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(54) **MODIFYING HAPTIC EFFECTS FOR SLOW MOTION**

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G11B 27/00	(2006.01)
A63F 13/285	(2014.01)
A63F 13/00	(2014.01)
G06F 3/0338	(2013.01)
G06F 3/038	(2013.01)

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CPC ***G06F 3/016*** (2013.01); ***A63F 13/00*** (2013.01); ***A63F 13/285*** (2014.09); ***G06F 3/038*** (2013.01); ***G06F 3/0338*** (2013.01); ***G11B 27/005*** (2013.01); *G06F 2203/013* (2013.01); *G06F 2203/015* (2013.01)

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See application file for complete search history.

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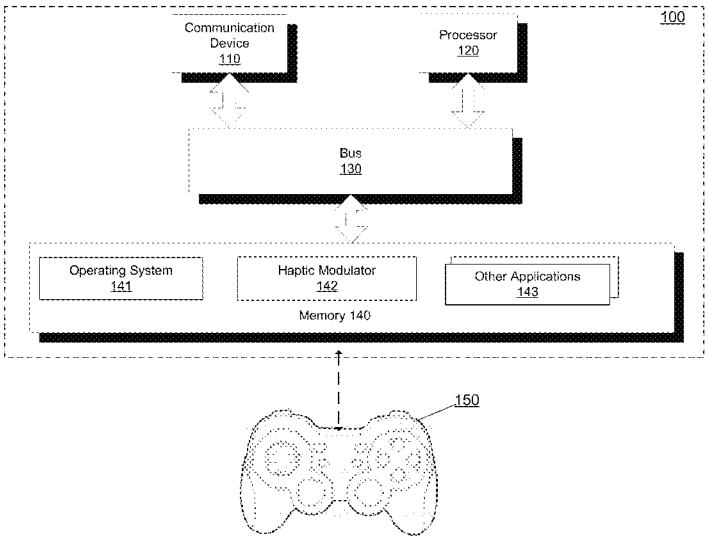
(57) **ABSTRACT**

Systems and methods for generating and modifying a haptic effect are provided. Haptic effects are rendered in slow motion by modifying the various parameters associated with each haptic effect of a haptic effect sequence. For example, the magnitude, frequency, and/or duration of each haptic effect may be altered to accurately convey the haptic effect sequence in slow motion.

21 Claims, 9 Drawing Sheets



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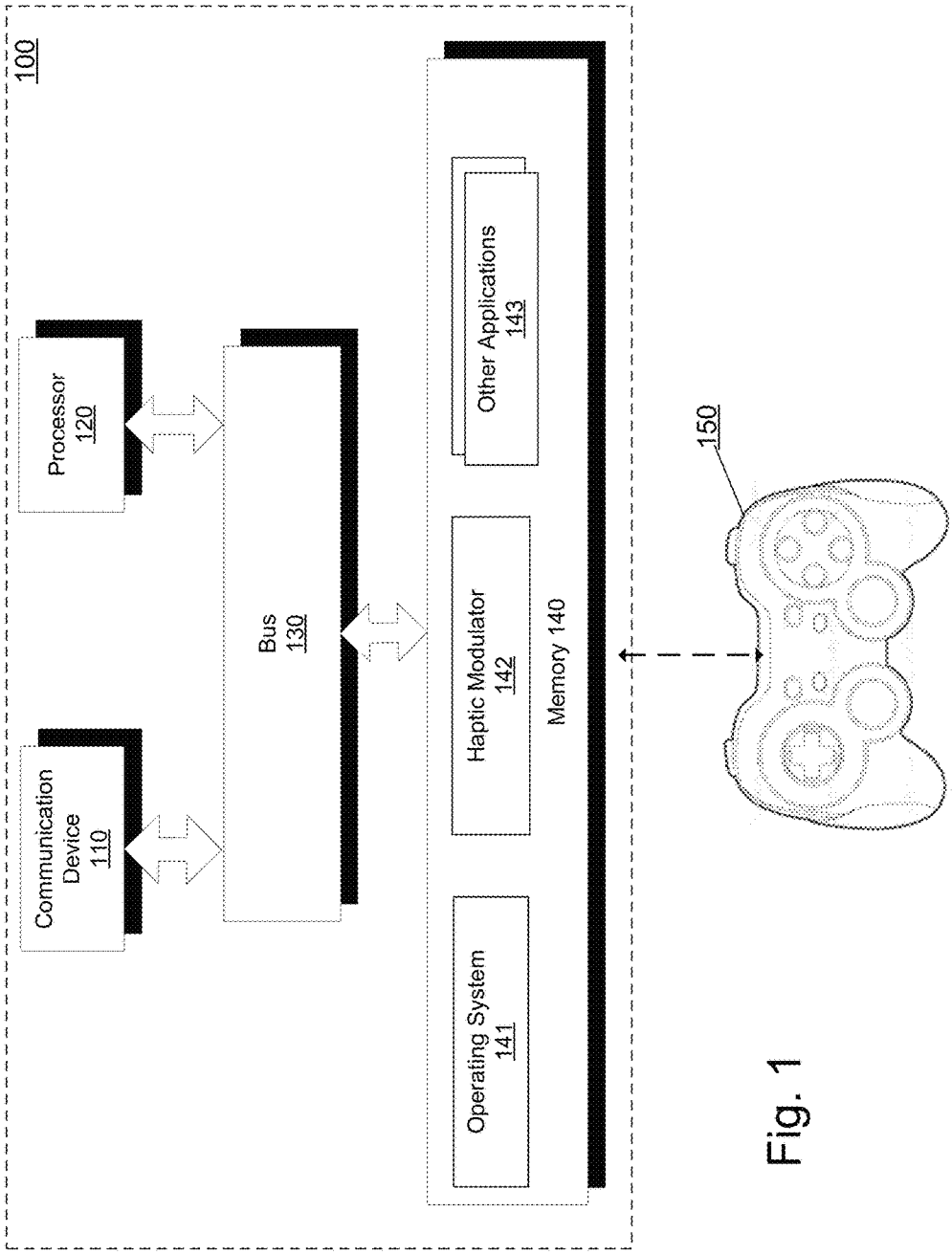
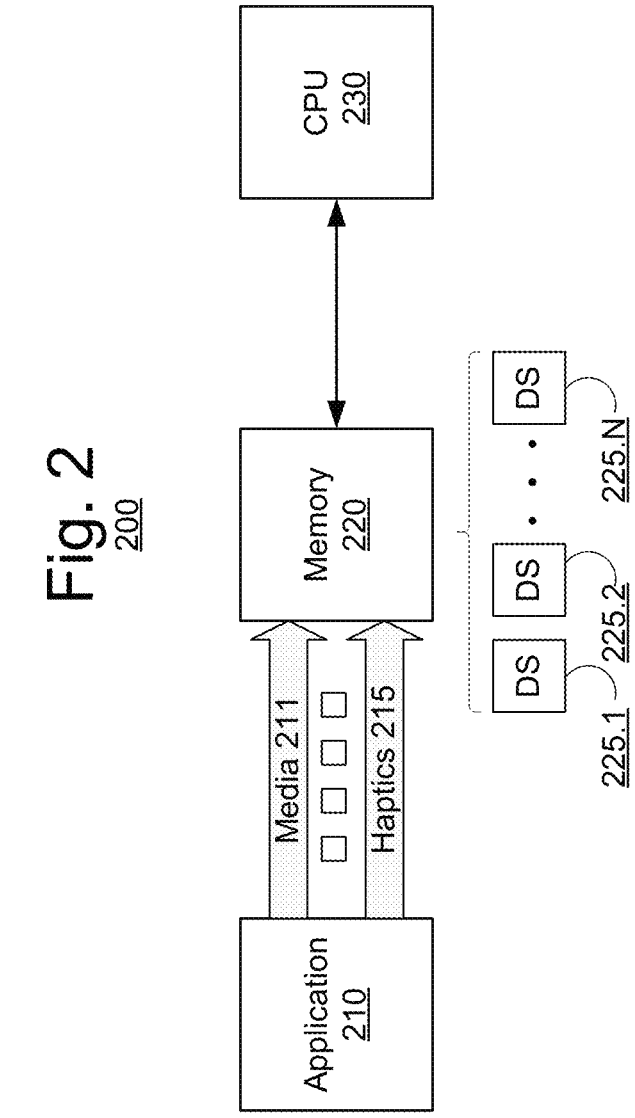

100
Processor 120
Bus 130
Communication Device 110
Other Applications 143
Haptic Modulator 142
Operating System 141
Memory 140
150

Fig. 1

Fig. 2
200


CPU
230
Memory
220
DS
DS
DS
225.N
225.2
225.1
Media 211
Haptics 215
Application
210

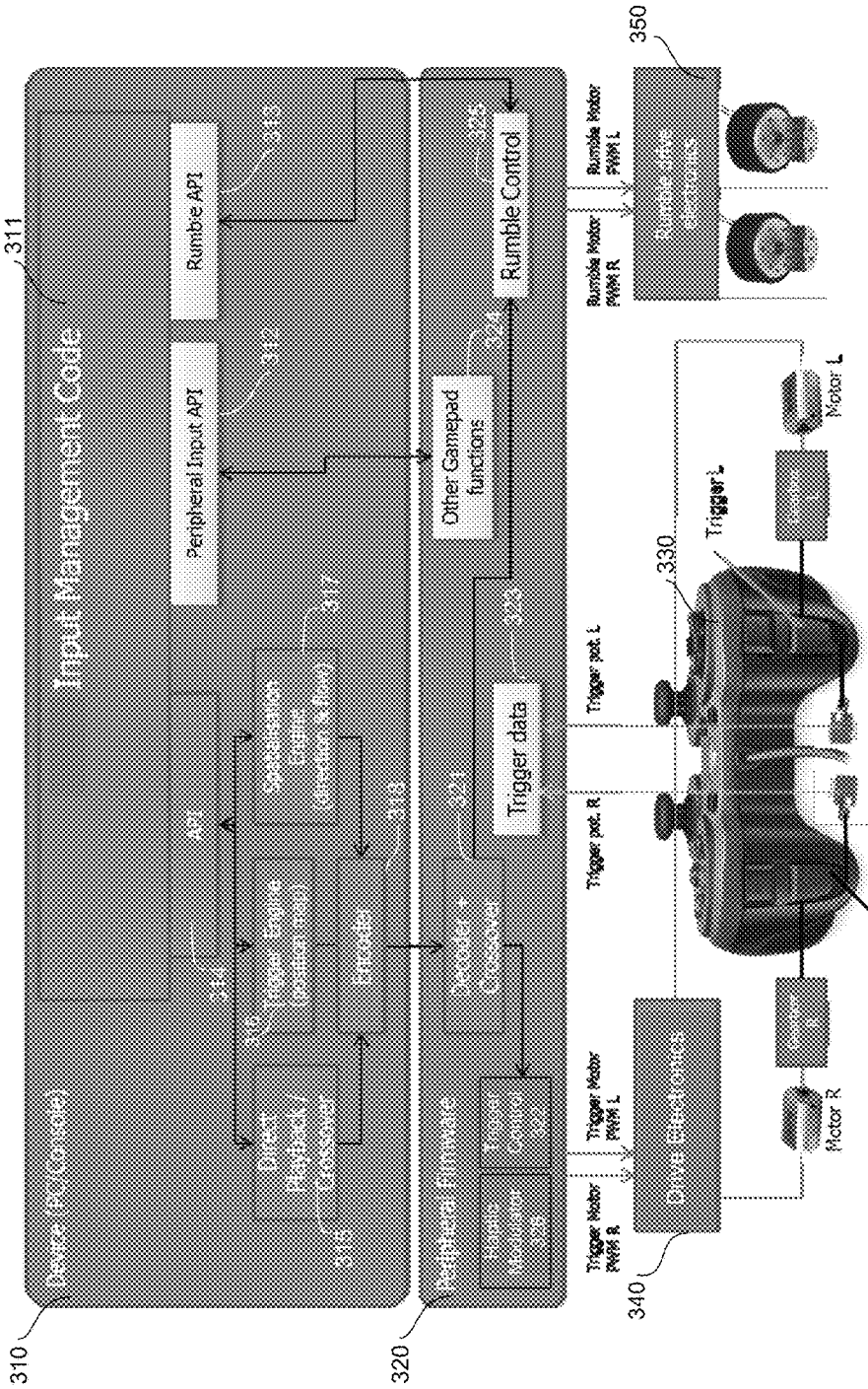

Input Management Code
Peripheral Input API
Rumble API
Other Gamepad functions
Rumble Control
Trigger data
Trigger pot. L
Trigger pot. R
Trigger Motor PWM L
Trigger Motor PWM R
Rumble Motor PWM L
Rumble Motor PWM R
Motor L
Motor R
Trigger L
Trigger R
310
311
320
330
340
350

Fig. 3
300

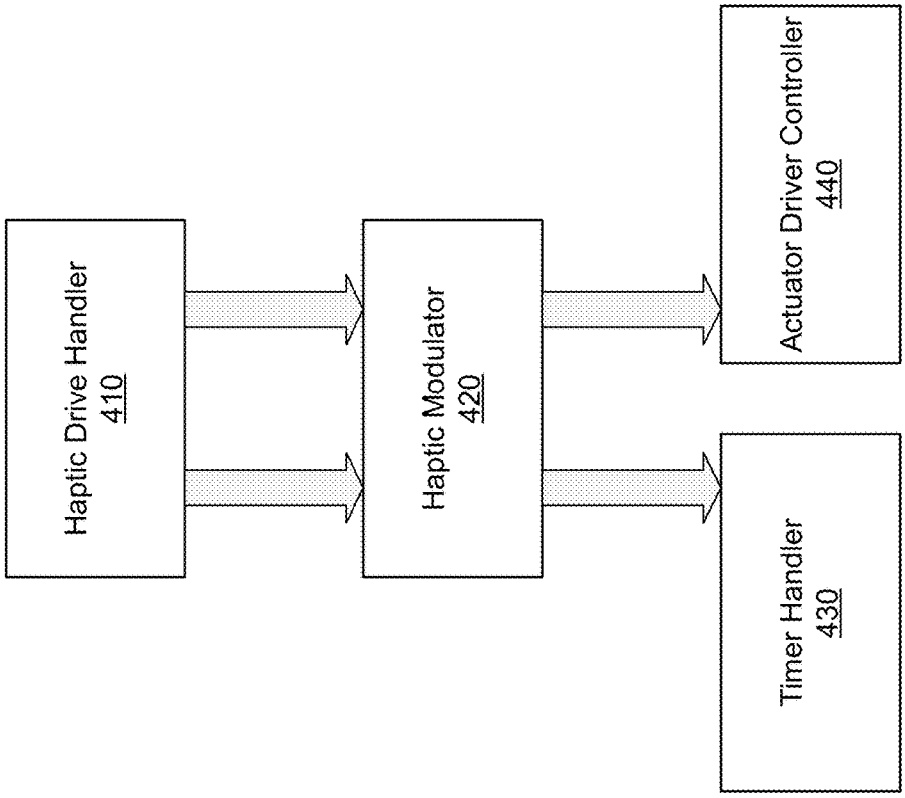

Haptic Drive Handler
410
Haptic Modulator
420
Actuator Driver Controller
440
Timer Handler
430

Fig. 4
400

Fig. 5
500

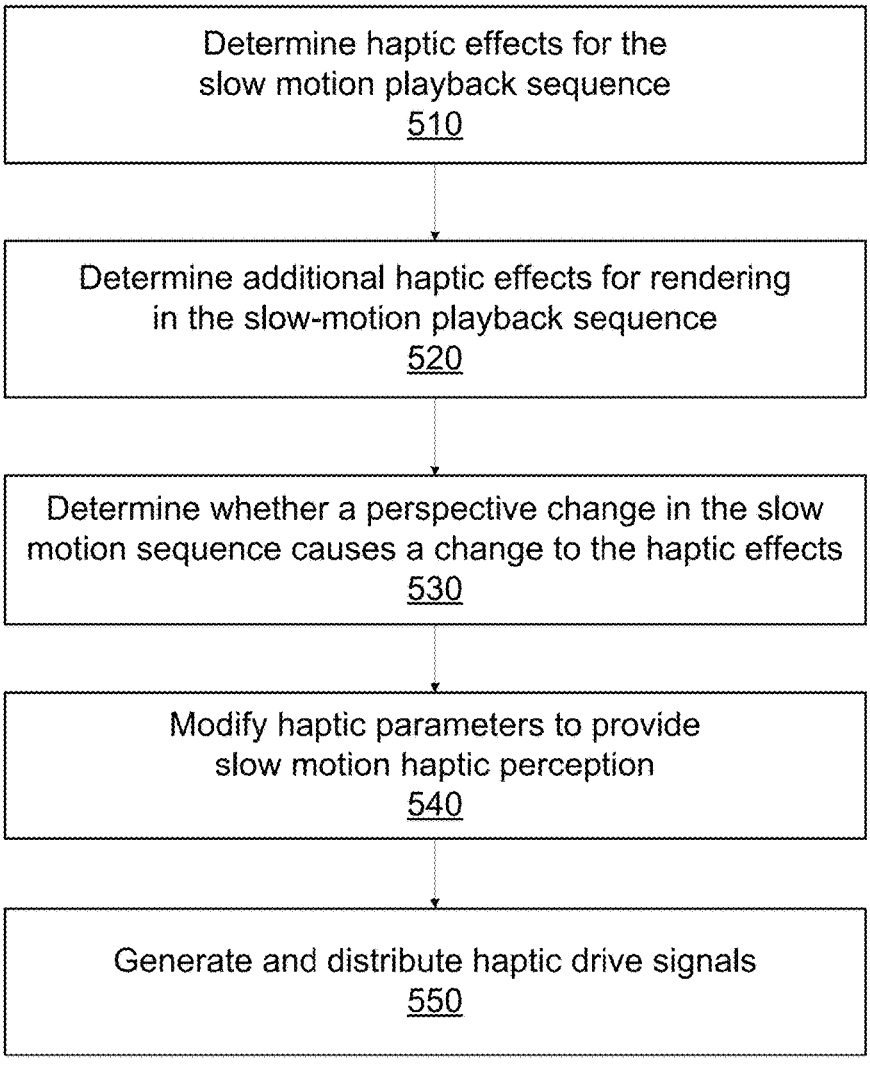
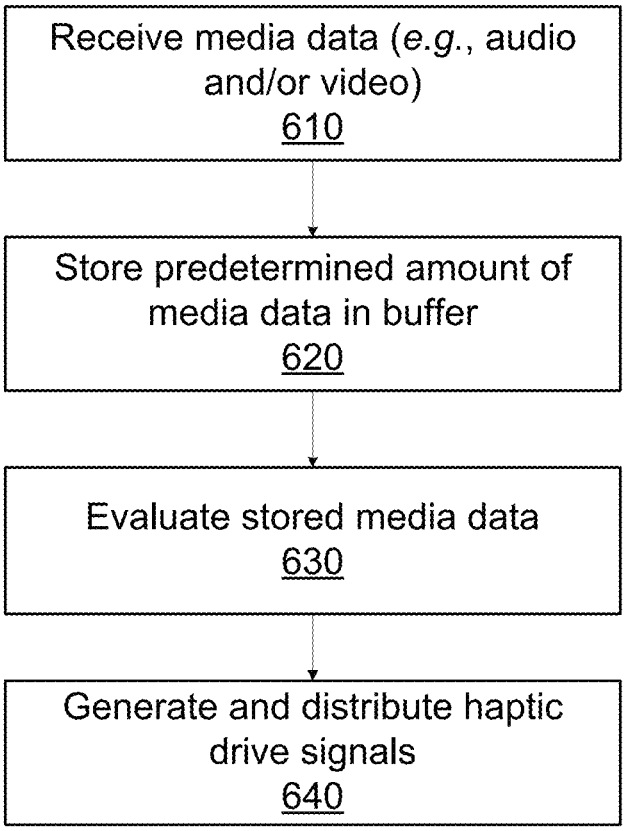

Determine haptic effects for the slow motion playback sequence
510
Determine additional haptic effects for rendering in the slow-motion playback sequence
520
Determine whether a perspective change in the slow motion sequence causes a change to the haptic effects
530
Modify haptic parameters to provide slow motion haptic perception
540
Generate and distribute haptic drive signals
550

Fig. 6
600


Receive media data (e.g., audio and/or video)
610
Store predetermined amount of media data in buffer
620
Evaluate stored media data
630
Generate and distribute haptic drive signals
640

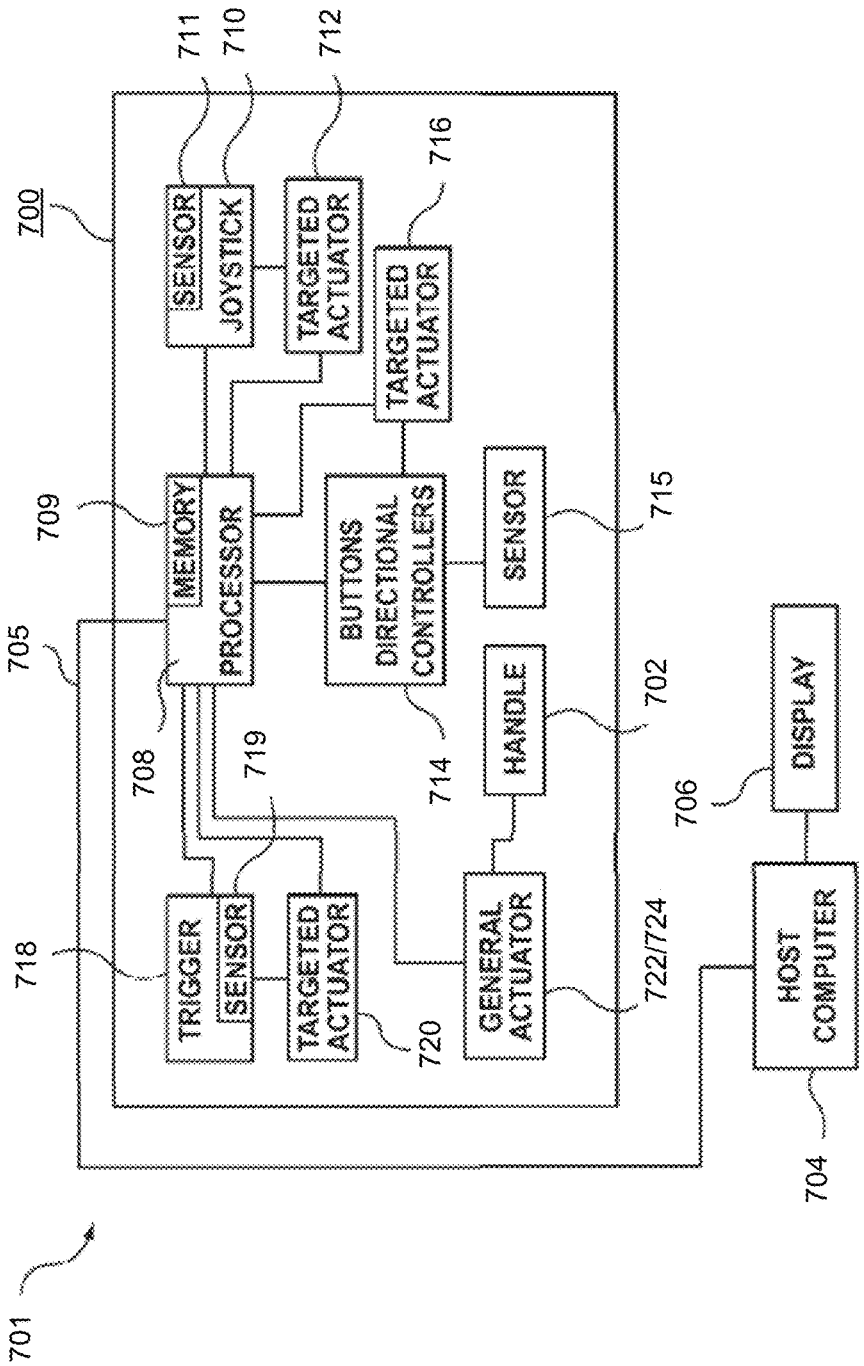

701
700
711
710
712
716
SENSOR
JOYSTICK
TARGETED ACTUATOR
TARGETED ACTUATOR
709
MEMORY
PROCESSOR
BUTTONS DIRECTIONAL CONTROLLERS
SENSOR
715
705
708
719
714
HANDLE
702
706
DISPLAY
718
TRIGGER SENSOR
TARGETED ACTUATOR
720
GENERAL ACTUATOR
722/724
HOST COMPUTER
704

Fig. 7

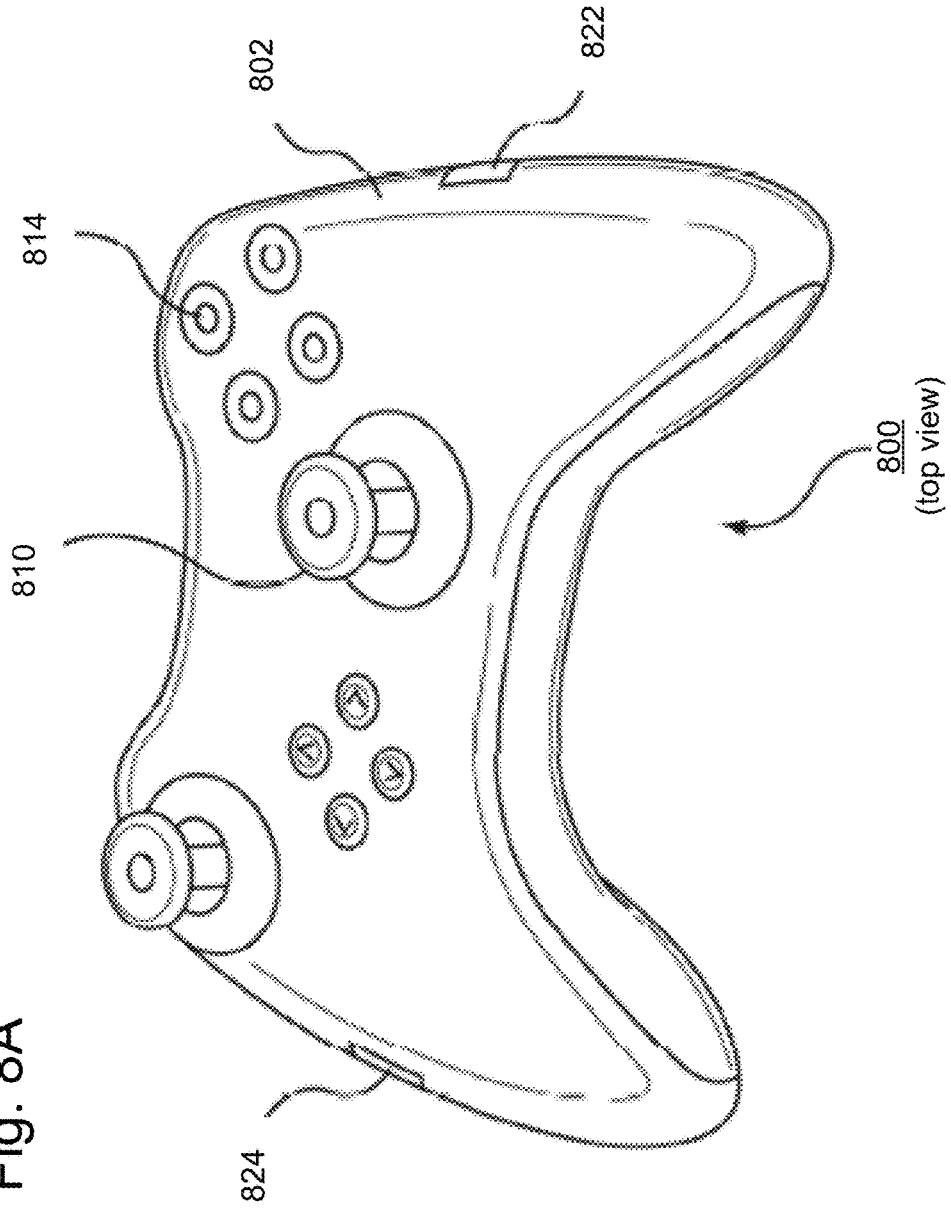


Fig. 8A

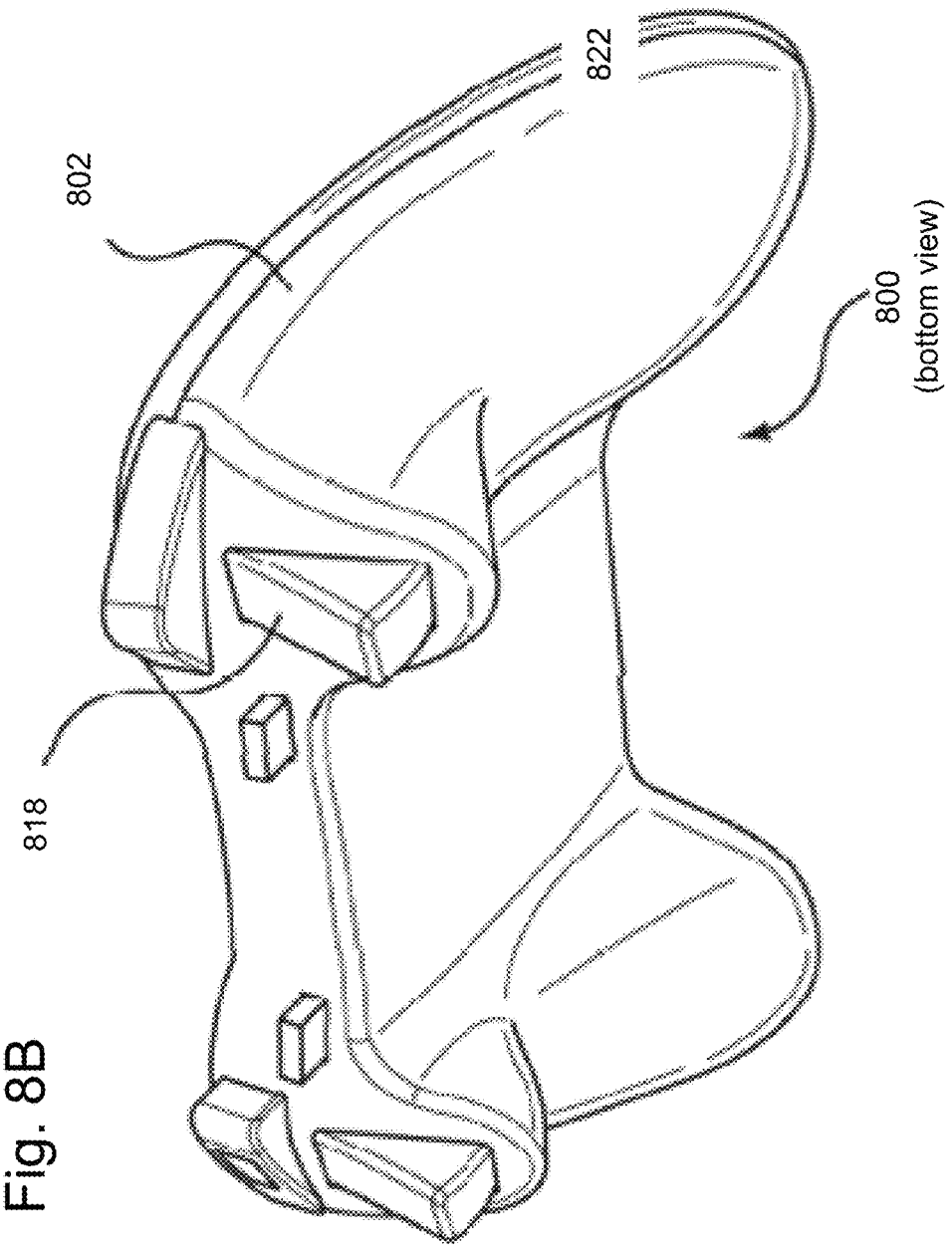


Fig. 8B

MODIFYING HAPTIC EFFECTS FOR SLOW MOTION

PRIORITY APPLICATION

This application claims the benefits of U.S. Provisional Patent Application No. 62/120,702, filed on Feb. 25, 2015, which is incorporated herein by reference in its entirety.

FIELD OF INVENTION

The embodiments of the present invention are generally directed to electronic devices, and more particularly, to electronic devices that produce haptic effects.

BACKGROUND

Video games and video game systems have become extremely popular. Video game devices or controllers typically use visual and auditory cues to provide feedback to a user. In some interface devices, kinesthetic feedback (e.g., active and resistive force feedback) and/or tactile feedback (e.g., vibration, texture, temperature variation, and the like) may be provided to the user. In general, such feedback is collectively known as "haptic feedback" or "haptic effects." Haptic feedback provides cues that enhance and simplify a user's interaction with a video game controller, or other electronic device. For example, haptic effects may provide cues to users of video game controllers or other electronic devices to alert the user to specific events, or provide realistic feedback to create greater sensory immersion within a simulated or virtual environment.

Other devices in which a user interacts with a user input element to cause an action also may benefit from haptic feedback or haptic effects. For example, such devices may include medical devices, automotive controls, remote controls, and other similar devices.

SUMMARY OF THE INVENTION

Embodiments of the present invention are directed toward electronic devices configured to produce haptic effects that substantially improve upon the related art.

Features and advantages of the embodiments are set forth in the description which follows, or will be apparent from the description, or may be learned by practice of the invention.

In one example, systems and methods for rendering haptic effects in slow motion are provided. A media stream (e.g., audio or video) and a haptic effect sequence that corresponds to the media stream are received. The haptic effect sequence includes a plurality of haptic effects. The media stream and the haptic effect sequence may be rendered in real-time. The media stream and a modified haptic effect sequence may also be rendered in slow motion. The modified haptic effect sequence includes a change to a parameter of at least one haptic effect of the haptic effect sequence.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not intended to limit the invention to the described examples.

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 system according to an example embodiment of the invention.

FIG. **2** is a simplified block diagram illustrating a system for modifying haptic effects according to an example embodiment of the present invention.

FIG. **3** illustrates a block diagram of a haptic effect software stack according to an example embodiment of the present invention.

FIG. **4** illustrates an architecture for haptic modification according to an example embodiment of the present invention.

FIG. **5** illustrates a flow diagram for modifying haptic effects according to an example embodiment of the present invention.

FIG. **6** illustrates a flow diagram for modifying haptic effects according to another example embodiment of the present invention.

FIG. **7** illustrates a functional block diagram of a controller suitable for use with the embodiments of the present invention.

FIGS. **8**A and **8**B illustrate different views of a controller suitable for use with the embodiments of the present invention.

DETAILED DESCRIPTION

Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings. In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one of ordinary skill in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components, and circuits have not been described in detail so as not to unnecessarily obscure aspects of the embodiments. Wherever possible, like reference numbers will be used for like elements.

Example embodiments are directed toward systems and methods for rendering modified haptic effects in slow motion. Although video may be accurately conveyed to a user in slow motion, the corresponding haptic effects are typically inaccurately rendered in slow motion. Accordingly, the various embodiments described herein render haptic effects in slow motion by modulating/modifying the various parameters associated with each haptic effect of a haptic effect sequence. For example, the magnitude, frequency, and/or duration of each haptic effect may be altered to accurately convey the haptic effect sequence in slow motion.

In the various embodiments, a variety of user interfaces and methods for using a device are described. In some embodiments, the device is a portable electronic device (e.g., a game controller, console, mobile phone, smartphone, tablet, etc.). It should be understood, however, that the user interfaces and associated methods may be applied to numerous other devices, such as personal computers, medical devices, laptops, and the like that may include one or more other physical user-interface devices, such as a keyboard, mouse, trackball and the like.

FIG. **1** illustrates a block diagram of a system **100** according to an example embodiment of the invention.

System **100** may include a communication device **110** configured to transmit and/or receive data from remote sources. Communication device **110** may enable connectivity between a processor **120** and other devices by encoding

data to be sent from processor **120** to another device over a network (not shown) and decoding data received from another system over the network for processor **120**.

For example, communication device **110** may include a network interface card that is configured to provide wireless network communications. A variety of wireless communication techniques may be used including infrared, radio, Bluetooth, Wi-Fi, and/or cellular communications. Alternatively, communication device **110** may be configured to provide wired network connection(s), such as an Ethernet connection.

Processor **120** may comprise one or more general or specific purpose processors to perform computation and control functions of system **100**. Processor **120** may include a single integrated circuit, such as a micro-processing device, or may include multiple integrated circuit devices and/or circuit boards working in cooperation to accomplish the functions of processor **120**. In addition, processor **120** may execute computer programs, such as an operating system **141**, a haptic modulator **142**, and other applications **143**, stored within memory **140**.

System **100** may include memory **140** for storing information and instructions for execution by processor **120**. Memory **140** may contain various components for retrieving, presenting, modifying, and storing data. For example, memory **140** may store software modules that provide functionality when executed by processor **120**. The modules may include operating system **141** that provides operating system functionality for system **100**. The modules may further include haptic modulator **142** that may control a variety of haptic parameters (e.g., magnitude, frequency, and/or duration) to modify haptic effects during replay at a varied playback rate, such as slow motion replay. In certain embodiments, haptic modulator **142** may include instructions for dynamically calculating the haptic parameters based on analysis of a media stream, such as audio and/or video streams. System **100** also may include one or more additional application modules **143** that include additional functionality, such as peripheral firmware configured to provide control functionality for a peripheral device, such as controller **150** (e.g., a gamepad, wearable device, etc.).

Non-transitory memory **140** may include a variety of computer-readable media that may be accessed by processor **120**. In the various embodiments, memory **140** may include volatile and nonvolatile medium, removable and non-removable medium. For example, memory **140** may include any combination of random access memory ("RAM"), dynamic RAM ("DRAM"), static RAM ("SRAM"), read only memory ("ROM"), flash memory, cache memory, and/or any other type of non-transitory computer-readable medium.

Although shown as a single system, the functionality of system **100** may be implemented as a distributed system. For example, memory **140** and processor **120** may be distributed across multiple different computers that collectively comprise system **100**. In one embodiment, system **100** may be part of a device (e.g., personal computer, console, video game console, etc.), and system **100** provides haptic effect functionality for the device. In another embodiment, system **100** may be separate from the device, and may remotely provide the aforementioned functionality for the device.

System **100** may be operably connected to controller **150**. Controller **150** may be a peripheral device configured to provide input to the system **100**. Controller **150** may be operably connected to system **100** using either a wireless connection or a wired connection. Controller **150** also may include a local processor configured to communicate with system **100** using either a wireless connection or a wired connection. Alternatively, controller **150** may be configured to not include a local processor, and all input signals and/or output signals associated with controller **150** may be processed by the components of system **100**. In embodiments in which controller **150** has a local processor, additional functionality, such as haptic modification modules and peripheral firmware configured to provide control functionality may reside within controller **150**.

Controller **150** may further include one or more digital buttons, one or more analog buttons, one or more bumpers, one or more directional pads, one or more analog or digital sticks, one or more driving wheels, and/or one or more user input elements that can be interacted with by a user, and that can provide input to system **100**. Controller **150** may also include one or more analog or digital trigger buttons (or "triggers") that can further be interacted with by the user, and that can further provide input to system **100**. As is described below in greater detail, controller **150** can further include a motor, or another type of actuator or haptic output device, configured to exert a bi-directional push/pull force on at least one trigger of controller **150**.

Controller **150** can also include one or more actuators, or other types of haptic output devices. The local processor of controller **150**, or processor **120** in embodiments where controller **150** does not include a local processor, may transmit a haptic signal associated with a haptic effect to at least one actuator of controller **150**. The actuator, in turn, outputs haptic effects such as vibrotactile haptic effects, kinesthetic haptic effects, or deformation haptic effects, in response to the haptic signal. The haptic effects can be experienced at a user input element (e.g., a trigger, digital button, analog button, bumper, directional pad, analog or digital stick, driving wheel, or trigger) of controller **150**. Alternatively, the haptic effects can be experienced at an outer surface of controller **150**.

An actuator is an example of a haptic output device, where a haptic output device is a device configured to output haptic effects, such as vibrotactile haptic effects, electrostatic friction haptic effects, temperature variation, and/or deformation haptic effects, in response to a drive signal. In alternate embodiments, the one or more actuators within controller **150** can be replaced by some other type of haptic output device. The haptic output device 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 harmonic ERM motor ("HERM"), 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 some instances, the haptic output device may include haptic output drive circuit. In some embodiments, the haptic output device may be unidirectional or bidirectional.

Controller **150** may further include one or more speakers. The local processor of controller **150**, or processor **120** in embodiments where controller **150** does not include a local processor, may transmit an audio signal to at least one speaker of controller **150**, which in turn outputs audio effects. The speaker may be, for example, a dynamic loudspeaker, an electrodynamic loudspeaker, a piezoelectric loudspeaker, a magnetostrictive loudspeaker, an electrostatic loudspeaker, a ribbon and planar magnetic loudspeaker, a bending wave loudspeaker, a flat panel loudspeaker, a heil air motion transducer, a plasma arc speaker, and a digital loudspeaker.

Controller **150** can further include one or more sensors. A sensor may be configured to detect a form of energy, or other physical property, such as, but not limited to, sound, movement, 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. The sensor may further be configured to convert the detected energy, or other physical property, into an electrical signal, or any signal that represents virtual sensor information, and controller **150** can send the converted signal to the local processor of controller **150**, or processor **120** in embodiments where controller **150** does not include a local processor.

FIG. **2** is a simplified block diagram illustrating a system **200** for modifying haptic effects according to an example embodiment of the present invention.

As shown in FIG. **2**, a central processing unit ("CPU") **230** may execute various programs, such as an application **210**. Application **210** generates media streams including audio and/or video streams, such as media stream **211**. In addition, application **210** generates haptic instructions, such as haptic instructions **215**. CPU **230** may modify haptic instructions **215** based on a variety of parameters that are determined by analyzing media stream **211**. For example, CPU **230** may alter the haptic instructions **215** based on a change in camera angle, or a change in replay speed. CPU **230** may further determine and/or adjust the execution times of the haptic instructions.

Media stream **211** and haptic instructions **215** may be stored in a memory **220**. Memory **220** also stores data structures **225**.1-**225**.N, each of the data structures defining characteristics associated with respective haptic output devices. CPU **230** may execute haptic instructions or determine changes to haptic instructions according to data structures **225**.1-**225**.N. For example, data structures **225**.1-**225**.N may store one or more values relating to minimum drive frequency, maximum drive frequency, minimum strength, maximum strength, startup current, steady state current, and the like that may be used by CPU **230** when modifying haptic effects for each haptic output device.

Modified haptic effects may be generated in a variety of ways. For example, a slow motion haptic effect may increase the duration of the haptic effect to match the slowing of the visual component. In another example, a constant haptic effect may become a periodic effect, or alternatively, the periodic haptic effect may become the constant haptic effect. In yet another example, the magnitude of the slow motion haptic effect may increase or decrease in strength, or may gradually fade out or ramp up. In an example of frequency shifting, if the real-time haptic effect is 10 ms on and 10 ms off, the corresponding slow motion haptic effect may be modified to 16 ms on and 16 ms off, or alternatively changed from 20 ms on/off and gradually decreased to 5 ms on/off. In the various frequency shifting embodiments, one or more filters may be configured to modify the haptic effects within a particular frequency range.

Although the embodiments described herein may be used in numerous applications, some non-limiting examples will now be described to better illustrate the embodiments. Within a gaming application, a game player is a first person shooter and dies from an explosion. In this explosion, haptic effects are played on one of or both of the triggers and/or the rumble actuators of controller **150**. After the game player's death, a slow motion video of the action (e.g., from a third person perspective) may be played. Here, the haptic effects may be changed from what was previously felt, to a weaker and more elongated version. Upon slow motion replay, the haptic effects may be altered to take camera angle and/or replay speed into consideration, which may optionally include dynamic haptic effects. In addition, the various embodiments may be applied to a variety of haptic effects, such as an "effect within effect," which provides an ability to play two or more simultaneous effects due to the slower playback rate (such as playing an effect between elongated gaps in a complex texture), whereas in real-time a priority system may prevent multiple effects from playing.

Thus, the embodiments may be configured to render slow motion haptic effects based on an initial haptic effect. In the various configurations, the haptic effect parameters may be dynamically changed, or selected from a set of predetermined slow motion haptic effects.

FIG. **3** illustrates a block diagram of a haptic effect software stack **300** according to an example embodiment of the present invention. As shown in FIG. **3**, software stack **300** includes device modules **310**, peripheral firmware modules **320**, controller modules **330**, drive modules **340**, and rumble drive modules **350**. Haptic effect software stack **300** is implemented on a system, such as system **100** of FIG. **1**.

Device modules **310** may include a variety of modules such as input management code **311**, peripheral input application programming interface ("API") **312**, rumble API **313**, haptic effect API **314**, direct playback/crossover **315**, trigger engine **316**, spatialization engine **317**, and encoder **318**.

Input management code **311** may include a set of computer-readable instructions that manage input provided by controller **330** in the context of a game application, or other type of application, executed within a device.

Peripheral input API **312** may include a set of computer-readable functions or routines that enable game input management code **311** to interact with peripheral firmware **320** in order to receive and manage input provided by controller **330**.

Rumble API **313** may include a set of computer-readable functions or routines that enable input management code **311** to interact with peripheral firmware **320** in order to transmit rumble instructions to one or more rumble motors or rumble actuators of controller **330** (e.g., rumble motors L and R of FIG. **3**). In addition, a rumble instruction may cause a rumble motor or rumble actuator of controller **330** to produce a general or rumble haptic effect.

Haptic effect API **314** (identified in FIG. **3** as "API") may include a set of computer-readable functions or routines that are accessible to input management code **311**, and that enable input management code **311** to interact with peripheral firmware **320** in order to transmit haptic instructions to controller **330**. In addition, a haptic instruction may cause one or more targeted motors or targeted actuators of controller **330** to produce a haptic effect at one or more user input elements of controller **330**.

Haptic effect API **314** also may store one or more haptic effect definitions. A haptic effect definition is a data structure that includes haptic data, such as a haptic signal, that is pre-defined and that can be stored within a storage, such as a haptic file or haptic stream, and that can be sent to one or more rumble motors, rumble actuators, targeted motors, or targeted actuators, to produce a haptic effect at a component, or user input element, of controller **330**. The haptic data can include one or more attributes of the corresponding haptic effect, where the attributes can be stored as parameters. Example parameters of a haptic effect definition may include an amplitude parameter, a frequency parameter, a waveform parameter, an envelope parameter, a magnitude (or strength) parameter, and a duration parameter.

Haptic effect API **314** may enable game input management code **311** to interact with direct playback/crossover **315**, trigger engine **316**, and spatialization engine **317**, and may further manage direct playback/crossover **315**, trigger engine **316**, and spatialization engine **317** according to requests invoked by game input management code **311**. Further, haptic effect API **314** may store data used for communication with peripheral firmware **320**, and used for generation of one or more haptic effects.

Direct playback/crossover **315** may receive haptic data as input, produce haptic data as output, and transmit haptic data to one or more targeted motors, or targeted actuators, of controller **330** (e.g., motors L and R of FIG. **3**). In some embodiments, direct playback/crossover **315** may output the input haptic data directly, without modifying a format of the input haptic data. This results in an "as-is" playback of the input haptic data. In other embodiments, direct playback/crossover **315** may convert the haptic data that is input from a first format to a second format, and can further output the converted haptic data. Depending on the type of playback, direct playback/crossover **315** may optionally use a programmable crossover to convert the haptic data. By converting the haptic data, device modules may deconstruct the haptic effect and playback the haptic effect at multiple actuators.

The format of the haptic data may be a haptic elementary stream ("HES") format. A HES format is a file or data format for representing haptic data that may be streamed to a device. The haptic data can be represented in a manner that is identical or similar to how uncompressed sound is represented, although the haptic data can be encrypted within the HES format.

Trigger engine **316** may receive haptic data, such as a haptic effect definition, and may modify the haptic data based on user input data, such as trigger data **323**. Trigger data is data that includes one or more parameters that indicate a position and/or range of one or more triggers of controller **330** (e.g., triggers L and R of FIG. **3**). Trigger engine **316** may further transmit haptic instructions to controller **330**. For example, trigger engine **316** may transmit haptic instructions to a variety of user-input elements of controller **330**. As previously described, a haptic instruction may cause one or more targeted motors or targeted actuators of controller **330** to produce a haptic effect at one or more user-input elements of controller **330**.

Spatialization engine **317** may receive haptic data and may modify the haptic data based on spatialization data. Spatialization data may include data that indicates a desired direction and/or flow of a haptic effect, such as an ordering of haptic effects on respective user input elements. In certain embodiments, spatialization engine **317** may receive spatialization data that includes a direction and/or flow from input management code **311**.

Spatialization engine **317** may modify the haptic data so that a haptic effect, such as a trigger haptic effect, is scaled for one or more rumble motors, or rumble actuators, of controller **330** (e.g., rumble motors L and R of FIG. **3**), and that the haptic effect is also scaled for one or more targeted motors, or targeted actuators, of controller **330** (e.g., motors L and R, as illustrated in FIG. **3**). In other words, spatialization engine **317** may modify the haptic data that is sent to each motor or actuator, and thus, modify the haptic effect that is experienced at each motor or actuator, in order to convey a sense of direction and flow of an overall haptic effect. For example, in order to emphasize a haptic effect experienced at a motor or actuator, spatialization engine **317** may scale one or more portions of the haptic effect. For example, spatialization engine **317** may scale haptic data that is sent to the motor or actuator that causes the haptic effect to be experienced, causing the haptic effect to be more pronounced (e.g., increased magnitude, duration, etc.). Additionally, spatialization engine **317** may scale haptic data that is sent to other motors or actuators, causing other haptic effects that are experienced at those motors or actuators to be less pronounced (e.g., decreased magnitude, duration, etc.). In some embodiments, spatialization engine **317** may modify the haptic data in real-time or substantially in real-time. Further, in some embodiments, spatialization engine **317** may have non-linear relationships between inputs and motor, or actuator, outputs in order to exaggerate an overall haptic effect.

Encoder **318** encodes haptic data received from direct playback/crossover **315**, trigger engine **316**, and/or spatialization engine **317** into a format. In one embodiment, the format may be an HES format. Encoder **318** may transmit the encoded haptic data to peripheral firmware **320**.

Peripheral firmware **320** is firmware for one or more peripheral devices (e.g., controllers). Peripheral firmware **320** may include a variety of modules such as decoder and crossover **321**, trigger control **322**, trigger data **323**, other functions **324**, and rumble control **325**.

Decoder and crossover **321** may receive the encoded haptic data from encoder **318** and decodes the encoded haptic data. In some embodiments, decoder and crossover **321** computes a programmable crossover in order to decode the encoded haptic data. Decoder and crossover **321** may compute the programmable crossover in real-time.

Trigger control **322** is a low-level control API for one or more targeted motors or targeted actuators of controller **330** (e.g., motors L and R of FIG. **3**). Trigger control **322** may receive a trigger instruction and may convert the trigger instruction into a low-level trigger instruction for a specified targeted motor or targeted actuator of controller **330**, and may transmit the low-level trigger instruction to the specified targeted motor or targeted actuator of controller **330**. The low-level trigger instruction may cause the specified targeted motor or targeted actuator to produce a trigger haptic effect at a specified trigger of controller **330**.

Trigger data **323**, as previously described, is data that includes one or more parameters that indicate a position and/or range of one or more triggers of controller **330** (e.g., triggers L and R of FIG. **3**). Trigger data **323** may be received from controller **330** by peripheral firmware **320**. Peripheral firmware **320** may further store trigger data **323**, and may further transmit trigger data **323** to device modules **310**.

Other gamepad functions **324** may be functions of controller **330** managed by peripheral firmware **320**. Such functions may include such functions as wired/wireless communications, input reporting, protocol implementation, power management, etc.

Rumble control **325** is a low-level control API for one or more rumble motors or rumble actuators of controller **330** (e.g., rumble motors L and R of FIG. **3**). Rumble control **325** may receive a rumble instruction, may convert the rumble instruction into a low-level rumble instruction for a specified rumble motor or rumble actuator of controller **330**, and may transmit the low-level trigger instruction to the specified rumble motor or rumble actuator of controller **330**.

Haptic modification module **326** may be a firmware module or standalone hardware chip (e.g., application specific integrated circuit, also referred to as "ASIC") that may modify the haptic effects of the haptic output devices of controller **330**. Haptic modification module **326** may be

configured to control a variety of haptic parameters (e.g., magnitude, frequency, duration) to modify haptic effects during replay at a varied playback rate, such as slow motion replay. In certain embodiments, modification module **326** may include instructions for dynamically calculating the haptic parameters based on analysis of a media signal, such as audio and/or video. Haptic modification module **326** and haptic modulator **142** of FIG. **1** may be the same modules.

Controller **330** may include triggers L and R. Controller **330** may further include gear boxes L and R and motors L and R. Motor L and gearbox L are operably coupled to trigger L within controller **330**. Likewise, motor R and gearbox R are operably coupled to trigger R within controller **330**. When motor L receives a trigger instruction, motor L and gearbox L may collectively cause a trigger haptic effect to be experienced at trigger L. Likewise, when motor R receives a trigger instruction, motor R and gearbox R may collectively cause a trigger haptic effect to be experienced at trigger R. Peripheral firmware **320** may send trigger instructions to motors L and R of controller **330** using drive electronics **340**.

Controller **330** may further include potentiometers L and R. Potentiometer L may detect a position and/or range of trigger L, and may further send the detected position and/or range of trigger L to peripheral firmware **320** as trigger data. Likewise, potentiometer R may detect a position and/or range of trigger R, and may further send the detected position and/or range of trigger R to peripheral firmware **320** as trigger data.

Controller **330** may further include rumble motors L and R. When rumble motor L receives a rumble instruction, rumble motor L causes a haptic effect to be experienced along a left component of controller **330**. Likewise, when rumble motor R receives a rumble instruction, rumble motor R causes a haptic effect to be experienced along a right component of controller **330**. Peripheral firmware **320** may send rumble instructions to rumble motors L and R using rumble drive electronics **350**.

FIG. **4** illustrates a haptic modification architecture according to an example embodiment of the present invention.

A haptic drive handler **410** may be configured with a timer handler **430** to track the timing and state of each haptic output device. Disposed between haptic drive handler **410** and timer handler **430**, a haptic modulator **420** may be configured to modify haptic effects that are distributed among the haptic output devices. In addition, haptic modulator **420** may be configured to control a variety of haptic parameters (e.g., magnitude, frequency, duration) to modify haptic effects during replay at a varied playback rate, such as slow motion replay. In certain embodiments, haptic modulator **420** may include instructions for dynamically calculating the haptic parameters based on analysis of a media signal, such as audio and/or video.

FIG. **5** illustrates a flow diagram of functionality **500** for modifying haptic effects according to an example embodiment of the present invention. In some instances, the functionality of the flow diagram of FIG. **5** is implemented by software stored in memory or other computer readable or tangible media, and executed by a processor. In other instances, 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.

At the outset, functionality **500** determines one or more haptic effects to include in a modified playback sequence, such as a slow motion sequence. For example, the haptic effects may include a subset or the entire set of haptic effects. Next, at **520**, functionality **500** determines whether additional haptic effects that were not rendered during the real-time sequence should be rendered in the slow motion playback sequence.

At **530**, functionality **500** determines whether the media steam, especially a video steam, includes a perspective change. For example, the detected perspective change in the slow motion playback sequence may cause a translation in the display locations of the haptic effects. Next, at **540**, functionality **500** may modify one or more haptic parameters, such as duration, magnitude, frequency, and other haptic parameters, such that the user's haptic perception of the event is equivalent to that which was triggered in the original (regular speed).

Lastly, at **550**, the haptic drive signals may be generated and distributed among the haptic output devices. Haptic drive signal may be generated by a software application, such as a gaming application. In some instances, functionality **500** may further distribute the operational characteristics associated with each of the haptic output devices. Here, one or more data structures may store the operational characteristics for respective haptic output devices.

FIG. **6** illustrates a flow diagram of functionality **600** for modifying haptic effects according to an example embodiment of the present invention.

At the outset, functionality **600** receives media data, such as an audio or video stream, at **610**. The media stream is received from an application program or other software layer or program running on the host device. Next, at **620**, a predetermined amount of the received media data is stored. For example, a predetermined number of media segments may be stored to enable quick processing and the determination of haptic effects.

Subsequently, at **630**, the stored media data is evaluated to identify particular media characteristics or features which as relevant in the determination of which haptic effects are to be output. For example, the embodiments may use intelligent heuristics to extract media features (e.g., change in video brightness or contrast, or change in sound volume, etc.) that are likely to have meaning in an application program and to associate such media features with changes to the haptic effects that correspond appropriately with the extracted media features and the likely events these features represent. In another example, the embodiments may use intelligent heuristics to distinguish between gradual haptic effects that are modified in slow motion (e.g., car skidding or rolling down a hill) and discrete haptic effects that are not modified (e.g., gunshot). In some instances, a duration threshold (e.g., 250 ms) may be used to distinguish between gradual and discrete haptic effects. Haptics may be applied to a variety of events, and likely events in many current video game applications may be explosions from bombs, grenades, missiles, etc., the firing of a weapon such as a gun or rocket, the crash of a vehicle, the patter of footsteps, the sound of an object splashing into water, an alert sound for alerting the player to some game event, etc. These events may have particular audio and video features which can be recognized from the received media data after appropriate analysis.

Lastly, at **640**, the haptic drive signals may be generated and distributed among the haptic output devices.

FIG. **7** illustrates a functional block diagram of a controller **700** suitable for use with the embodiments of the present invention.

As illustrated in FIG. **7**, controller **700** may include one or more of a variety of user input elements. A user input element may refer to any interface device manipulated by the user to interact with host computer **704**. Example user input elements include analog or digital joy stick **710**, button **714**, trigger **718**, and the like. As understood by one of ordinary skill in the art, one or more of each user input element may be included on controller **700**. For example, the present description of trigger **718** does not limit controller **700** to a single trigger. Similarly, those skilled in the art understand that multiple analog or digital sticks, buttons, and other user input elements may be used.

Controller **700** may include local processor **708**. Local processor **708** may exchange commands and data with host computer **704** via connection **705**. Connection **705** may be a wired or wireless connection using one or more communication protocols known to those skilled in the art. In some instances, controller **700** may be alternatively configured to not include local processor **708**. Here, input/output signals from controller **700** may be handled and processed directly by host computer **704**. Host computer **704** may be a gaming device console and display device **706** may be screen which is operably coupled to the gaming device console. In some instances, host computer **704** and display device **706** may be combined into a single device.

Controller **700** may include targeted actuators **712**, **716**, **720** (e.g., motors) to directly drive each of the user input elements thereof as well as one or more general or rumble actuators **722**, **724** operably coupled to housing **902** in a location where a hand of the user is generally located. More particularly, analog or digital stick **710** includes a targeted actuator or motor **712** operably coupled thereto, button **714** includes a targeted actuator or motor **716** operably coupled thereto, and trigger **718** includes a targeted actuator or motor **720** operably coupled thereto. In addition to a plurality of targeted actuators, controller **700** includes a position sensor operably coupled to each of the user input elements thereof. More particularly, analog or digital stick **710** includes a position sensor **711** operably coupled thereto, button **714** includes a position sensor **715** operably coupled thereto, and trigger **718** includes a position sensor **719** operably coupled thereto. Local processor **708** is operably coupled to targeted actuators **712**, **716**, **720** as well as position sensors **711**, **715**, **719** of analog or digital stick **710**, button **714**, and trigger **718**, respectively. In response to signals received from position sensors **711**, **715**, **719**, local processor **708** instructs targeted actuators **712**, **716**, **720** to provide directed or targeted kinesthetic effects directly to analog or digital stick **710**, button **714**, and trigger **718**, respectively. Such targeted kinesthetic effects are discernible or distinguishable from general or rumble haptic effects produced by general actuators **722**, **724** along the entire body of the controller. The collective haptic effects provide the user with a greater sense of immersion to the game as multiple modalities are being simultaneously engaged (e.g., video, audio, and haptics).

FIGS. **8**A and **8**B illustrate different views of a controller **800** suitable for use with the embodiments of the present invention. As shown in FIG. **8**A and FIG. **8**B, controller **800** may include a variety of components such as housing **802**, analog or digital joy stick **810**, button(s) **814**, trigger **818**, and rumble actuators **822** and **824**.

Housing **802** is shaped to easily accommodate user gripping of controller **1000**. Controller **800** is an example embodiment of a controller, and the embodiments of the invention may be readily applied to other controller shapes.

Accordingly, the embodiments described herein provide systems and methods for generating and modifying a haptic effect. Haptic effects are rendered in slow motion by modifying the various parameters associated with each haptic effect of a haptic effect sequence. For example, the magnitude, frequency, and/or duration of each haptic effect may be altered to accurately convey the haptic effect sequence in slow motion.

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 method for rendering haptic effects in slow motion, the method comprising:

receiving a media stream and a haptic effect sequence that corresponds to a real-time rendering of the media stream, the haptic effect sequence including a plurality of haptic effects;

analyzing the media stream to extract one or more features of the media steam used to calculate a parameter of at least one haptic effect of the haptic effect sequence;

determining a modified haptic effect sequence that corresponds to a slow motion rendering of the media stream; and

rendering the media stream and the modified haptic effect sequence in slow motion,

wherein the modified haptic effect sequence includes a change to the parameter according to a replay speed, the modified haptic effect sequence including at least one haptic effect that is elongated or weakened, and the modified haptic effect sequence including additional haptic effects that are not included in the haptic effect sequence.

2. The method according to claim **1**, wherein the modified haptic effect sequence is determined according to a characteristic of the media stream.

3. The method according to claim **1**, wherein the parameter includes one of magnitude, frequency, or duration of the haptic effect.

4. The method according to claim **1**, wherein the modified haptic effect sequence includes a first subset of haptic effects having a modified duration and a second subset of haptic effects having a duration that is not modified.

5. The method according to claim **1**, wherein the modified haptic effect sequence is produced at one or more user input elements of a peripheral device.

6. The method according to claim **1**, wherein the modified haptic effect sequence is produced at one or more trigger or rumble output devices.

7. The method according to claim **1**, wherein the media stream and the haptic effect sequence are rendered in real-time prior to rendering the media stream and a modified haptic effect sequence in slow motion.

8. A non-transitory computer readable storage medium storing one or more programs configured to be executed by a processor, the one or more programs comprising instructions for:

receiving a media stream and a haptic effect sequence that corresponds to a real-time rendering of the media stream, the haptic effect sequence including a plurality of haptic effects;

analyzing the media stream to extract one or more features of the media steam used to calculate a parameter of at least one haptic effect of the haptic effect sequence;

determining a modified haptic effect sequence that corresponds to a slow motion rendering of the media stream; and

rendering the media stream and the modified haptic effect sequence in slow motion,

wherein the modified haptic effect sequence includes a change to the parameter according to a replay speed, the modified haptic effect sequence including at least one haptic effect that is elongated or weakened, and the modified haptic effect sequence including additional haptic effects that are not included in the haptic effect sequence.

9. The non-transitory computer readable storage medium according to claim **8**, wherein the modified haptic effect sequence is determined according to a characteristic of the media stream.

10. The non-transitory computer readable storage medium according to claim **8**, wherein the parameter includes one of magnitude, frequency, or duration of the haptic effect.

11. The non-transitory computer readable storage medium according to claim **8**, wherein the modified haptic effect sequence includes a first subset of haptic effects having a modified duration and a second subset of haptic effects having a duration that is not modified.

12. The non-transitory computer readable storage medium according to claim **8**, wherein the modified haptic effect sequence is produced at one or more user input elements of a peripheral device.

13. The non-transitory computer readable storage medium according to claim **8**, wherein the modified haptic effect sequence is produced at one or more trigger or rumble output devices.

14. The non-transitory computer readable storage medium according to claim **8**, wherein the media stream and the haptic effect sequence are rendered in real-time prior to rendering the media stream and a modified haptic effect sequence in slow motion.

15. A device comprising:

a processor; and

a memory storing one or more programs for execution by the processor, the one or more programs including instructions for:

receiving a media stream and a haptic effect sequence that corresponds to a real-time rendering of the media stream, the haptic effect sequence including a plurality of haptic effects;

analyzing the media stream to extract one or more features of the media steam used to calculate a parameter of at least one haptic effect of the haptic effect sequence;

determining a modified haptic effect sequence that corresponds to a slow motion rendering of the media stream; and

rendering the media stream and the modified haptic effect sequence in slow motion,

wherein the modified haptic effect sequence includes a change to the parameter according to a replay speed, the modified haptic effect sequence including at least one haptic effect that is elongated or weakened, and the modified haptic effect sequence including additional haptic effects that are not included in the haptic effect sequence.

16. The device according to claim **15**, wherein the modified haptic effect sequence is determined according to a characteristic of the media stream.

17. The device according to claim **15**, wherein the parameter includes one of magnitude, frequency, or duration of the haptic effect.

18. The device according to claim **15**, wherein the modified haptic effect sequence includes a first subset of haptic effects having a modified duration and a second subset of haptic effects having a duration that is not modified.

19. The device according to claim **15**, wherein the modified haptic effect sequence is produced at one or more user input elements of a peripheral device.

20. The device according to claim **15**, wherein the modified haptic effect sequence is produced at one or more trigger or rumble output devices.

21. The device according to claim **15**, wherein the media stream and the haptic effect sequence are rendered in real-time prior to rendering the media stream and a modified haptic effect sequence in slow motion.

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