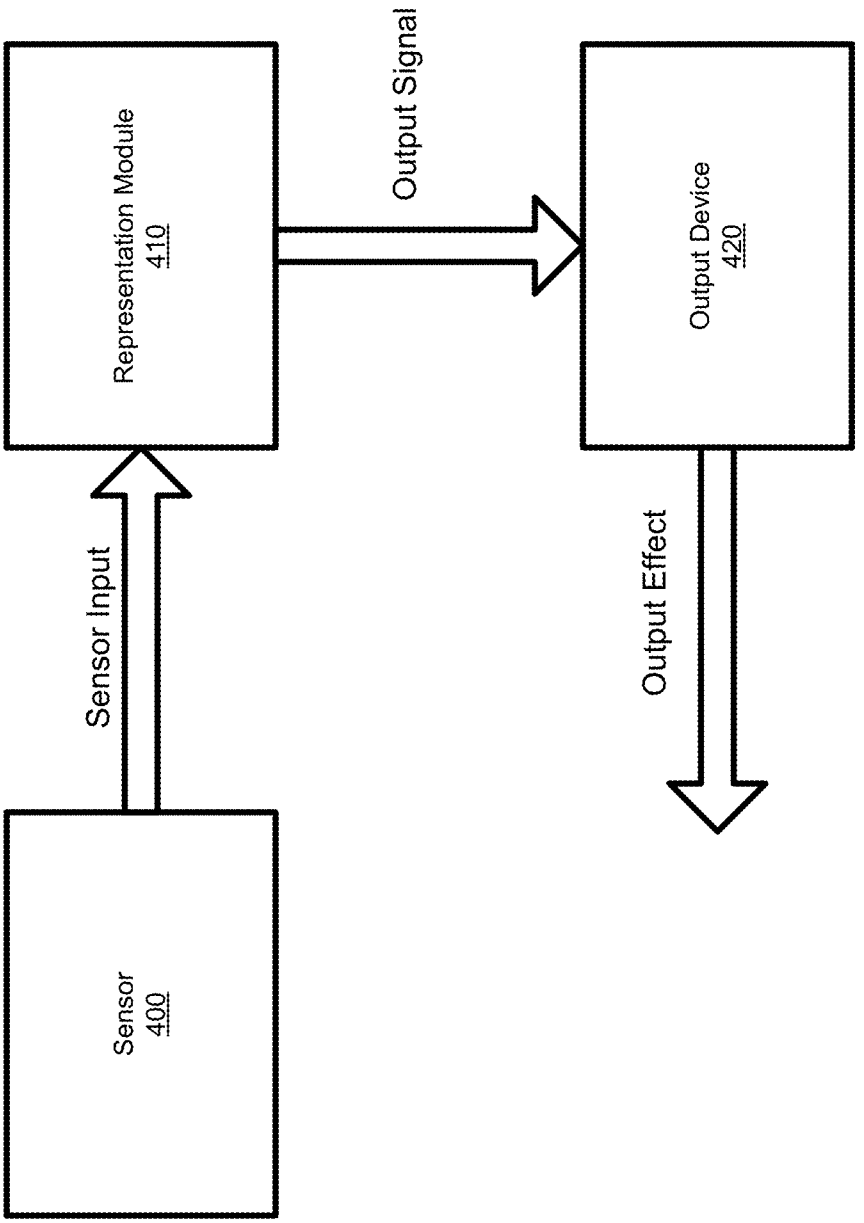
Representation Module
410
Output Signal
Output Device
420
Sensor Input
Output Effect
Sensor
400

Fig. 4

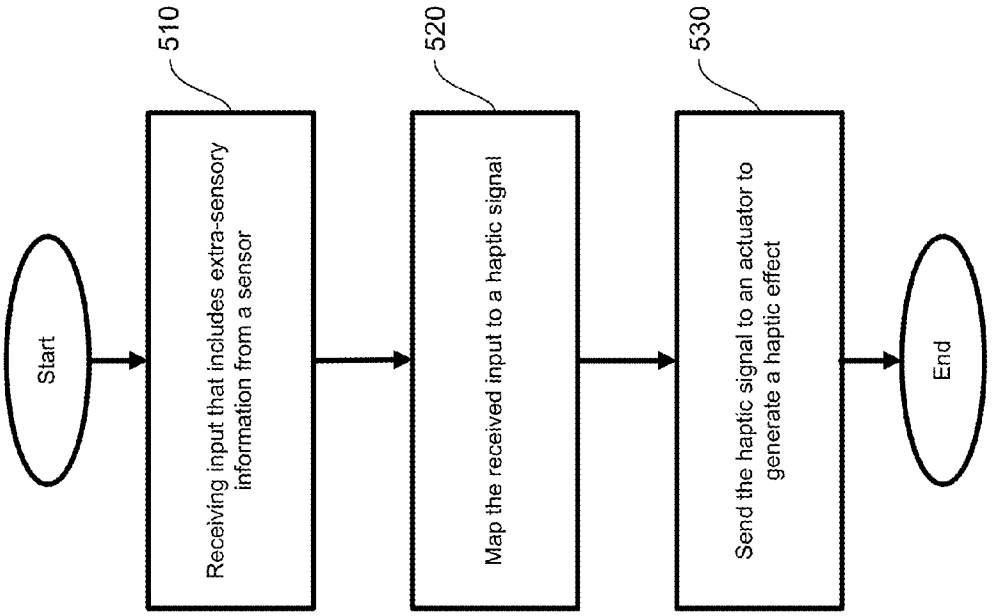
Start
510
Receiving input that includes extra-sensory information from a sensor
520
Map the received input to a haptic signal
530
Send the haptic signal to an actuator to generate a haptic effect
End

Fig. 5

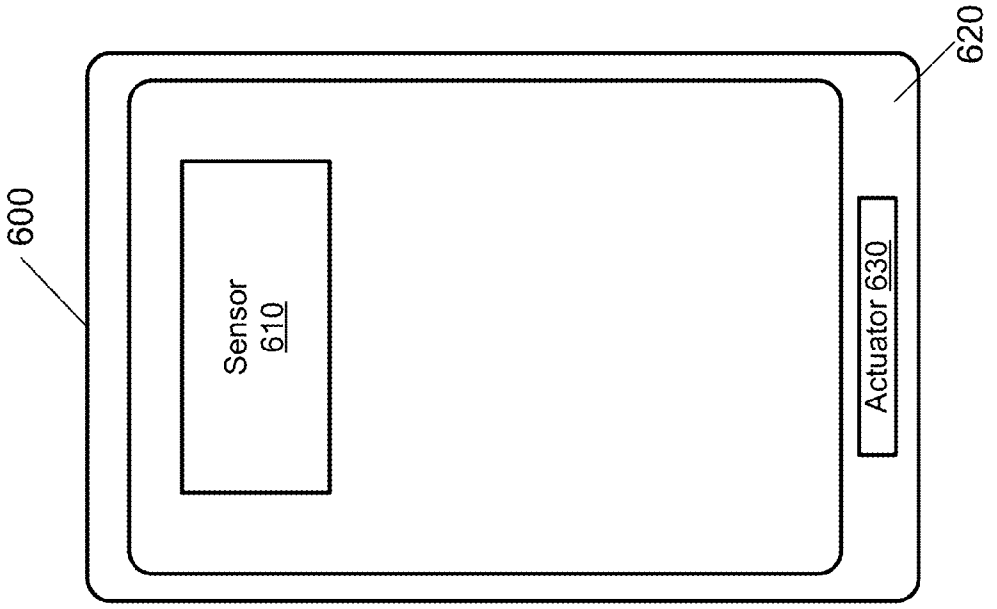


Fig. 6

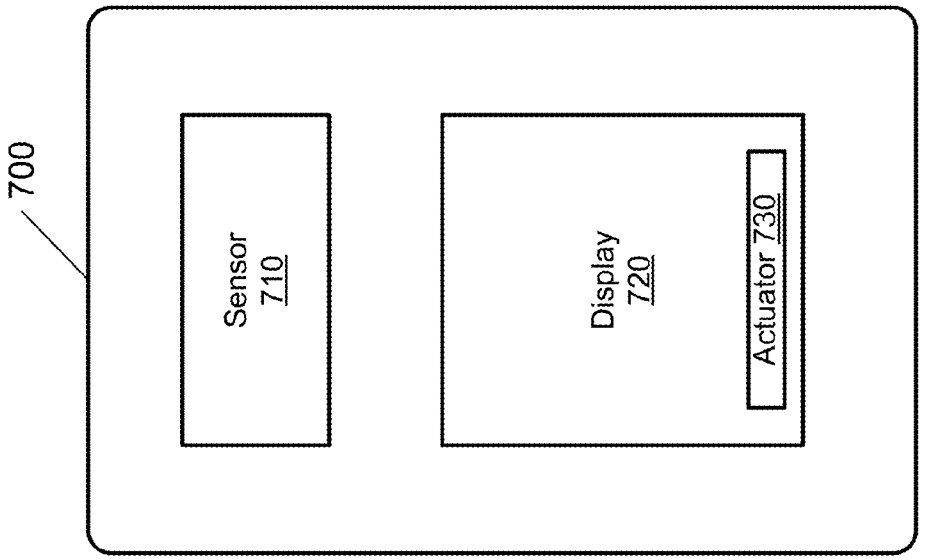


Fig. 7

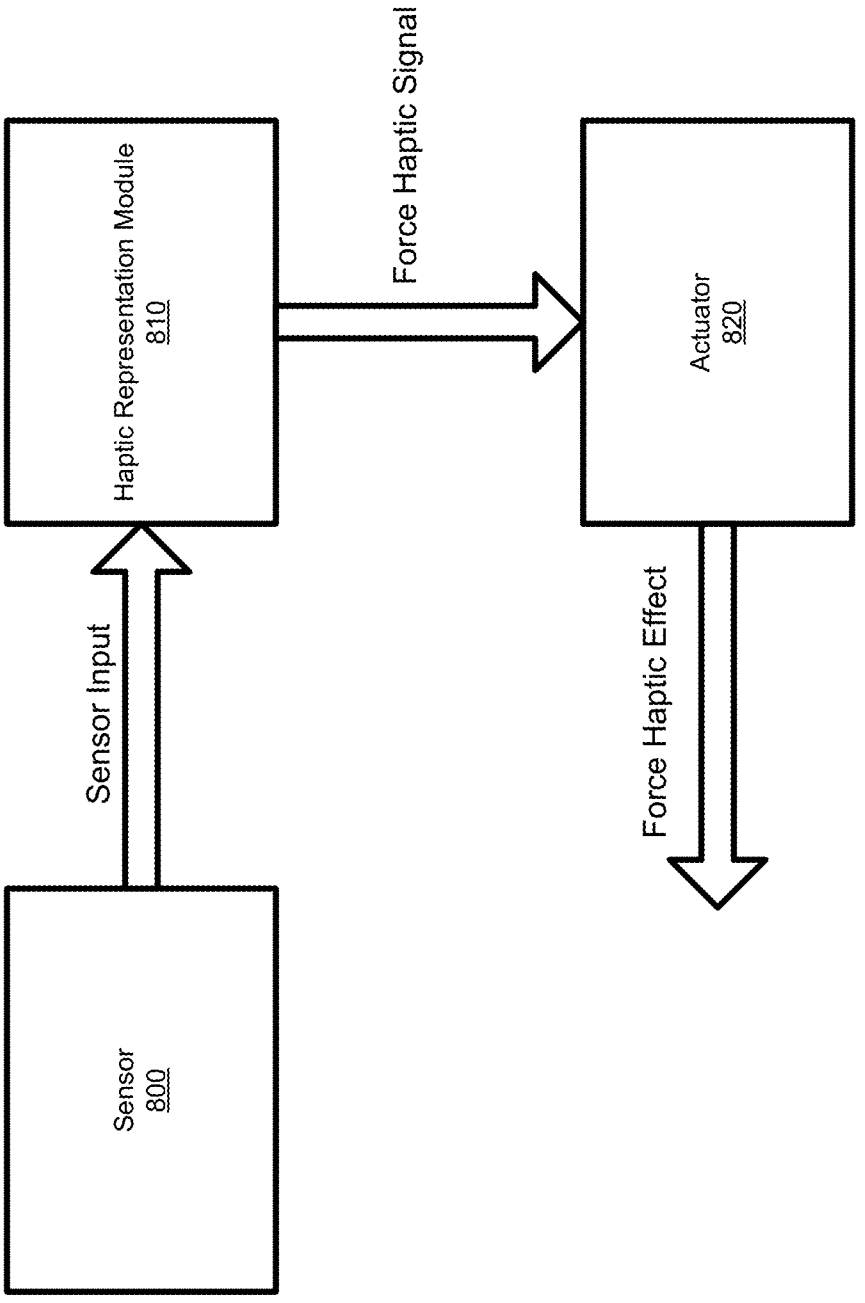
Haptic Representation Module
810
Force Haptic Signal
Actuator
820
Sensor Input
Force Haptic Effect
Sensor
800

Fig. 8

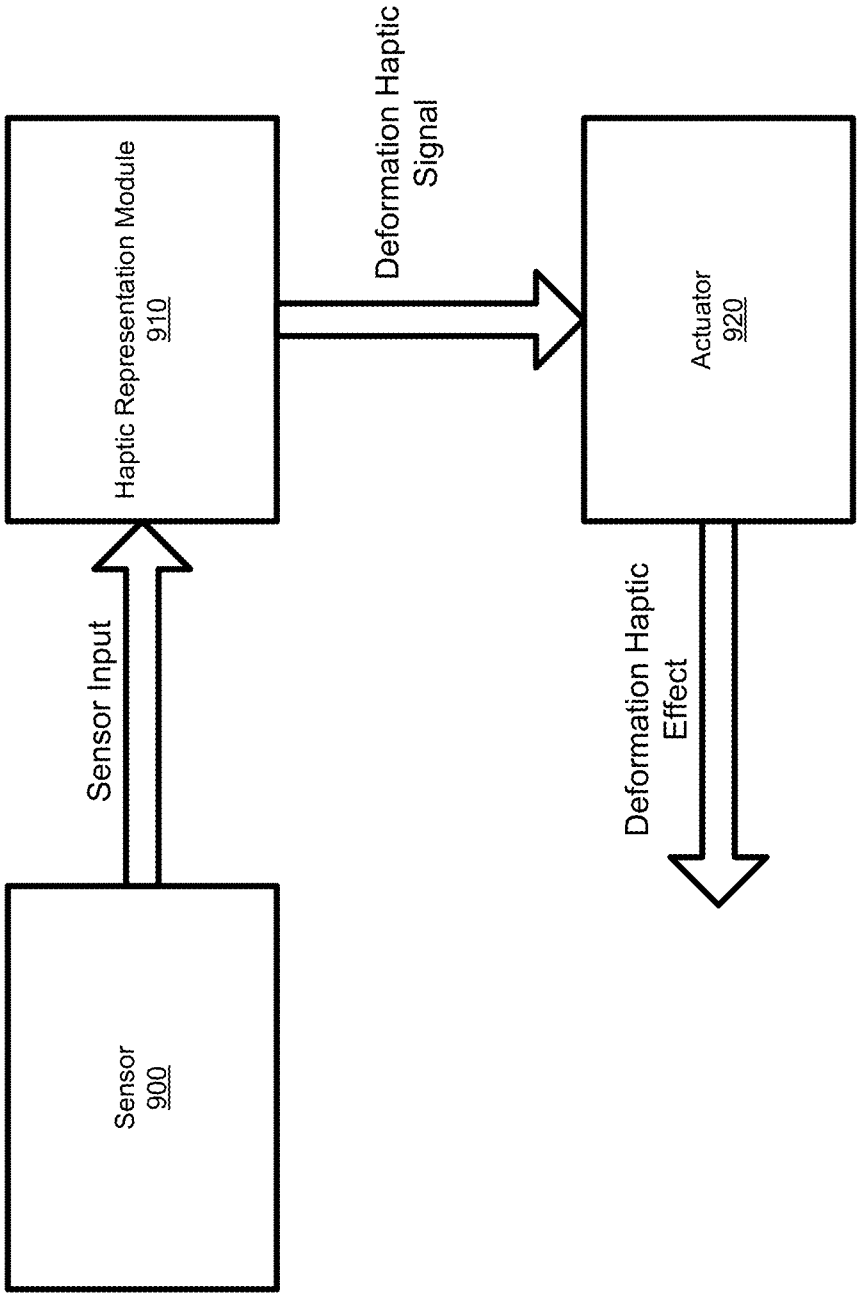
Haptic Representation Module
910
Deformation Haptic
Signal
Actuator
920
Sensor Input
Deformation Haptic
Effect
Sensor
900

Fig. 9

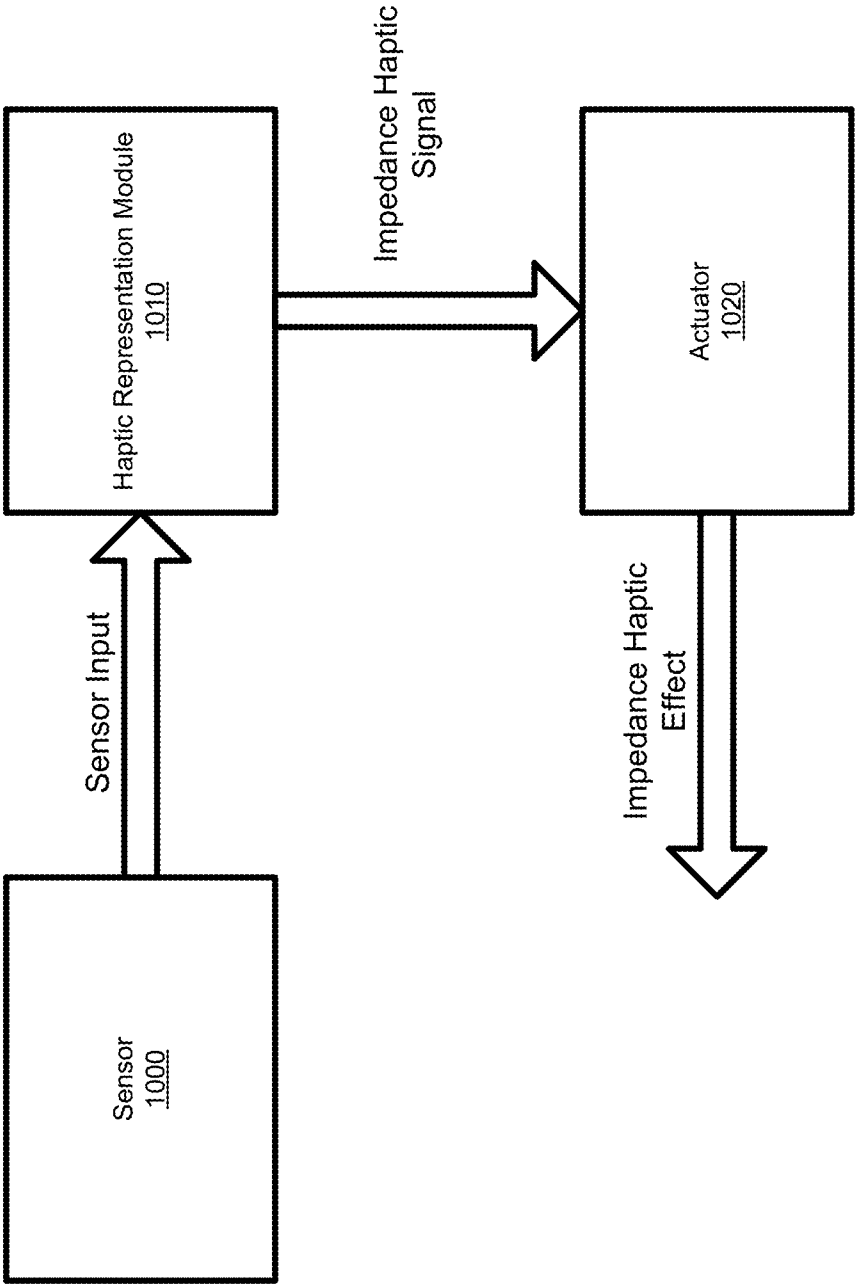
Haptic Representation Module
1010
Impedance Haptic
Signal
Actuator
1020
Sensor Input
Impedance Haptic
Effect
Sensor
1000

Fig. 10

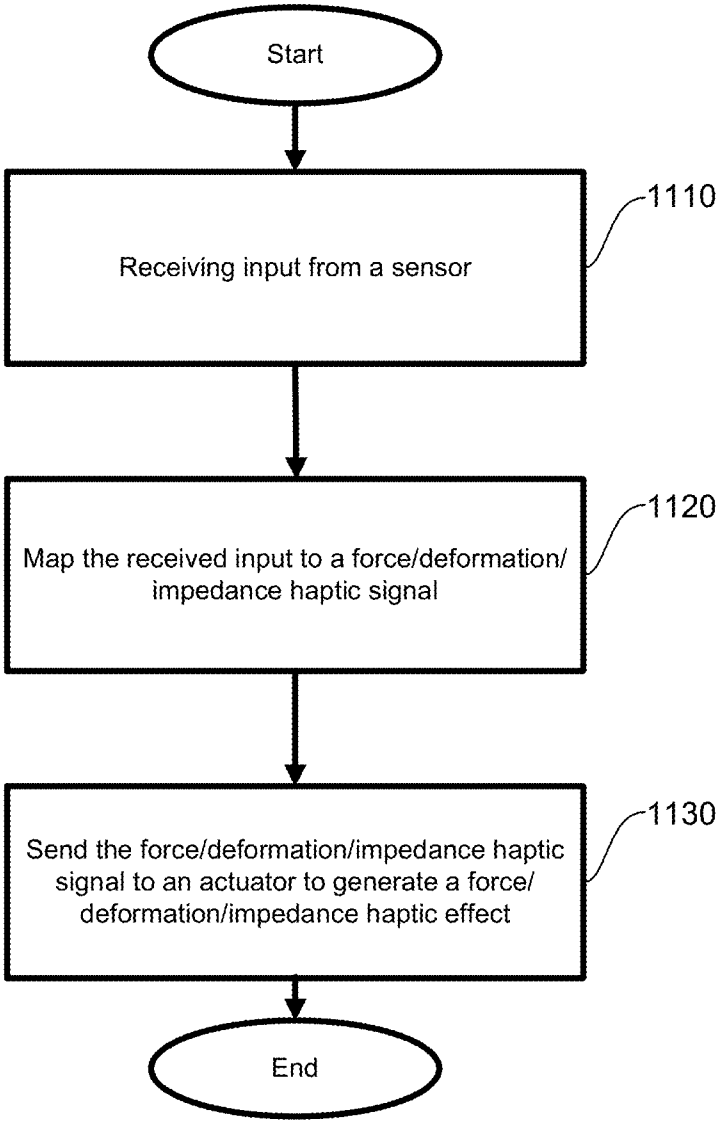
Start
Receiving input from a sensor
1110
Map the received input to a force/deformation/ impedance haptic signal
1120
Send the force/deformation/impedance haptic signal to an actuator to generate a force/ deformation/impedance haptic effect
1130
End

Fig. 11

# SYSTEM FOR HAPTICALLY REPRESENTING SENSOR INPUT

## FIELD

One embodiment is directed generally to a device, and more particularly, to a device that produces haptic effects.

## BACKGROUND

Haptics is a tactile and force feedback technology that takes advantage of a user's sense of touch by applying haptic feedback effects (i.e., "haptic effects"), such as forces, vibrations, and deformations, to the user. A device, such as a mobile device, touchscreen device, and personal computer, can be configured to generate haptic effects in order to provide a more immersive experience for the user. For example, when a user interacts with the device using, for example, a button, touchscreen, lever, joystick, wheel, or some other control, a haptic signal can be generated, where the haptic signal causes the device to produce an appropriate haptic effect. The user can experience the haptic effect, and the user's interaction with the device can be enhanced.

## SUMMARY

One embodiment is a haptic representation system that generates a haptic effect. The system receives input from a sensor. The system maps the received input to a haptic signal. The system further sends the haptic signal to an actuator to generate the haptic effect.

## BRIEF DESCRIPTION OF THE DRAWINGS

Further embodiments, details, advantages, and modifications will become apparent from the following detailed description of the preferred embodiments, which is to be taken in conjunction with the accompanying drawings.

FIG. **1** illustrates a block diagram of a haptic representation system in accordance with one embodiment of the invention.

FIG. **2** illustrates an example of a device with sensor input and haptic output, according to one embodiment of the invention.

FIG. **3** illustrates a block diagram of a device capable of providing vibrotactile effects and/or kinesthetic effects, according to one embodiment of the invention.

FIG. **4** illustrates a diagram of an example mapping of sensor input to an output signal that, when played at an output device, produces an output effect, according to one embodiment of the invention.

FIG. **5** illustrates a flow diagram of the functionality of a haptic representation module, according to one embodiment of the invention.

FIG. **6** illustrates a block diagram of a device capable of producing a haptic effect to augment sensory perception, according to one embodiment of the invention.

FIG. **7** illustrates a block diagram of a device capable of producing a haptic effect to augment visual information displayed within a display screen, according to one embodiment of the invention.

FIG. **8** illustrates a diagram of an example mapping of sensor input to a force haptic signal that, when played at an actuator, produces a force haptic effect, according to one embodiment of the invention.

FIG. **9** illustrates a diagram of an example mapping of sensor input to a deformation haptic signal that, when played at an actuator, produces a deformation haptic effect, according to one embodiment of the invention.

FIG. **10** illustrates a diagram of an example mapping of sensor input to a impedance haptic signal that, when played at an actuator, produces an impedance haptic effect, according to one embodiment of the invention.

FIG. **11** illustrates a flow diagram of the functionality of a haptic representation module, according to another embodiment of the invention.



## DETAILED DESCRIPTION

One embodiment is a haptic representation system that can produce a haptic effect that represents input that is generated by a sensor and received by the haptic representation system. In certain embodiments, the received input includes extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being, such as an electromagnetic field, infra-red light, ultra-violet light, radiation, or subtle changes in temperature. In some embodiments, the haptic effect is a deformation haptic effect produced by a deformation actuator, where a deformation haptic effect includes an alteration of a shape and/or size of a component operably coupled to the deformation actuator. In certain embodiments, the deformation haptic effect that is produced by the deformation actuator is generated based on the extra-sensory information included in the received input generated by the sensor.

As described below in greater detail, a "vibration effect" or "vibration haptic effect" is an effect that produces a vibration. A "vibration actuator" is an actuator configured to produce a vibration haptic effect. A "force effect" or "force haptic effect" is an effect that produces a force. A "force actuator" is an actuator configured to produce a force haptic effect. A "deformation effect" or "deformation haptic effect" is an effect that deforms a structure or shape. A "deformation actuator" is an actuator configured to produce a deformation haptic effect. An "impedance effect" or "impedance haptic effect" is an effect that produces resistance or opposition to an applied force. An "impedance actuator" is an actuator configured to produce an impedance haptic effect.

FIG. **1** illustrates a block diagram of a haptic representation system **10** in accordance with one embodiment of the invention. In one embodiment, system **10** is part of a device (such as device **200** illustrated in FIG. **2**, where device **200** is described below in greater detail), and system **10** provides a haptic representation functionality for the device. Although shown as a single system, the functionality of system **10** can be implemented as a distributed system. System **10** includes a bus **12** or other communication mechanism for communicating information, and a processor **22** coupled to bus **12** for processing information. Processor **22** may be any type of general or specific purpose processor. System **10** further includes a memory **14** for storing information and instructions to be executed by processor **22**. Memory **14** can be comprised of any combination of random access memory ("RAM"), read only memory ("ROM"), static storage such as a magnetic or optical disk, or any other type of computer-readable medium.

A computer-readable medium may be any available medium that can be accessed by processor **22** and may include both a volatile and nonvolatile medium, a removable and non-removable medium, a communication medium, and a storage medium. A communication medium may include computer readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism, and may include

any other form of an information delivery medium known in the art. A storage medium may include RAM, flash memory, ROM, erasable programmable read-only memory ("EPROM"), electrically erasable programmable read-only memory ("EEPROM"), registers, hard disk, a removable disk, a compact disk read-only memory ("CD-ROM"), or any other form of a storage medium known in the art.

In one embodiment, memory **14** stores software modules that provide functionality when executed by processor **22**. The modules include an operating system **15** that provides operating system functionality for system **10**, as well as the rest of a device in one embodiment. The modules further include a haptic representation module **16** that generates a haptic effect that represents received input, as disclosed in more detail below. In certain embodiments, haptic representation module **16** can comprise a plurality of modules, where each individual module provides specific individual functionality for generating a haptic effect that represents received input. System **10** will typically include one or more additional application modules **18** to include additional functionality, such as the Integrator® Haptic Development Platform by Immersion Corporation.

System **10**, in embodiments that transmit and/or receive data from remote sources, further includes a communication device **20**, such as a network interface card, to provide mobile wireless network communication, such as infrared, radio, Wi-Fi, or cellular network communication. In other embodiments, communication device **20** provides a wired network connection, such as an Ethernet connection or a modem.

Processor **22** is further coupled via bus **12** to a display **24**, such as a Liquid Crystal Display ("LCD"), for displaying a graphical representation or user interface to a user. The display **24** may be a touch-sensitive input device, such as a touchscreen, configured to send and receive signals from processor **22**, and may be a multi-touch touchscreen.

System **10**, in one embodiment, further includes an actuator **26**. Processor **22** may transmit a haptic signal associated with a generated haptic effect to actuator **26**, which in turn outputs haptic effects, such as vibrotactile haptic effects and deformation haptic effects. Actuator **26** includes an actuator drive circuit. Actuator **26** may be, for example, 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"), a linear resonant actuator ("LRA"), a piezoelectric actuator, a high bandwidth actuator, an electroactive polymer ("EAP") actuator, an electrostatic friction display, or an ultrasonic vibration generator. In alternate embodiments, system **10** can include one or more additional actuators, in addition to actuator **26** (not illustrated in FIG. **1**). In other embodiments, a separate device from system **10** includes an actuator that generates the haptic effects, and system **10** sends generated haptic effect signals to that device through communication device **20**.

System **10**, in one embodiment, further includes a sensor **28**. Sensor **28** can be configured to detect a form of energy, or other physical property, such as, but not limited to, acceleration, bio signals, distance, flow, force/pressure/strain/bend, humidity, linear position, orientation/inclination, radio frequency, rotary position, rotary velocity, manipulation of a switch, temperature, vibration, or visible light intensity. Sensor **28** can further be configured to convert the detected energy, or other physical property, into an electrical signal, or any signal that represents virtual sensor information. Sensor **28** can be any device, such as, but not limited to, an accelerometer, an electrocardiogram, an electroencephalogram, an electromyograph, an electrooculogram, an electropalatograph, a galvanic skin response sensor, a capacitive sensor, a hall effect sensor, an infrared sensor, an ultrasonic sensor, a pressure sensor, a fiber optic sensor, a flexion sensor (or bend sensor), a force-sensitive resistor, a load cell, a LuSense $CPS^2$ 155, a miniature pressure transducer, a piezo sensor, a strain gage, a hygrometer, a linear position touch sensor, a linear potentiometer (or slider), a linear variable differential transformer, a compass, an inclinometer, a magnetic tag (or radio frequency identification tag), a rotary encoder, a rotary potentiometer, a gyroscope, an on-off switch, a temperature sensor (such as a thermometer, thermocouple, resistance temperature detector, thermistor, or temperature-transducing integrated circuit), microphone, photometer, altimeter, bio monitor, or a light-dependent resistor.

FIG. **2** illustrates an example of a device **200** with sensor input and haptic output, according to one embodiment of the invention. As previously described, in one embodiment, device **200** can include a haptic representation system (such as haptic representation system **10** illustrated in FIG. **1**) that can represent the sensor input as haptic output. According to the embodiment, device **200** is a mobile device that can be carried within a user's hand. Device **200** can include a sensor (such as sensor **28** of FIG. **1**), where the sensor not illustrated in FIG. **2**, extensions **210** and **220**, and display **230**. The sensor can be configured to detect sensory information and extra-sensory information, where sensory information is information that can normally be perceived by a human being, and where extra-sensory information is information that cannot normally be perceived by a human being. The sensor can be further configured to produce sensor input based on the detected information. Extensions **210** and **220** can each be coupled to an actuator (not illustrated in FIG. **2**). The actuator can be a vibration actuator or a deformation actuator. A vibration actuator can cause extensions **210** and **220** to vibrate based on the sensor input produced by the sensor. A deformation actuator can cause extensions **210** and **220** to deform based on the sensor input produced by the sensor. The specifics of a vibration actuator and a deformation actuator are further described in greater detail. Display **230** can display visual information based on the sensor input produced by the sensor.

FIG. **3** illustrates a block diagram of a device **300** capable of providing vibrotactile effects (also identified as "vibration haptic effects") and/or kinesthetic effects (also identified as "deformation haptic effects"), according to one embodiment of the invention. Device **300** includes a housing **302**, a display **304**, a keypad **306**, and extensions **308-0** and **308-1**. In another embodiment, keypad **306** is part of a touchscreen display **304**. Device **300**, in one embodiment, is a wireless portable system capable of providing wireless audio/video communication, mobile data communication, a remote game console, and the like. For example, device **300** may be a cellular phone, a PDA, a smart phone, a laptop computer, a game console, and/or a handheld electronic device capable of processing information as well as providing haptic feedback.

To provide a haptic feedback to a user's hand in accordance with an operation mode, device **300** is capable of macroscopically altering its outer enclosure or housing **302** (which includes extensions **308**) in response to the nature of the application. Depending on the application, extensions **308** can expand or contract (as indicated by arrows in FIG. **3**) thereby macroscopically altering the shape and/or size of housing **302**. In one embodiment, a shape is "macroscopically" altered if it changes to the extent that the change can be detected by the user via, for example, sight or feel. For example, a cell phone or smart phone device capable of changing its outer enclosure shape ("shape changing device") may be used to emulate a handshake between two users. To

convey a handshake, a first user, for instance, might squeeze its first shape changing device to cause a pulse or squeeze of a second shape changing device of a second user, where the first and second users are engaged in a communication, such as a telephone call, via the first and second shape changing devices connected to the first shape changing device. In other words, a shape input or shape signal is sent from the first shape changing device to a second shape changing device indicating that the second device should activate its haptic mechanism to change its shape for emulating a handshake. In other embodiments, additional portions of device **300** besides housing **302** may also change shape, such as display **304**, or input elements such as keypad **306**.

Systems such as device **300** may employ vibrotactile effects (also identified as vibration haptic effects) and/or kinesthetic effects (also identified as deformation haptic effects) to emulate shape changing effects. Vibrotactile effects, for instance, may be used to incorporate haptic feedback to a user via a handheld device. Such haptic feedback effects may be characterized by relatively high-frequency (e.g., about 160-220 Hz) and relatively small displacement (e.g., about 50-500 micrometers) vibrations. Further, different types of haptic information such as confirmation of button clicks and alerts can also be conveyed. Kinesthetic effects, on the other hand, may be characterized by relatively large displacements (e.g., about 1-10 mm) and relatively low-frequency (e.g., about 0-40 Hz) motions. Deformable or flexible surfaces can be used for effective emulation of kinesthetic effects, such as macroscopically changing surface properties depending on the application or activated feature.

Kinesthetic effects may be effectively emulated using deformable haptic surfaces. For example, kinesthetic effects may allow a handheld device to be used as a directional navigation tool. In this example, activation of deformable surfaces at different locations on the handheld device can be used as a haptic display of directional information. In another example, kinesthetic effects allow performance of specific effects (e.g., pulsation, heartbeat, etc.), which could be of value in virtual tele-presence and/or social networking applications. In one example, a heartbeat of one person can be emulated by expanding and contracting deformable pads on the sides of a cell phone of another person connected via a telephone call. In another example, a squeezing of a cell phone at one end of a call can be emulated as a handshake sensation at another cell phone at the other end of the call.

Force haptic effects or "force effects" may be emulated using various types of input signals to drive a haptic actuator, such as, but not limited to, an ERM. Certain types of input signals may be used to provide various impulse force effects or a "jerk sensation" as opposed to more constant force effects (e.g., pushing or pulling force effects). In one example, such impulse force effects may simulate being poked by a finger. In one example, such impulse force effects may simulate a strike, for example, of a golf club impacting a golf ball. In one example, such impulse force effects may simulate a racket impacting a tennis ball. Impulse force effects may be used to simulate other gaming environments.

Device **300**, in one embodiment, is able to change shape based on an operating mode (e.g., application, activated feature, etc.), as opposed to merely being manipulated by a user. Various haptic materials and/or actuators can be used in the haptic mechanism to cause varying shapes in a flexible surface of device **300**. For example, EAPs may be used to form one or more actuators in the haptic mechanism for shape changing based on activation of control signals. In other embodiments, a piezoelectric element, programmable gels, or a fiber of shape memory alloys ("SMAs") can be used as actuators.

In one embodiment, indications of a device operating mode such as an activated feature and application can activate predetermined patterns of a haptic mechanism. Such patterns can then be applied to the flexible surface of device **300** using a deformation mechanism. A haptic substrate that includes a plurality of actuators can be applied to the surface to enact or form the patterns. EAPs, for example, can be employed to form one or more actuators in a haptic mechanism such that activating signals received by the haptic mechanism can convey flexible surface shapes. The haptic substrate can be formed from micro-electro-mechanical systems ("MEMS") elements, thermal fluid pockets, MEMS pumps, resonant devices, variable porosity membranes, laminar flow modulation, etc.

Extensions **308** can be controllable as to displacement, as well as any pulsation or other suitable effects and/or patterns. For example, one user can squeeze a first device, and a second device connected on a call to the first device can pulse or squeeze in the hand of a second user to convey a physical handshake. Thus, a signal can be sent from the first device to the second device to indicate that the second device should change shape to emulate a handshake (e.g., a low frequency force or pressure like a squeeze of a hand). In this fashion, any predetermined shape change characteristics or patterns supportable by the underlying haptic mechanism, substrate, and/or actuator control can be employed.

Further details of devices capable of producing shape changing or deformation haptic effects are described in U.S. patent application Ser. No. 12/776,121, filed on May 7, 2010, herein incorporated by reference.

FIG. **4** illustrates a diagram of an example mapping of sensor input to an output signal that, when played at an output device, produces an output effect, according to one embodiment of the invention. More specifically, FIG. **4** illustrates sensor **400**. Sensor **400** can be identical to sensor **28** of FIG. **1**. Sensor **400** can be a sensor configured to detect information. In certain embodiments, sensor **400** can be a sensor configured to detect extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being. For example, in one embodiment, sensor **400** can be a magnetometer configured to detect electromagnetic fields. In another embodiment, sensor **400** can be a light sensor configured to detect light frequencies that are out of range of the human eye, such as an infra-red light frequency. In another embodiment, sensor **400** can be a temperature sensor configured to detect a change in temperature, even when the temperature change could not normally be detected by a human being. Based on the detected extra-sensory information, the sensor can generate sensor input, where the sensor input represents the detected extra-sensory information. In other embodiments, sensor **400** can be a sensor configured to detect sensory information, where sensory information is information that can normally be perceived by a human being.

FIG. **4** also illustrates representation module **410**. When executed by a processor (not illustrated in FIG. **4**), representation module **410** can receive the sensor input from sensor **400**, map the sensor input to an output signal, and send the output signal to output device **420**. According to the embodiment, representation module **410** can include an algorithm that maps the sensor input to an output signal, where the output signal is configured to produce an output effect when played at output device **420**. Thus, in certain embodiments, representation module **410** can represent the extra-sensory

information detected by sensor **400** (and which cannot normally be perceived by a human being) as an output effect that can be played at output device **420** (and thus, can be perceived by a human being). In this manner, representation module **410** can allow a human being to perceive extra-sensory information detected by sensor **400**, which normally could not be perceived. In other embodiments, representation module **410** can also represent the sensory information detected by sensor **400** as an output effect that can be played at output device **420**. In this manner, representation module **410** can augment a human being's normal perception of the sensory information detected by sensor **400**.

In certain embodiments, representation module **410** can be a haptic representation module, such as haptic representation module **16** of FIG. **1**. In these embodiments, when executed by a processor, representation module **410** can receive the sensor input from sensor **400**, map the sensor input to a haptic signal, and send the haptic signal to output device **420**, where output device **420** is an actuator, such as actuator **26** of FIG. **1**. According to the embodiment, representation module **410** can include an algorithm that maps the sensor input to a haptic signal, where the haptic signal is configured to produce a haptic effect when played at output device **420**. Thus, representation module **410** can represent the extra-sensory information detected by sensor **400** (and which cannot normally be perceived by a human being) as a haptic effect that can be played at output device **420** (and thus, can be perceived by a human being).

For example, in an embodiment where sensor **400** is a magnetometer, representation module **410** can map the input from the magnetometer into a deformation haptic signal or a vibration haptic signal for an actuator. A deformation haptic signal can be played at an actuator to generate a deformation haptic effect. A vibration haptic signal can be played at an actuator to generate a vibration haptic effect. As another example, in an embodiment where sensor **400** is a light sensor, representation module **410** can map the input from the light sensor into a video signal that can be displayed on a display screen, or an audio signal that can be played at a speaker. As yet another example, in an embodiment where sensor **400** is a radiation sensor, representation module **410** can map the input from the radiation sensor into either a deformation haptic signal or a vibration haptic signal for an actuator.

In certain embodiments, sensor **400** can be local to representation module **410** (i.e., sensor **400** and representation module **410** can be located within a single device). In other embodiments, sensor **400** is located on a separate device from representation module **410**, and the sensor input is sent to representation module **410** over a network.

In certain embodiments, the mapping performed at representation module **410** includes determining whether the received sensor input exceeds a specified threshold (i.e., "specified value"). If the received sensor input exceeds the specified value, a corresponding output signal (such as a haptic signal) is generated, and the received sensor input is mapped to the generated output signal. If the received sensor input does not exceed the specified value, no output signal is generated.

In alternate embodiments, the mapping performed at representation module **410** includes mathematically transforming the received sensor input into a corresponding output signal (such as a haptic signal). This can be done continuously as sensor input is received, and thus, the corresponding output signal can be continuously modulated. As the output signal is continuously modulated, the corresponding output effect (such as a haptic effect) that is generated can also be continuously modulated.

FIG. **4** also illustrates output device **420**. Output device **420** can receive the output signal sent by representation module **410**, and can generate an output effect based on the output signal. In certain embodiments, output device **420** can be an actuator, such as actuator **26** of FIG. **1**. In some of these embodiments, output device **420** can be a vibration actuator configured to produce vibration haptic effects. In other embodiments, output device **420** can be a deformation actuator configured to produce deformation haptic effects. In these embodiments, output device **420** can receive a haptic signal sent by representation module **410**, and can generate a haptic effect based on the output signal. In embodiments where the haptic signal is a vibration haptic signal, output device **420** can produce a vibration haptic effect. In embodiments where the haptic signal is a deformation haptic signal, output device **420** can produce a deformation haptic effect. In other embodiments, output device **420** can be an output device configured to produce video effects, such as a display screen, or an output device configured to produce audio effects, such as a speaker.

For example, in an embodiment where sensor **400** is a magnetometer, and output device **420** is an actuator (such as a vibration actuator or a deformation actuator), output device **420** can deform and/or vibrate according to a presence of an electromagnetic field, the intensity of the electromagnetic field, or other attributes of the electromagnetic field. More specifically, sensor **400** can detect the electromagnetic field and produce sensor input based on one or more attributes of the electromagnetic field. Representation module **410** can map the sensor input produced by sensor **400** to a vibration haptic signal, a deformation haptic signal, or a combination therein. Based on the vibration haptic signal, the deformation haptic signal, or the combination therein, output device **420** can produce a vibration haptic effect (by vibrating), a deformation haptic effect (by deforming), or a combination therein.

As another example, in an embodiment where sensor **400** is a light sensor, and output device **420** is a display screen, output device **420** can display a visual representation based on the detection of infra-red light (or ultraviolet light). More specifically, sensor **400** can detect the infra-red light (or ultraviolet light) and produce sensor input based one or more attributes of the infra-red light (or ultraviolet light). Representation module **410** can map the sensor input produced by sensor **400** to a video signal. Based on the video signal, output device **420** can produce a video effect (e.g., a visual representation of the detected light). In an alternate embodiment, output device **420** can be an actuator rather than a display screen. In this embodiment, representation module **410** can map the sensor input produced by sensor **400** to a vibration haptic signal or a deformation haptic signal. Based on the vibration haptic signal, or the deformation haptic signal, output device can produce a vibration haptic effect, or a deformation haptic effect, that represents the detected light. For example, if sensor **400** detects a significant amount of infra-red light, output device **420** can deform an amount that reflects the amount of detected infra-red light.

Thus, according to certain embodiments, a user's senses can be augmented, as the user can perceive attributes of an environment that would normally be difficult or impossible to perceive.

FIG. **5** illustrates a flow diagram of the functionality of a haptic representation module (such as haptic representation module **16** of FIG. **1**), according to one embodiment of the invention. In one embodiment, the functionality of FIG. **5**, as

well as the functionality of FIG. **11**, which is described below in greater detail, is implemented by software stored in memory or another computer-readable or tangible medium, and executed by a processor. In other embodiments, the functionality may be performed by hardware (e.g., through the use of an application specific integrated circuit ("ASIC"), a programmable gate array ("PGA"), a field programmable gate array ("FPGA"), etc.), or any combination of hardware and software. Furthermore, in alternate embodiments, the functionality may be performed by hardware using analog components.

The flow begins and proceeds to **510**. At **510**, input is received from a sensor. The input can include extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being. In certain embodiments, the input can include one or more interaction parameters, where each interaction parameter can include a value. In certain embodiments, the sensor can be a magnetometer configured to generate the input based on an electro-magnetic field that the magnetometer detects. In other embodiments, the sensor can be a light sensor configured to generate the input based on energy that the light sensor detects. The energy can include ultraviolet light. Alternately, the energy can include infra-red light. In other embodiments, the sensor can be a radiation sensor configured to generate the input based on radiation that the radiation sensor detector. The flow proceeds to **520**.

At **520**, the received input is mapped to a haptic signal. In certain embodiments, the mapping the received input to the haptic signal includes generating the haptic signal when the value of at least one interaction parameter exceeds a specified value. In other embodiments, the mapping the received input to the haptic signal includes continuously modulating the haptic signal based on a continuous updating of the value of at least one interaction parameter. The flow proceeds to **530**.

At **530**, the haptic signal is sent to an actuator to generate a haptic effect. In certain embodiments, the actuator is a vibration actuator, and the haptic effect generated by the vibration actuator is a vibration haptic effect. In other embodiments, the actuator is a deformation actuator, and the haptic effect generated by the deformation actuator is a deformation haptic effect. The flow then ends.

In certain embodiments, a haptic device can output various types of information based on sensor input. Examples include: outputting haptic effects based on input from a magnetometer; outputting deformation haptic effects on a display of the device to create a "geofence"; augmenting sensory perception by outputting deformation haptic effects; enhancing normal sensory perception by outputting deformation haptic effects; and outputting haptic effects based on either a user's mood, ambient awareness, or bio feedback.

Furthermore, in certain embodiments, a deformation actuator of a haptic device can output deformation haptic effects using one of a plurality of interaction modes. Examples of the interaction modes include: applying pressure to the body of a user; changing shape (where the shape-change can include a change in a macro-shape of the haptic device or a change in a texture of the haptic device); and outputting an impedance haptic effect (where the haptic device assesses user input and outputs one or more haptic effects based on the user input).

FIG. **6** illustrates a block diagram of a device **600** capable of producing a haptic effect to augment sensory perception, according to one embodiment of the invention. Device **600** can include sensor **610**. Sensor **610** can be identical to sensor **28** of FIG. **1**. Sensor **610** can be a sensor configured to detect information. Based on the detected information, the sensor can generate sensor input, where the sensor input represents the detected information. In certain embodiments, sensor **610** can be a sensor configured to detect extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being.

Device **600** can further include a housing **620**. Housing **620**, also identified as an outer enclosure of device **600**, can be operatively coupled to an actuator **630**. Housing **620** can also include a haptic surface which overlays at least a portion of housing **620**. In certain embodiments, the haptic surface can be configured to apply a force in response to a force haptic effect produced by actuator **630**. In these embodiments, actuator **630** can be a force actuator that can be configured to produce a force haptic effect. In other certain embodiments, the haptic surface can be configured to macroscopically alter its physical shape in response to a deformation haptic effect produced by actuator **630**. In these embodiments, actuator **630** can be a deformation actuator that can be configured to produce a deformation haptic effect. In other certain embodiments, the haptic surface can be configured to produce a mechanical impedance in response to an impedance haptic effect produced by actuator **630**. In these embodiments, actuator **630** can be an impedance actuator that can be configured to produce an impedance haptic effect. Thus, in certain embodiments, actuator **630** can cause housing **620** of device **600** to reflect the information detected by sensor **610**, including the extra-sensory information detected by sensor **610**.

In one embodiment, sensor **610** can be a sensor configured to detect a barometric pressure, and actuator **630** can cause housing **620** to apply a force, to deform, or to produce a mechanical impedance based on the detected barometric pressure. Thus, in this embodiment, device **600** can indicate possible imminent changes in weather patterns due to an increase or decrease in detected barometric pressure. In another embodiment, sensor **610** can be a magnetometer configured to detect an electromagnetic field, and actuator **630** can cause housing **620** to apply a force, to deform, or to produce a mechanical impedance based on one or more properties of the detected electromagnetic field, such as the presence of the electromagnetic field, the intensity of the electromagnetic field, or the periodicity of the electromagnetic field. For example, a user could hold device **600** near an electrical cord to determine whether the electrical cord is connected to a power source in response to housing **620** of device **600** applying a force, applying a deformation, or producing a mechanical impedance in the presence of an alternating electromagnetic field surrounding the cord.

In another embodiment, sensor **610** can be a radiation sensor configured to detect radiation, and actuator **630** can cause housing **620** to apply a force, to deform, or to produce a mechanical impedance based on the detected radiation. For example, device **600** can detect a level of ambient radiation within an environment using sensor **610**, and actuator **630** can cause housing **620** to apply a force, to deform, or to produce a mechanical impedance based on the detected level of ambient radiation. In another embodiments, sensor **610** can be a sensor configured to detect a signal sent by a global positioning system ("GPS"), where the signal can represent a position of device **600**, and actuator **630** can cause housing **620** to apply a force, to deform, or to produce a mechanical impedance based on the detected signal (i.e., the detected position of device **600**). Thus, device **600** can create a geofence (i.e., a virtual perimeter for a real-world geographical area).

In another embodiment, sensor **610** can be a galvanic skin response sensor configured to detect an electrical conductance of the skin of a user, and actuator **630** can cause housing

620 to apply a force, to deform, or to produce a mechanical impedance based on characteristics of the user identified from the detected electrical conductance of the skin of the user, such as mood, ambient awareness, and bio feedback. Thus, device 600 can apply a force, deform, or produce a mechanical impedance in order to mirror an identified state of the user.

FIG. 7 illustrates a block diagram of a device 700 capable of producing a haptic effect to augment visual information displayed within a display screen, according to one embodiment of the invention. Device 700 can include sensor 710. Sensor 710 can be identical to sensor 28 of FIG. 1. Sensor 710 can be a sensor configured to detect information. Based on the detected information, the sensor can generate sensor input, where the sensor input represents the detected information. In certain embodiments, sensor 710 can be a sensor configured to detect extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being. Device 700 can further include a display 720. Display 720 can be configured to display a visual image. Display 720 can be operatively coupled to an actuator 730. Display 720 can be configured to macroscopically alter its physical shape in response to a deformation haptic output effect produced by actuator 730. In certain embodiments, actuator 730 can be a deformation actuator that can be configured to produce a deformation haptic effect. Thus, in these embodiments, device 700 can be configured to overlay a visual image displayed within display 720 with a deformation of at least a portion of a screen of display 720, where the deformation is produced by actuator 730 and based on information detected by sensor 710. For example, display 720 can display a scene, and can further display invisible features of the scene as screen surface features/deformations within display 720. Thus, the visual scene displayed within 720 is generally not changed from how it actually looks.

In one embodiment, sensor 710 can be a light sensor configured to detect light frequencies, including light frequencies that are within a range of the human eye, and also including light frequencies that are out of range of the human eye, and sensor 710 can be configured to capture a full-spectrum photograph of a scene. According to the embodiment, a visual image that represents the light frequencies that are within a range of the human eye can be displayed within display 720, and a deformation of at least a portion of a screen of display 720 that represents the light frequencies that are out of range of the human eye can be produced, where the deformation is produced by actuator 730 and based on information detected by sensor 710. Thus, the visual image that is displayed within display 720 is preserved, but the light frequencies that are out of range of the human eye detected by sensor 710 can be perceived by the user.

FIG. 8 illustrates a diagram of an example mapping of sensor input to a force haptic signal that, when played at an actuator, produces a force haptic effect, according to one embodiment of the invention. More specifically, FIG. 8 illustrates sensor 800. Sensor 800 can be identical to sensor 28 of FIG. 1. Sensor 800 can be a sensor configured to detect information. In certain embodiments, sensor 800 can be a sensor configured to detect extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being. In other embodiments, sensor 800 can be a sensor configured to detect sensory information, where sensory information is information that can normally be perceived by a human being.

FIG. 8 also illustrates haptic representation module 810. When executed by a processor (not illustrated in FIG. 8), haptic representation module 810 can receive the sensor input from sensor 800, map the sensor input to a force haptic signal, and send the force haptic signal to actuator 820. According to the embodiment, haptic representation module 810 can include an algorithm that maps the sensor input to a force haptic signal, where the force haptic signal is configured to produce a force haptic effect when played at actuator 820. Thus, in certain embodiments, haptic representation module 810 can represent information (which can include sensory information or extra-sensory information) detected by sensor 800 as a force haptic effect that can be played at actuator 820.

In certain embodiments, sensor 800 can be local to haptic representation module 810 (i.e., sensor 800 and haptic representation module 810 can be located within a single device). In other embodiments, sensor 800 is located on a separate device from haptic representation module 810, and the sensor input is sent to haptic representation module 810 over a network.

In certain embodiments, the mapping performed at haptic representation module 810 includes determining whether the received sensor input exceeds a specified threshold (i.e., "specified value"). If the received sensor input exceeds the specified value, a corresponding force haptic signal is generated, and the received sensor input is mapped to the generated force haptic signal. If the received sensor input does not exceed the specified value, no force haptic signal is generated.

In alternate embodiments, the mapping performed at haptic representation module 810 includes mathematically transforming the received sensor input into a corresponding force haptic signal. This can be done continuously as sensor input is received, and thus, the corresponding force haptic signal can be continuously modulated. As the force haptic signal is continuously modulated, the corresponding force haptic effect that is generated can also be continuously modulated.

FIG. 8 also illustrates actuator 820. Actuator 820 can be identical to actuator 26 of FIG. 1. Actuator 820 can receive the force haptic signal sent by haptic representation module 810, and can generate a force haptic effect based on the force haptic signal. In some embodiments, actuator 820 can be a force actuator configured to produce force haptic effects.

Thus, in certain embodiments, actuator 820 can cause a device to apply a static force (such as pressure) to a user of the device. For example, the device can apply a static force to a user as the user grips the device. As another example, the device can apply a static force to the user while the device is in the user's pocket. The static force can be of a sufficient degree that the static force causes the device to deform or change shape. The user can feel the device deform by virtue of the device being in static contact with some part of the user's body. In some embodiments, the device can apply a static force, such that the device deforms only to a degree that the deformation can be felt, but not seen. In other embodiments, the device can apply a static force, such that the device deforms to a sufficient degree so that the user can visually assess the state of the deformation as well. In certain embodiments, actuator 820 can cause a device to apply a dynamic force (such as pressure) to a user of the device, where the device continually applies the force in a rhythmic or periodic way over a period of time.

FIG. 9 illustrates a diagram of an example mapping of sensor input to a deformation haptic signal that, when played at an actuator, produces a deformation haptic effect, according to one embodiment of the invention. More specifically, FIG. 9 illustrates sensor 900. Sensor 900 can be identical to sensor 28 of FIG. 1. Sensor 900 can be a sensor configured to detect information. In certain embodiments, sensor 900 can be a sensor configured to detect extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being. In other embodi-

ments, sensor **900** can be a sensor configured to detect sensory information, where sensory information is information that can normally be perceived by a human being.

FIG. **9** also illustrates haptic representation module **910**. When executed by a processor (not illustrated in FIG. **9**), haptic representation module **910** can receive the sensor input from sensor **900**, map the sensor input to a deformation haptic signal, and send the deformation haptic signal to actuator **920**. According to the embodiment, haptic representation module **910** can include an algorithm that maps the sensor input to a deformation haptic signal, where the deformation haptic signal is configured to produce a deformation haptic effect when played at actuator **920**. Thus, in certain embodiments, haptic representation module **910** can represent information (which can include sensory information or extra-sensory information) detected by sensor **900** as a deformation haptic effect that can be played at actuator **920**.

In certain embodiments, sensor **900** can be local to haptic representation module **910** (i.e., sensor **900** and haptic representation module **910** can be located within a single device). In other embodiments, sensor **900** is located on a separate device from haptic representation module **910**, and the sensor input is sent to haptic representation module **910** over a network.

In certain embodiments, the mapping performed at haptic representation module **910** includes determining whether the received sensor input exceeds a specified threshold (i.e., "specified value"). If the received sensor input exceeds the specified value, a corresponding deformation haptic signal is generated, and the received sensor input is mapped to the generated deformation haptic signal. If the received sensor input does not exceed the specified value, no deformation haptic signal is generated.

In alternate embodiments, the mapping performed at haptic representation module **910** includes mathematically transforming the received sensor input into a corresponding deformation haptic signal. This can be done continuously as sensor input is received, and thus, the corresponding deformation haptic signal can be continuously modulated. As the deformation haptic signal is continuously modulated, the corresponding deformation haptic effect that is generated can also be continuously modulated.

FIG. **9** also illustrates actuator **920**. Actuator **920** can be identical to actuator **26** of FIG. **1**. Actuator **920** can receive the deformation haptic signal sent by haptic representation module **910**, and can generate a deformation haptic effect based on the deformation haptic signal. In some embodiments, actuator **920** can be a deformation actuator configured to produce deformation haptic effects.

Thus, in certain embodiments, actuator **920** can cause a device to deform or change shape. In some embodiments, the device can deform only to a degree that the deformation can be felt, but not seen. For example, if the device is in a pocket of a user, the user can reach into his pocket and feel the device and assess the shape of the device. In one example, if the housing of the device is flat, the user has not received any voicemail messages. However, if the housing of the device is extended (i.e., actuator **920** has caused the housing of the device to deform and extend out), then the user has received voicemail messages. In other embodiments, the device can deform to a sufficient degree so that the user can visually assess the state of the deformation as well. In certain embodiments, actuator **920** can cause a device to continually deform in a rhythmic or periodic way over a period of time. For example, the sides of the device can pulse in a way that simulates a breathing pattern. In this example, the device can also display information about its internal state according to how hard or how fast it is "breathing". As another example, the deformation of the device can simulate a heartbeat, and the device can display information about its internal state depending on how hard or fast it is "beating." Furthermore, the device can overlay one or more deformations on top of each other. As an example, the device could deform in a manner to simulate a breathing pattern, and deform in a manner to simulate a heartbeat pattern, simultaneously, but the user would able to differentiate the simultaneous patterns.

FIG. **10** illustrates a diagram of an example mapping of sensor input to a impedance haptic signal that, when played at an actuator, produces an impedance haptic effect, according to one embodiment of the invention. More specifically, FIG. **10** illustrates sensor **1000**. Sensor **1000** can be identical to sensor **28** of FIG. **1**. Sensor **1000** can be a sensor configured to detect information, such as pressure applied to a device by a user.

FIG. **10** also illustrates haptic representation module **1010**. When executed by a processor (not illustrated in FIG. **10**), haptic representation module **1010** can receive the sensor input from sensor **1000**, map the sensor input to an impedance haptic signal, and send the impedance haptic signal to actuator **1020**. According to the embodiment, haptic representation module **1010** can include an algorithm that maps the sensor input to an impedance haptic signal, where the impedance haptic signal is configured to produce an impedance haptic effect when played at actuator **1020**. Thus, in certain embodiments, haptic representation module **1010** can represent information (which can include sensory information or extra-sensory information) detected by sensor **1000** as an impedance haptic effect that can be played at actuator **1020**.

In certain embodiments, sensor **1000** can be local to haptic representation module **1010** (i.e., sensor **1000** and haptic representation module **1010** can be located within a single device). In other embodiments, sensor **1000** is located on a separate device from haptic representation module **1010**, and the sensor input is sent to haptic representation module **1010** over a network.

In certain embodiments, the mapping performed at haptic representation module **1010** includes determining whether the received sensor input exceeds a specified threshold (i.e., "specified value"). If the received sensor input exceeds the specified value, a corresponding impedance haptic signal is generated, and the received sensor input is mapped to the generated impedance haptic signal. If the received sensor input does not exceed the specified value, no impedance haptic signal is generated.

FIG. **10** also illustrates actuator **1020**. Actuator **1020** can be identical to actuator **26** of FIG. **1**. Actuator **1020** can receive the impedance haptic signal sent by haptic representation module **1010**, and can generate an impedance haptic effect based on the impedance haptic signal. In some embodiments, actuator **1020** can be an impedance actuator configured to produce impedance haptic effects.

Thus, in certain embodiments, actuator **1020** can cause a device to produce an impedance haptic effect in response to user input, such as pressure applied to the device by the user. For example, a user may "query" the device to find out a shape of the device, by haptically exploring the contours of the device with a hand or finger. In another example, the user squeezes the device to feel the impedance or deformability. In this way, actuator **1020** can cause the housing of the device to display information to the user, not in a form of deformation, but in a form of mechanical impedance. For example, the user can squeeze the device, and if the device feels "soft," then the user does not have any urgent voicemail messages. However, the user can also squeeze the device, and if the device feels

"hard," then the user does have urgent voicemail messages. Thus, the information can be queried by a user in a discreet, intuitive way by applying pressure to the device and ascertaining the amount of mechanical impedance felt.

While the embodiments described above have involved individual force haptic effects, deformation haptic effects, or impedance haptic effects, in alternate embodiments, an actuator can cause a device to produce various combinations of force haptic effects, deformation effects, and impedance haptic effects, as well as vibrotactile effects or any other haptic effects.

FIG. **11** illustrates a flow diagram of the functionality of a haptic representation module (such as haptic representation module **16** of FIG. **1**), according to one embodiment of the invention. The flow begins and proceeds to **1110**. At **1110**, input is received from a sensor. The input can include extra-sensory information, where extra-sensory information is information that cannot normally be perceived by a human being. In certain embodiments, the input can include one or more interaction parameters, where each interaction parameter can include a value.

Also, in certain embodiments, the sensor can be a sensor configured to detect a barometric pressure. In other embodiments, the sensor can be a magnetometer configured to detect an electromagnetic field. In other embodiments, the sensor can be a radiation sensor configured to detect radiation. In other embodiments, the sensor can be a sensor configured to detect a signal sent by a GPS, where the signal can represent a position of a device. In other embodiments, the sensor can be a galvanic skin response sensor configured to detect an electrical conductance of the skin of a user. In other embodiments, the sensor can be a light sensor configured to detect light frequencies, including light frequencies that are within a range of the human eye, and also including light frequencies that are out of range of the human eye. The flow proceeds to **1120**.

At **1120**, the received input is mapped to a haptic signal. In certain embodiments, the mapping the received input to the haptic signal includes generating the haptic signal when the value of at least one interaction parameter exceeds a specified value. In other embodiments, the mapping the received input to the haptic signal includes continuously modulating the haptic signal based on a continuous updating of the value of at least one interaction parameter. The haptic signal can be a force haptic signal. The haptic signal can be a deformation haptic signal. The haptic signal can be an impedance haptic signal. The haptic signal can be any combination of a force haptic signal, a deformation haptic signal, or an impedance haptic signal. The flow proceeds to **1130**.

At **1130**, the haptic signal is sent to an actuator to generate a haptic effect. In embodiments where the haptic signal is a force haptic signal, the haptic effect is a force haptic effect. In embodiments where the haptic signal is a deformation haptic signal, the haptic effect is a deformation haptic effect. In embodiments where the haptic signal is an impedance haptic signal, the haptic effect is an impedance haptic effect. In some embodiments where the haptic effect is a force haptic effect, the force haptic effect can cause a device to apply a static force to a user. In other embodiments where the haptic effect is a force haptic effect, the force haptic effect can cause the device to apply a dynamic force to the user. In certain embodiments where the haptic effect is a force haptic effect, the force haptic effect can cause the device to apply pressure to the user's body. In certain embodiments where the haptic effect is a deformation haptic effect, the deformation haptic effect can cause a device to deform. In other embodiments where the haptic effect is a deformation haptic effect, the deformation haptic effect can cause the device to continuously deform over a period of time. In certain embodiments where the haptic effect is a deformation haptic effect, the deformation haptic effect can cause the device to modify at least one of a macro-shape of the device or a texture of the device, and the deformation of the devices can comprise at least one of a visual deformation, a haptic deformation, a quasi-static deformation, or a dynamic deformation. In embodiments where the haptic effect is an impedance haptic effect, the impedance haptic effect can cause a device to produce a mechanical impedance in response to user input. In certain embodiments where the haptic effect is an impedance haptic effect, the impedance haptic effect can cause the device to stiffen in response to pressure that is applied to the device by a user.

In embodiments where the sensor is a sensor configured to detect a barometric pressure, the haptic effect that is generated by the actuator can cause a device to deform based on the detected barometric pressure. In embodiments where the sensor is a magnetometer configured to detect an electromagnetic field, the haptic effect that is generated by the actuator can cause a device to deform based on one or more properties of the detected electromagnetic field. In embodiments where the sensor is a radiation sensor configured to detect radiation, the haptic effect that is generated by the actuator can cause a device to deform based on the detected radiation. In embodiments where the sensor is a sensor configured to detect a signal sent by a GPS, where the signal represents a position of a device, the haptic effect that is generated by the actuator can cause the device to deform based on the detected signal. In embodiments where the sensor is a galvanic skin response sensor configured to detect an electrical conductance of the skin of a user, the haptic effect that is generated by the actuator can cause the device to deform based on one or more characteristics of the user identified from the detected electrical conductance of the skin of the user. In embodiments where the sensor is a light sensor configured to detect light frequencies, including light frequencies that are within a range of the human eye, and also including light frequencies that are out of range of the human eye, the haptic effect that is generated by the actuator can cause a display of the device to deform based on the detected light frequencies that are out of range of the human eye. The flow then ends.

Thus, a haptic representation system is provided that represents sensor input as one or more haptic effects. The haptic representation system can enable richer, more informative, and more interactive experiences for a user. The haptic representation system has wide ranging use cases, such as military, medical, automotive, and mobility.

The features, structures, or characteristics of the invention described throughout this specification may be combined in any suitable manner in one or more embodiments. For example, the usage of "one embodiment," "some embodiments," "certain embodiment," "certain embodiments," or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present invention. Thus, appearances of the phrases "one embodiment," "some embodiments," "a certain embodiment," "certain embodiments," or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with

steps in a different order, and/or with elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. In order to determine the metes and bounds of the invention, therefore, reference should be made to the appended claims.

We claim:

**1**. A non-transitory computer-readable medium having instructions stored thereon that, when executed by a processor, cause the processor to generate a haptic effect, the generating the haptic effect comprising:

receiving input from a sensor, wherein the input comprises extra-sensory information, wherein the input further comprises one or more interaction parameters, and wherein each interaction parameter comprises a value;

mapping the received input to a haptic signal; and

sending the haptic signal to an actuator to generate the haptic effect;

the mapping the received input to the haptic signal further comprising modulating the haptic signal when new input is received, wherein the new received input comprises an update of at least one value of at least one interaction parameter of the received input; and

the sending the haptic signal to the actuator to generate the haptic effect further comprising sending the modulated haptic signal to the actuator to modulate the generated haptic effect.

**2**. The non-transitory computer-readable medium of claim **1**,

the mapping the received input to the haptic signal further comprising generating the haptic signal when the value of at least one interaction parameter exceeds a specified value.

**3**. The non-transitory computer-readable medium of claim **1**, wherein the actuator comprises a vibration actuator, and wherein the haptic effect generated by the vibration actuator comprises a vibration haptic effect.

**4**. The non-transitory computer-readable medium of claim **1**, wherein the actuator comprises a deformation actuator, and wherein the haptic effect generated by the deformation actuator comprises a deformation haptic effect.

**5**. A computer-implemented method for generating a haptic effect, the computer-implemented method comprising:

receiving input from a sensor, wherein the input comprises extra-sensory information, wherein the input further comprises one or more interaction parameters, and wherein each interaction parameter comprises a value;

mapping the received input to a haptic signal; and

sending the haptic signal to an actuator to generate the haptic effect;

the mapping the received input to the haptic signal further comprising modulating the haptic signal when new input is received, wherein the new received input comprises an update of at least one value of at least one interaction parameter of the received input; and

the sending the haptic signal to the actuator to generate the haptic effect further comprising sending the modulated haptic signal to the actuator to modulate the generated haptic effect.

**6**. The computer-implemented method of claim **5**,

the mapping the received input to the haptic signal further comprising generating the haptic signal when the value of at least one interaction parameter exceeds a specified value.

**7**. The computer-implemented method of claim **5**, wherein the actuator comprises a vibration actuator, and wherein the haptic effect generated by the vibration actuator comprises a vibration haptic effect.

**8**. The computer-implemented method of claim **5**, wherein the actuator comprises a deformation actuator, and wherein the haptic effect generated by the deformation actuator comprises a deformation haptic effect.

**9**. A haptic representation system comprising:

a memory configured to store a haptic representation module;

a processor configured to execute the haptic representation module stored on the memory; and

an actuator configured to output one or more haptic effects;

wherein the haptic representation module is configured to receive input from a sensor, wherein the input comprises extra-sensory information, wherein the input further comprises one or more interaction parameters, and wherein each interaction parameter comprises a value;

wherein the haptic representation module is further configured to map the received input to a haptic signal;

wherein the haptic representation module is further configured to send the haptic signal to an actuator to generate the haptic effect;

wherein the haptic representation module is further configured to modulate the haptic signal when new input is received, wherein the new input comprises an update of at least one value of at least one interaction parameter of the received input; and

wherein the haptic representation module is further configured to send the modulated haptic signal to the actuator to modulate the generated haptic effect.

**10**. The haptic representation system of claim **9**,

wherein the haptic representation module is further configured to generate the haptic signal when the value of at least one interaction parameter exceeds a specified value.

**11**. The haptic representation system of claim **9**, wherein the actuator comprises a vibration actuator, and wherein the haptic effect generated by the vibration actuator comprises a vibration haptic effect.

**12**. The haptic representation system of claim **9**, wherein the actuator comprises a deformation actuator, and wherein the haptic effect generated by the deformation actuator comprises a deformation haptic effect.

**13**. A non-transitory computer-readable medium having instructions stored thereon that, when executed by a processor, cause the processor to generate a haptic effect, the generating the haptic effect comprising:

receiving input from a sensor, wherein the input further comprises one or more interaction parameters, and wherein each interaction parameter comprises a value;

mapping the received input to a haptic signal; and

sending the haptic signal to an actuator to generate the haptic effect;

wherein the haptic signal is at least one of a force haptic signal, a deformation haptic signal, or an impedance haptic signal;

wherein the haptic effect is at least one of a force haptic effect, a deformation haptic effect, or an impedance haptic effect;

the mapping the received input to the haptic signal further comprising modulating the haptic signal when new input is received, wherein the new received input comprises an update of at least one value of at least one interaction parameter of the received input; and

the sending the haptic signal to the actuator to generate the haptic effect further comprising sending the modulated haptic signal to the actuator to modulate the generated haptic effect.

**14**. The non-transitory computer-readable medium of claim **13**, wherein the input comprises extra-sensory information.

**15**. The non-transitory computer-readable medium of claim **13**, wherein the haptic effect is a force haptic effect, and wherein the force haptic effect causes a device to apply a force to a user.

**16**. The non-transitory computer-readable medium of claim **15**, wherein the force haptic effect causes the device to apply pressure to the user's body.

**17**. The non-transitory computer-readable medium of claim **13**, wherein the haptic effect is a deformation haptic effect, and wherein the deformation haptic effect causes a device to deform.

**18**. The non-transitory computer-readable medium of claim **17**, wherein the deformation haptic effect causes the device to modify at least one of a macro-shape of the device or a texture of the device, and wherein the deformation of the devices comprises at least one of a visual deformation, a haptic deformation, a quasi-static deformation, or a dynamic deformation.

**19**. The non-transitory computer-readable medium of claim **13**, wherein the haptic effect is an impedance haptic effect, and wherein the impedance haptic effect causes a device to produce a mechanical impedance in response to user input.

**20**. The non-transitory computer-readable medium of claim **19**, wherein the impedance haptic effect causes the device to stiffen in response to pressure that is applied to the device by a user.

**21**. A computer-implemented method for generating a haptic effect, the computer-implemented method comprising:

receiving input from a sensor, wherein the input further comprises one or more interaction parameters, and wherein each interaction parameter comprises a value;

mapping the received input to a haptic signal; and

sending the haptic signal to an actuator to generate the haptic effect;

wherein the haptic signal is at least one of a force haptic signal, a deformation haptic signal, or an impedance haptic signal;

wherein the haptic effect is at least one of a force haptic effect, a deformation haptic effect, or an impedance haptic effect;

the mapping the received input to the haptic signal further comprising modulating the haptic signal when new input is received, wherein the new received input comprises an update of at least one value of at least one interaction parameter of the received input; and

the sending the haptic signal to the actuator to generate the haptic effect further comprising sending the modulated haptic signal to the actuator to modulate the generated haptic effect.

**22**. The computer-implemented method of claim **21**, wherein the input comprises extra-sensory information.

**23**. The computer-implemented method of claim **21**, wherein the haptic effect is a force haptic effect, and wherein the force haptic effect causes a device to apply a force to a user.

**24**. The computer-implemented method of claim **21**, wherein the haptic effect is a deformation haptic effect, and wherein the deformation haptic effect causes a device to deform.

**25**. The computer-implemented method of claim **21**, wherein the haptic effect is an impedance haptic effect, and wherein the impedance haptic effect causes a device to produce a mechanical impedance in response to user input.

**26**. A haptic representation system comprising:

a memory configured to store a haptic representation module;

a processor configured to execute the haptic representation module stored on the memory; and

an actuator configured to output one or more haptic effects;

wherein the haptic representation module is configured to receive input from a sensor, wherein the input further comprises one or more interaction parameters, and wherein each interaction parameter comprises a value;

wherein the haptic representation module is further configured to map the received input to a haptic signal;

wherein the haptic representation module is further configured to send the haptic signal to an actuator to generate the haptic effect;

wherein the haptic signal is at least one of a force haptic signal, a deformation haptic signal, or an impedance haptic signal;

wherein the haptic effect is at least one of a force haptic effect, a deformation haptic effect, or an impedance haptic effect;

wherein the haptic representation module is further configured to modulate the haptic signal when new input is received, wherein the new input comprises an update of at least one value of at least one interaction parameter of the received input; and

wherein the haptic representation module is further configured to send the modulated haptic signal to the actuator to modulate the generated haptic effect.

**27**. The haptic representation system of claim **26**, wherein the input comprises extra-sensory information.

**28**. The haptic representation system of claim **26**, wherein the haptic effect is a force haptic effect, and wherein the force haptic effect causes a device to apply a force to a user.

**29**. The haptic representation system of claim **26**, wherein the haptic effect is a deformation haptic effect, and wherein the deformation haptic effect causes a device to deform.

**30**. The haptic representation system of claim **26**, wherein the haptic effect is an impedance haptic effect, and wherein the impedance haptic effect causes a device to produce a mechanical impedance in response to user input.

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