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(54) **HANDHELD COMPUTER INTERFACE WITH HAPTIC FEEDBACK**

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(51) **Int. Cl.**

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G08B 6/00	(2006.01)
A63F 9/24	(2006.01)
A63F 7/20	(2006.01)
G01D 13/22	(2006.01)
G09G 5/00	(2006.01)
G06F 3/033	(2013.01)
G06F 3/01	(2006.01)

(52) **U.S. Cl.**
USPC **340/407.1**; 340/407.2; 463/2; 463/37; 463/38; 273/317.1; 116/205; 345/156; 345/184; 715/701; 715/702

(58) **Field of Classification Search**
USPC 340/407.1, 407.2; 345/156, 173–179; 715/700–702
See application file for complete search history.

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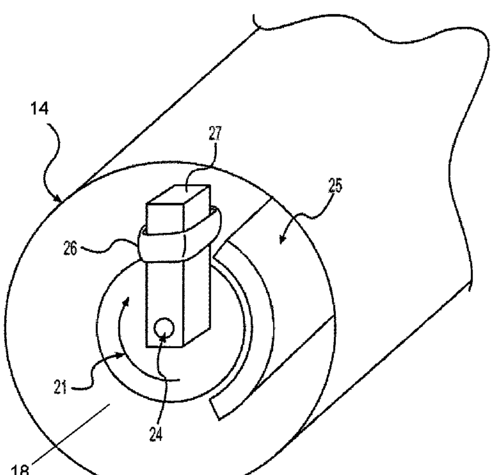
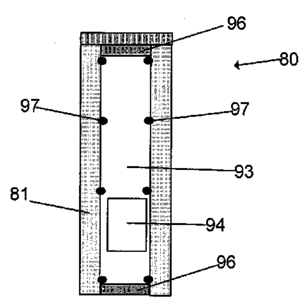
(57) **ABSTRACT**

Various systems, devices, and methods are provided for generating an impact and/or surface haptic effect for a handheld computer interface such as a video game controller. For example, the handheld computer interface may include a handle coupled to an impact actuator. The impact actuator includes a movable mass and an end stop. The impact actuator may receive a haptic effect signal and in response cause the mass to contact the end stop to generate a haptic effect. A smart material that outputs a surface haptic effect may be coupled to a surface of the handle such that the surface haptic effect is output substantially from the smart material rather than the handle. The handle may be coupled to an end piece having a shape that simulates an object such as a tennis racket, golf club, or other object.

13 Claims, 8 Drawing Sheets





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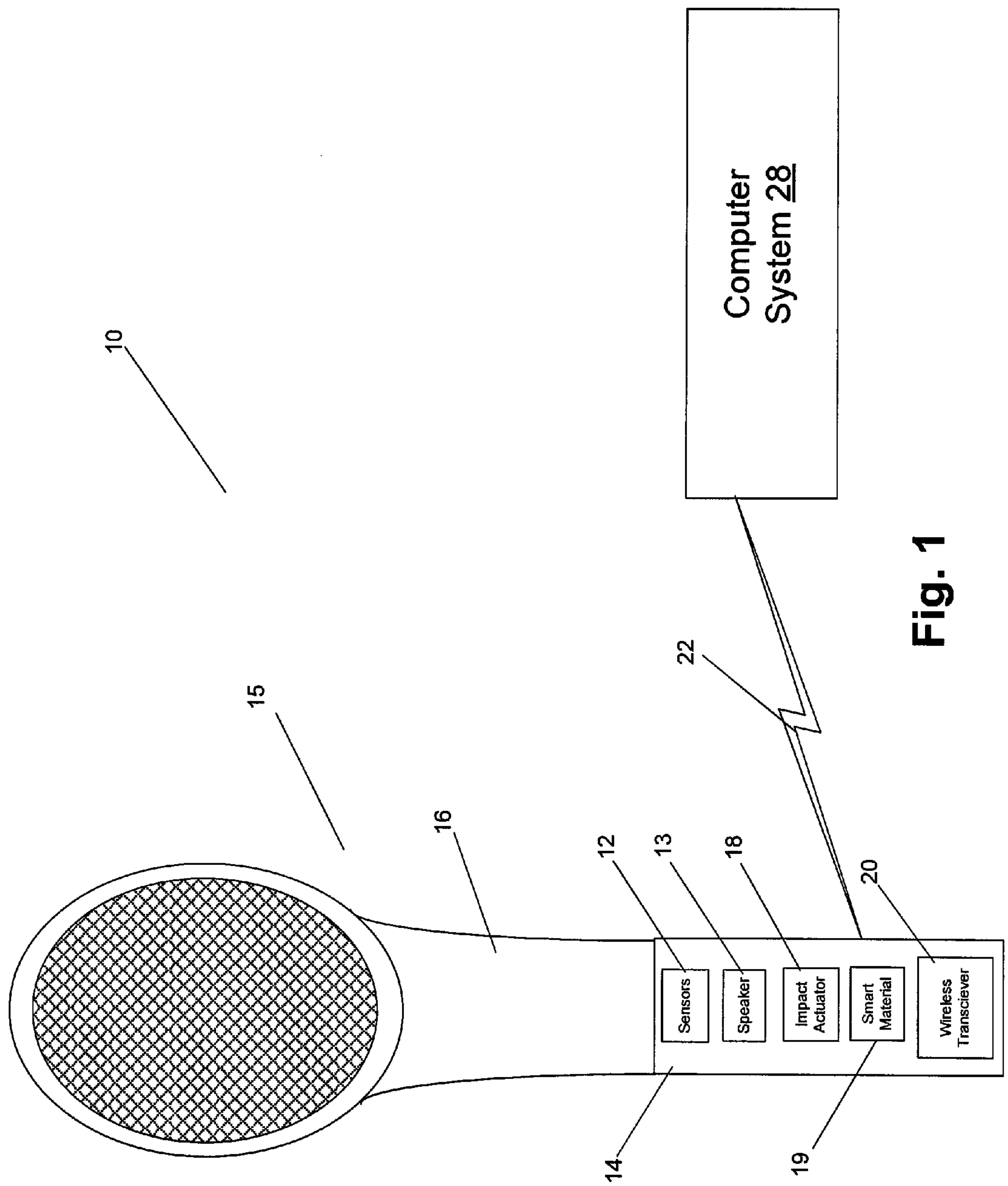
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Computer System 28
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Sensors
Speaker
Impact Actuator
Smart Material
Wireless Transciever
14
19

Fig. 1

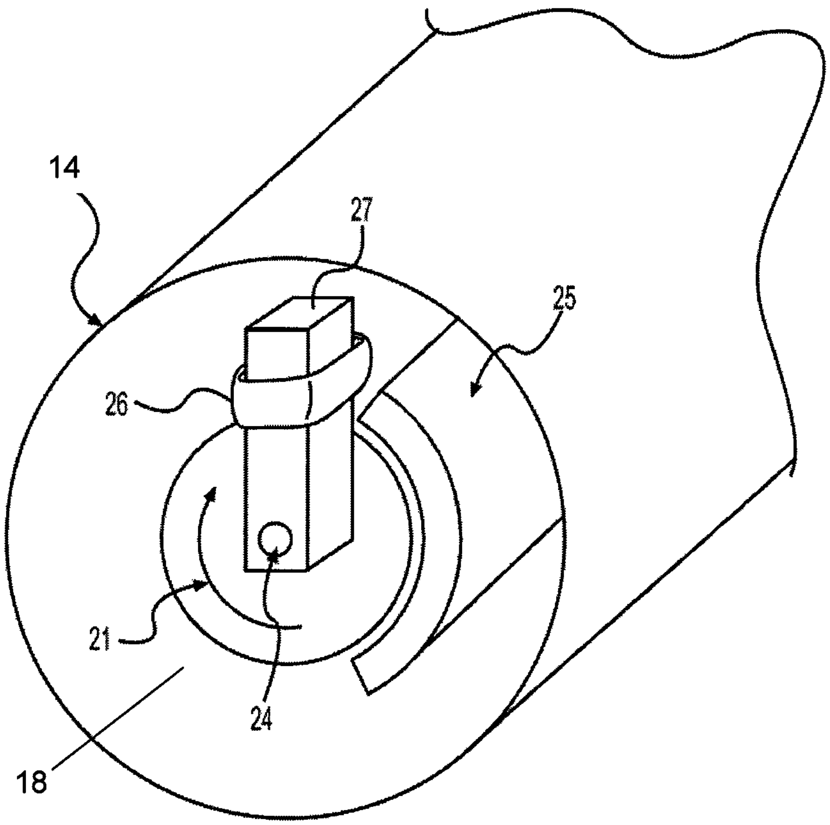
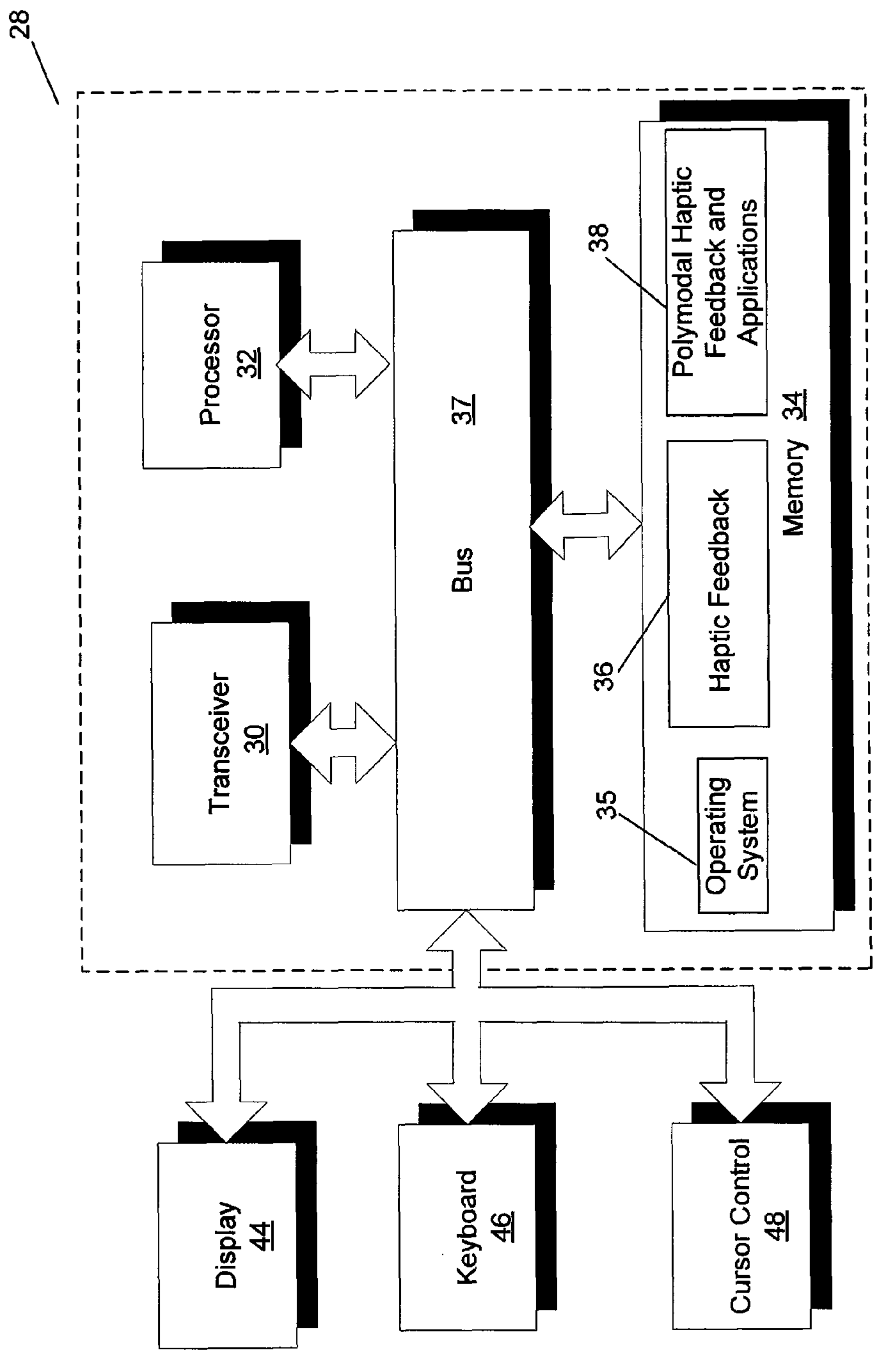


Fig.2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Haptic Feedback
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Operating System
Memory 34
Display
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Keyboard
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Cursor Control
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Fig. 3

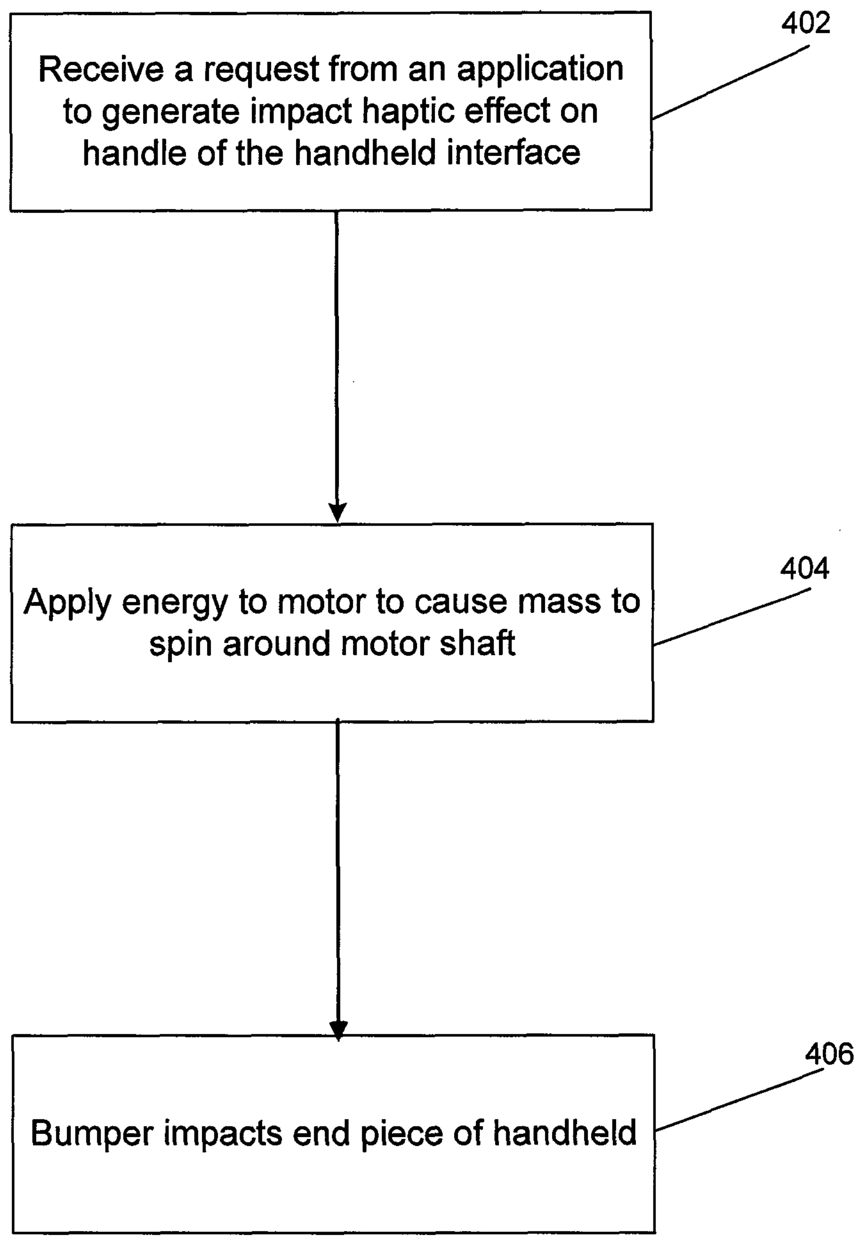
Receive a request from an application to generate impact haptic effect on handle of the handheld interface
402
Apply energy to motor to cause mass to spin around motor shaft
404
Bumper impacts end piece of handheld
406

Fig.4

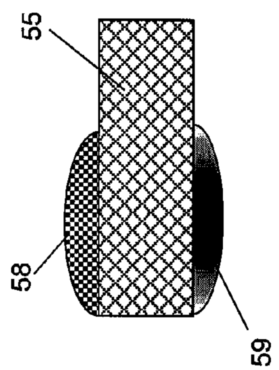

Fig. 5b

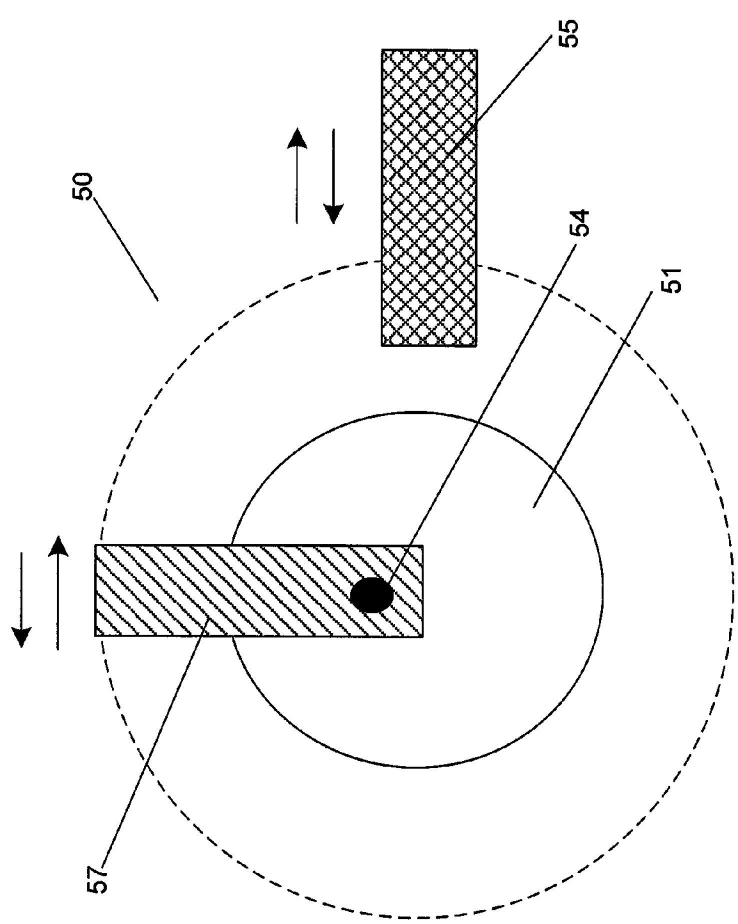

Fig. 5a

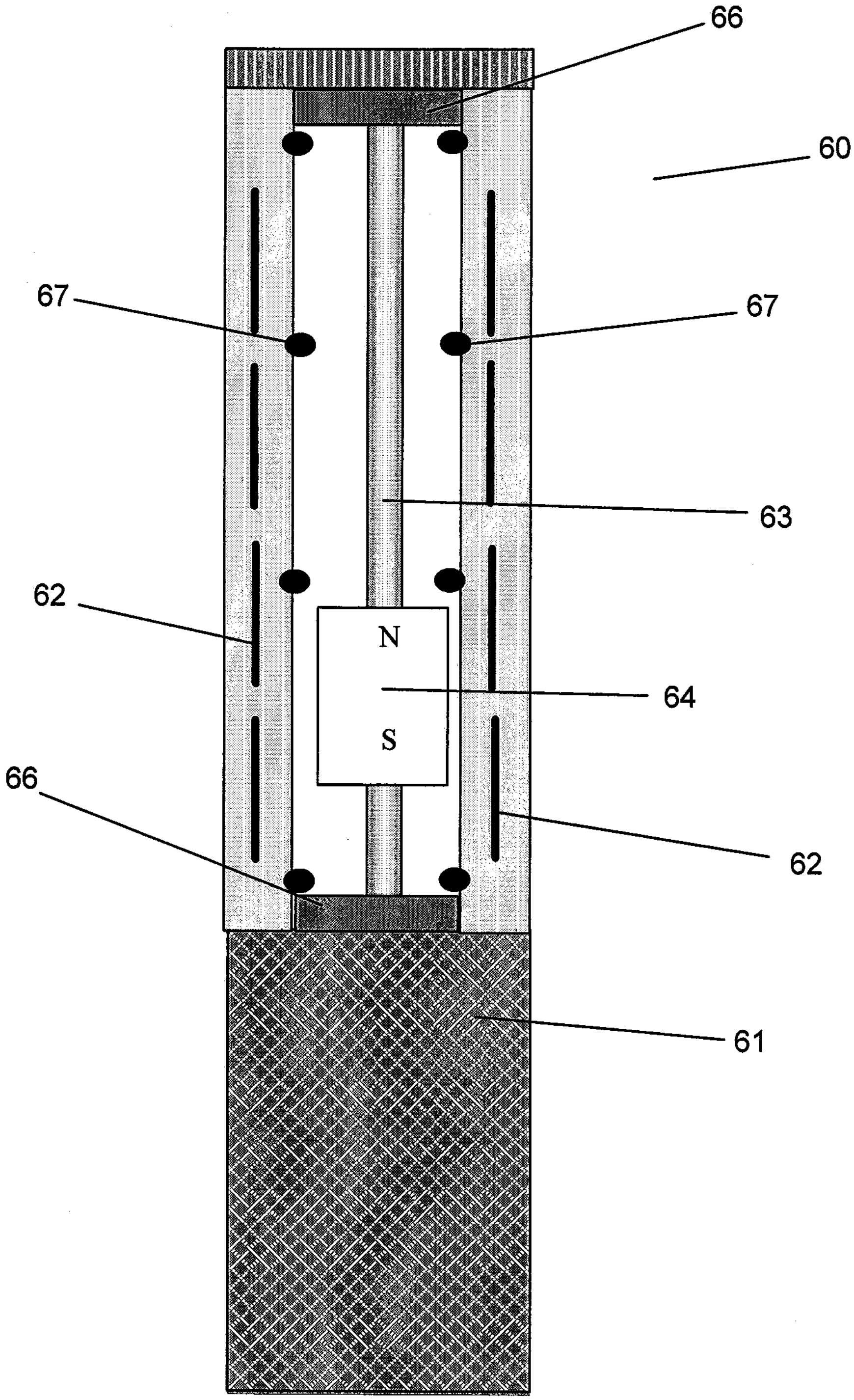

Fig.6

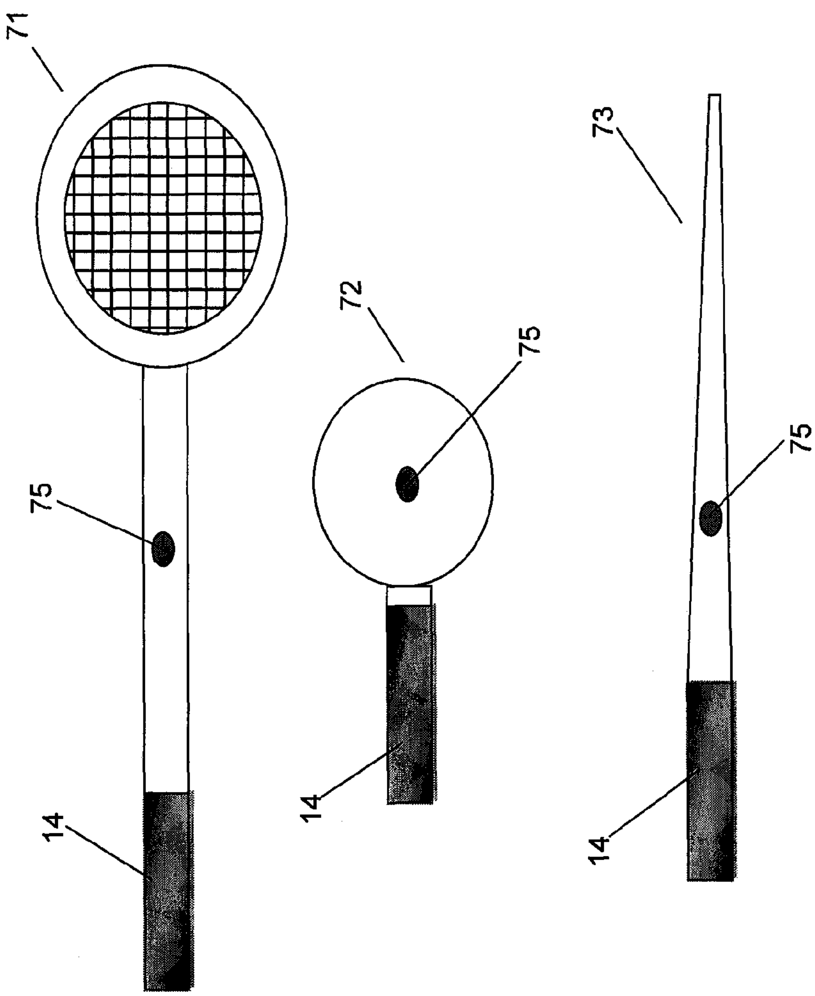

Fig. 7

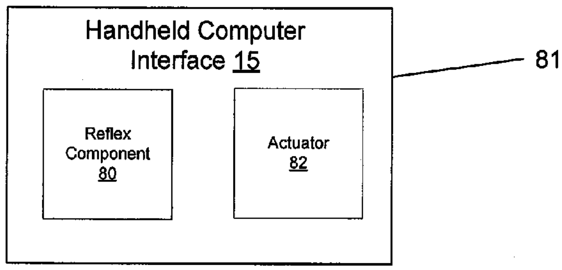

Fig.8

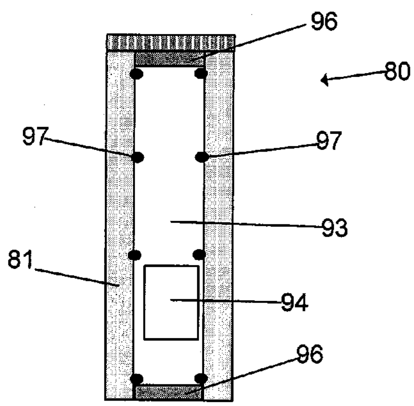

Fig.9 a

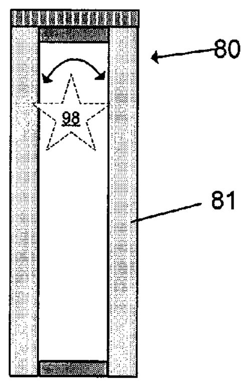

Fig.9 b

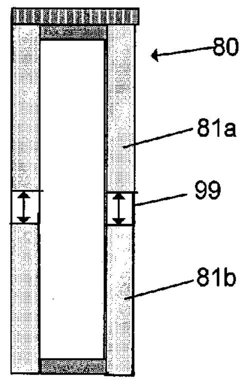

Fig. 9c

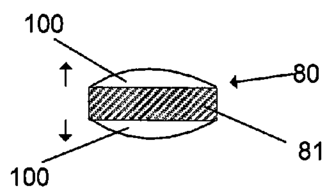

Fig. 9d

HANDHELD COMPUTER INTERFACE WITH HAPTIC FEEDBACK

FIELD OF THE INVENTION

One embodiment is directed generally to a computer interface, and in particular to a handheld computer interface that includes haptic feedback.

BACKGROUND INFORMATION

Haptic feedback can be generated by a device and sensed by kinesthetic receptors to allow a user of the device to perceive forces such as inertia and acceleration. Typically, this kind of haptic feedback is created by applying a force to the body through a physical interface which is grounded to a wall or desk. Also known as "tethered" interfaces, such devices are limited in their range, mobility, and ultimately usability because of their reliance on being coupled to an external structure.

SUMMARY OF THE INVENTION

Various systems, devices, and methods are provided for generating an impact and/or surface haptic effect for a handheld computer interface such as a video game controller. The computer interface can be used with, for example, computer games and device simulators to create a high intensity, high frequency, short duration haptic effect used to simulate collisions with external objects such as baseballs or swords, or recoil from shooting projectiles.

According to various embodiments of the invention, the handheld computer interface may include a handle coupled to an impact actuator. The impact actuator may include a movable mass and an end stop. The impact actuator may receive a haptic effect signal and in response cause the mass to contact the end stop to generate a haptic effect.

According to various embodiments of the invention, a smart material that outputs a surface haptic effect may be coupled to a surface of the handle such that the surface haptic effect is output substantially from the smart material rather than the handle or otherwise housing of the handheld computer interface.

According to various embodiments of the invention, the handle may be coupled to an end piece having a shape that simulates an object such as a tennis racket, golf club, or other object. In some embodiments, the end piece may be removably coupled to the handle. In this manner, the handheld computer interface may be used to simulate various real-world objects.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a computer interface system in accordance with one embodiment.

FIG. **2** is a cross-sectional perspective view of a handle and impact actuator in accordance with one embodiment.

FIG. **3** is a block diagram of a computer system that is wirelessly coupled to a handheld interface in accordance with one embodiment.

FIG. **4** is a flow diagram of the functionality of a haptic feedback module when initiating impact haptic effects on the handheld interface in accordance with one embodiment.

FIG. **5***a* is a plan view of an impact actuator in accordance with another embodiment.

FIG. **5***b* is a plan view of an end stop or blocker in accordance with another embodiment.

FIG. **6** is a partial cut-away view of a linear impact actuator in accordance with another embodiment.

FIG. **7** is a plan view of embodiments of a handle coupled to various end pieces to emulate different sport related interfaces.

FIG. **8** is a block diagram of an example handheld computer interface, according to an embodiment.

FIGS. **9***a*, **9***b*, **9***c*, and **9***d* are examples of a reflex component, according to various embodiments

DETAILED DESCRIPTION

One embodiment is a handheld computer interface that generates a haptic feedback effect with an impact actuator that impacts a portion of a handle of the interface. The computer interface can be used with, for example, computer games and device simulators to create a high intensity, high frequency, short duration haptic effect used to simulate collisions with external objects such as baseballs or swords, or recoil from shooting projectiles.

FIG. **1** is a block diagram of a computer interface system **10** in accordance with one embodiment. Computer interface system **10** includes a handheld computer interface **15** that includes a handle **14** coupled to an end piece **16**. Handle **14**, described in more detail below, includes an impact actuator **18** to create haptic feedback. Handle **14** can also include other types of actuators to create additional haptic feedback. End piece **16** in one embodiment is removably attached to handle **14** so that it can be changed depending on the device that interface **15** is intended to simulate. For example, in FIG. **1** end piece **16** allows interface **15** to simulate and represent a tennis racquet. Other shaped end pieces can be used to simulate a ping pong paddle, pool cue, baseball bat, golf club, gun, sword, etc. According to various embodiments of the invention, end piece **16** may also include additional haptic actuators (not otherwise illustrated in FIG. **1**). In some embodiments, the additional haptic actuators may be general-purpose such that they may be used for various haptic effects. In some embodiments, the additional haptic actuators may pertain specifically to the device that interface **15** is intended to simulate via a particular type of end piece **16**. In these embodiments, an end piece **16** simulating a golf club, for example, may include additional haptic actuators that are used to generate haptic effects related to a golf swing. Interface **15** may house a speaker **13** that outputs audio. Interface **15** further houses a wireless transceiver **20** and one or more sensors **12**. Wireless transceiver **20** wirelessly couples interface **15** to a computer system **28** via wireless link **22**. In other embodiments, interface **15** can be coupled to computer system **28** via any other known methods, including wired methods.

Sensors **12** may include one or more of the following types of sensors:

- An accelerometer for sensing acceleration and estimating orientation against gravity;
- A gyroscope for sensing swings and rotary velocity to improve gestural capture;
- Electric field sensors on the body of interface **15**, for multi-touch and/or proximity sensing;
- A strain gauge and/or piezo for sensing bend, twist, and/or physical impact;
- An infrared reflection sensor for proximity sensing;
- A camera for pickup of onscreen cues and/or other visual recognition tasks;
- A microphone for ambient sound, voice input, vibration, and/or breath pressure sensing; and

Buttons/joysticks/X-pads/triggers for standard gaming operations.

In other embodiments, handheld interface **15** includes other actuators in addition to impact actuator **18**. These additional actuators can be used to create other haptic feedback in addition to the haptic feedback that is generated by impact actuator **18**. The additional actuators may include:

An center of mass ("COM") actuator that varies a position of a mass to create inertial effects to change the perceived "weight" of interface **15**;

A vibrotactile/vibration actuator, capable of generating a wide variety of vibrotactile effects such as confirmation, envelopes, kinetic-like physics simulations, etc. In one embodiment, a piezoelectric-based actuator wrapped around handle **14** generates the vibrotactile effects, an example of which is described below with respect to smart material **19**;

A "flying mass actuator" that is similar to the COM actuator but that is capable of responding to user input by changing its position in real-time and at high speed, an example of which is described with respect to FIG. **6** below.

According to various embodiments of the invention, handle **14** may include or otherwise be coupled with a smart material **19**, which may include a piezo, shape-memory alloy, or other smart material. Smart material **19** may be coupled to a surface of handle **14**, thereby directly imparting a surface haptic effect to the user substantially from smart material **19** rather than from handle **14**. In some embodiments, the surface haptic effect may supplement (i.e., be in addition to) vibrotactile haptic feedback described above. Smart material **19** may be in a shape of a strip coupled to the surface of handle **14**, may encompass (fully or partially wrap) handle **14**, and/or other configuration coupled to the surface of handle **14**.

In some embodiments, a cover portion (not otherwise illustrated in FIG. **1**) may be coupled to smart material **19**. For example, smart material **19** may be protected from contact by the user and/or environment with the cover portion. The cover portion may be made of any material such as rubber, plastic, or other material that protects smart material **19** from contact by the user and/or environment. In these embodiments, the surface haptic effect may be imparted substantially from smart material **19** and at least in part through the cover portion rather than the surface of handle **14**.

FIG. **2** is a cross-sectional perspective view of handle **14** and impact actuator **18** in accordance with one embodiment. Impact actuator **18** includes a motor **21** and an end stop **25**. End stop **25** in one embodiment is a cut-away portion of a plastic tube that is coupled to handle **14**. In one embodiment, motor **21** is a high performance linear or rotary motor that is capable of generating relatively high torque. Motor **21** includes a shaft **24** that rotates in a circular motion. A weight **27** is coupled to shaft **24**. A rubber bumper or band **26** is coupled to weight **27**.

In operation, computer system **28** of FIG. **1** generates a signal to create an impact haptic effect. The signal is applied to motor **21**, which causes shaft **24** and weight **27** to rotate with a relatively high torque. Shaft **24** rotates in either direction to the point where bumper **26** contacts end stop **25**. This contact creates the impact haptic effect. As shown, shaft **24** rotates approximately 180° and less than 360° before contacting end stop **25**. The rotation and contact of bumper can be repeated to create a series of impact haptic effects.

FIG. **3** is a block diagram of computer system **28** that is wirelessly coupled to handheld interface **15** in one embodiment. System **28** includes a bus **37** or other communication mechanism for communicating information, and a processor **32** coupled to bus **37** for processing information. Processor **32** may be any type of general or specific purpose processor. System **28** further includes a memory **34** for storing information and instructions to be executed by processor **32**. Memory **34** 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 media. System **28** further includes a transceiver **30** that provides communication with transceiver **20** of handheld interface **15**. Computer system **28** may be a general purpose computer, or it may be a specialty computer system such as a video game console.

Computer readable media may be any available media that can be accessed by processor **32** and includes both volatile and nonvolatile media, removable and non-removable media, and communication media. Communication media 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 includes any information delivery media.

Processor **32** is further coupled via bus **37** to a display **44**, such as a Liquid Crystal Display ("LCD"), for displaying information to a user. A keyboard **46** and a cursor control device **48**, such as a computer mouse, is further coupled to bus **37** to enable a user to interface with system **28** as an alternative or in addition to using handheld interface **15**.

In one embodiment, memory **34** stores software modules that provide functionality when executed by processor **32**. The modules include an operating system **35** that provides operating system functionality for system **28**. The modules further include a haptic feedback module **36** that generates haptic feedback on handheld interface **15** through impact actuator **18**. System **28** further includes a polymodal haptic feedback and applications module **38** that generates additional haptic feedback on handheld interface **15**, and includes an application such as a video game that requires haptic feedback to be generated on handheld interface **15** in conjunction with the application. In another embodiment, the functionality of modules **36** and **38** is subsumed in a single haptic feedback management module that is responsible for synthesizing and displaying polymodal haptic effects, including mass bias (kinesthesia), mass motion (kinesthesia), vibration (vibrotaction), impact (vibrotaction), etc. The haptic feedback management module takes a generalized, physics-based feedback profile (e.g., size of interface, position of interface, position of ball impact, and other contextual factors within the virtual environment) and dispatches haptic feedback signals to individual actuators as appropriate (e.g., vibration, impact, COM, etc.).

In one embodiment, haptic feedback module **36** initiates impact haptic effects on handheld interface **15**. FIG. **4** is a flow diagram of the functionality of haptic feedback module **36** when initiating impact haptic effects on handheld interface **15** in accordance with one embodiment. In one embodiment, portions of the functionality of the flow diagram of FIG. **4** is implemented by software stored in memory or other 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.

At **402**, haptic feedback module **36** receives a request from application **38** to generate an impact haptic effect on handle **14** of handheld interface **15**. Application **38** may be an interactive video game such as a golf or baseball game, or any type of application that may be enhanced or requires an impact haptic effect.

At **404**, haptic feedback module **36** initiates the application of energy to motor **21** to cause mass **27** to spin around motor shaft **24**.

At **406**, bumper **28** impacts end stop **25**, thus causing an impact haptic effect. The functionality of **402**, **404** and **406** can be repeatedly applied to generate multiple impact haptic effects. Further, bumper **28** can repeatedly contact end stop **25** at high frequency and a small travel path to generate a vibration haptic effect.

Concurrently with the haptic feedback requests at **402**, polymodal haptic feedback and application module **38** may also generate other haptic feedback requests that are sent to other actuators of handheld interface **15** to generate other types of haptic feedback such as vibrations, COM variations, etc.

FIG. **5***a* is a plan view of an impact actuator **50** in accordance with another embodiment. Similar to impact actuator **18** of FIG. **2**, impact actuator **50** includes a motor **51** with a shaft **54**, and a rotating mass **57**. In operation, mass **57** can rotate unobstructed through one or more revolutions in order to build up the necessary speed. At that point, an end stop or blocker **55** is mechanically moved into the path of mass **57**, which creates an impact. Therefore, motor **51** does not require a high level of torque in comparison with motor **21** of actuator **18**, and can be a relatively low cost rotary motor. However, in one embodiment, haptic feedback module **36** when using actuator **50** to generate an impact haptic effect anticipates farther in advance when an impact haptic effect should be generated because actuator **50** takes longer than actuator **18** to generate the effect.

FIG. **5***b* is a plan view of end stop or blocker **55** in accordance with another embodiment. Blocker **55** includes bumpers **58** and **59** on opposite sides made from different impact materials to create different impact sensations depending on the rotation direction of mass **57**. For example, bumper **58** can be made from soft rubber and bumper **59** can be made from hard plastic.

FIG. **6** is a partial cut-away view of a linear impact actuator **60** in accordance with another embodiment. Impact actuator **60** includes a handle section **61**, coils **62**, and a magnetic mass **64** that travels along guide shaft **63**. Guide shaft **63** includes a position sensor for detecting the position of mass **64**. Actuator **60** further includes end stops or bumpers **66** that are made of the same material (e.g., soft rubber) as one another or different materials (e.g., soft rubber, hard rubber) from one another. Finally, actuator **60** includes retractable brakes **67**. Each brake **67** may be made of the same material (e.g., soft rubber) as one another or different materials (e.g., soft rubber, hard rubber) from one another.

In operation, a signal is generated by haptic feedback module **36** which energizes coils **62**, which causes mass **64** to travel along shaft **63**. To create the impact haptic effect, mass **64** can be allowed to impact one of bumpers **63**, or can be stopped by one of brakes **67** for a shorter travel length. The variations in travel length causes different impact haptic effects. For example, to emulate the impact from a relatively long golf swing, mass **64** can travel the full length of shaft **63**. To emulate the impact from a relatively short ping pong swing, brakes **67** can shorten the length of travel of mass **64**. Further, the material properties of brakes **67** and bumpers **63** can be used to modulate the properties of an impact haptic effect. For example, to emulate the impact for a baseball bat, a foul tip can use soft rubber materials while a hard solid baseball hit can use hard rubber materials.

In some embodiments, linear impact actuator **60** may be configured such that a user-generated motion at least partially causes mass **64** to travel along shaft **63**, thereby supplementing the travel of mass **64** along shaft **63** caused by energizing coils **62**. For example, a golf swing motion may cause mass **64** to travel along shaft **63**, supplementing the travel of mass **64** caused by energizing coils **62**. In this manner, energizing coils **62** and the motion of linear impact actuator **60** may cause mass **64** to travel along shaft **63**. In some embodiments, linear impact actuator **60** may include sensors (not otherwise illustrated in FIG. **6**) configured to measure movement of mass **64** and/or linear impact actuator **60**. Motion information from the sensors may be used to tailor one or more signals to linear impact actuator **60** to cause a haptic effect, thereby supplementing, arresting, and/or otherwise modulating the haptic effect imparted by mass **64**.

FIG. **7** is a plan view of embodiments of handle **14** coupled to various end pieces to emulate different sport related interfaces. As shown, the interfaces include a badminton racquet **71**, a ping pong paddle **72**, and a pool cue **73**. A speaker **75** is included in each of the embodiments. In one embodiment, the interface, including the handle and end piece, has a weight of less than 1000 grams, a handle diameter less than 45 mm, a handle length less than 200 mm, and an end piece length of 100 mm-500 mm, depending on the type of sport that the interface is emulating.

In addition to the impact actuator, one embodiment includes eccentric rotating mass ("ERM") actuators and linear resonant actuators ("LRAs"), possibly at each end of the interface, in order to create complimentary haptic effects. In one embodiment, the audio speaker generates less than 30 decibels and is located on the various end pieces to create realistic impact sounds at the virtual impact location. In one embodiment, the interface includes a sensor for sensing six degree of freedom of the interface's position, and a sensor for sensing the position of the shaft of the rotary actuator or the position of the mass of the linear actuator.

As an example of scenarios that can effectively utilize the interface in accordance with embodiments, consider a user facing a large screen capable of displaying three-dimensional images. The user is holding a computer interface in accordance with one embodiment that has an end piece with the appearance of a badminton racquet. On the screen an opponent is getting ready to serve. After the serve the bird appears to come out of the screen towards the user who swings and hits the bird back toward the screen. The sensation of impact is faithfully conveyed to the user via the impact haptic actuator in the handle and the "swish" of contact is heard from the speaker that is located on the end piece. The opponent successfully returns the bird and this time the user misses and receives no haptic feedback and a low audible whoosh of the racquet from the speaker as it passes through thin air.

In another scenario, a large flat screen may be placed on a table, displaying a pool table in three-dimensions. The balls are capable of interacting in a familiar and natural manner. The user is holding a computer interface in accordance with one embodiment that has an end piece with the appearance of a pool cue. As the user lines up for a shot, vibrotactile haptic feedback is generated to guide the user to the right position. The vibrotactile haptic feedback is a changing haptic pattern that is conveyed to allow the user to recognize when the cue is properly aligned for a tricky combination shot. The user initiates the shot and feels the impact of the cue hitting the white ball through the impact actuator. The user then feels a vibrotactile haptic pattern that provides feedback on the quality of the stroke, as the balls move naturally on the table.

In another scenario, the user is holding a computer interface in accordance with one embodiment that is used to control a virtual sword and has an end piece with the appearance of a sword. As the user causes the virtual sword to move using the computer interface, vibrotactile haptic feedback may be provided. In some embodiments, when the user causes the virtual sword to impact another virtual object (such as, for instance, another virtual sword, a virtual shield, a virtual character), vibrotactile haptic feedback may be provided. The vibrotactile haptic feedback may differ based on a type of virtual object impacted by the virtual sword, thereby providing different vibrotactile haptic feedback for different types and/or materials of virtual objects that are impacted.

FIG. **8** is a block diagram of an example handheld computer interface **15**, according to an embodiment. According to the embodiment illustrated in FIG. **8**, handheld computer interface **15** includes a reflex component **80**, a housing (or body) **81**, and an actuator **82**. Reflex component **80** may respond to a user-generated force exerted on handheld computer interface **15** by outputting a reflex haptic effect via handheld computer interface **15**. The user-generated force may include, for example, a swinging motion of handheld computer interface **15**, a squeezing force (such as a pressure exerted by the user against housing **81**), or other force exerted on handheld computer interface **15**. Actuator **82** may include, for example, a rotary actuator, a piezo-electric actuator, a solenoid, or other haptic actuator configured to generate haptic feedback.

In some embodiments, the reflex haptic effect may supplement (i.e., be in addition to) or be resistive to the haptic effect caused by actuator **82** and vice versa. In other embodiments, actuator **82** causes substantially all of the haptic effect on handheld computer interface **15**. Thus, according to various embodiments, reflex component **80** and/or actuator **82** may cause a haptic effect to be imparted on handheld computer interface **15**. In some embodiments, handheld computer interface **15** may include sensors (not otherwise illustrated in FIG. **8**) configured to measure forces exerted on and/or by reflex component **80**, the reflex haptic effect, actuator **82**, the haptic effect, and/or handheld computer interface **15**. Information from the sensors may be used to tailor one or more signals to actuator **82** to cause a haptic effect, thereby supplementing, arresting, and/or otherwise modulating the reflex haptic effect imparted by reflex component **80**. In some embodiments, reflex component **80** is a mechanical device that generates substantially all of the reflex haptic effect mechanically rather than using signals or currents. In some embodiments, reflex component **80** may be coupled to an actuator or other device that assists or otherwise resists the reflex haptic effect.

FIGS. **9***a*, **9***b*, **9***c*, and **9***d* are examples of reflex component **80**, according to various embodiments.

FIG. **9***a* is a cut-away view of handheld computer interface **15** that illustrates reflex component **80**, according to an embodiment. According to the embodiment illustrated in FIG. **9***a*, reflex component **80** includes a moving mass **94** disposed inside a cavity **93** disposed within handheld computer interface **15**. In some embodiments, moving mass **94** moves inside cavity **93** in response to the user-generated force, thereby imparting a haptic effect to handheld computer interface **15**. Cavity **93** may be any shape, including cylindrical, conical, spherical, or other shape in which moving mass **94** may move.

Movement of moving mass **94** in response to the user-generated force may cause the moving mass **94** to impact an inner surface of cavity **93** or other component of handheld computer interface **15**, thereby imparting a haptic effect to handheld computer interface **15**. In some embodiments, the haptic effect caused by moving mass **94** may cause substantially all of the haptic effect imparted to handheld computer interface **15**. In other embodiments, the haptic effect caused by moving mass **94** may supplement (i.e., be in addition to) a haptic effect caused by actuator **82** and vice versa. In other embodiments, actuator **82** causes substantially all of the haptic effect on handheld computer interface **15**. Thus, according to various embodiments, moving mass **94** responsive to user-generated motion and/or actuator **82** may cause a haptic effect to be imparted on handheld computer interface **15**.

In some embodiments, cavity **93** may include or otherwise be coupled with bumpers **96** that are made of the same material (e.g., soft rubber) as one another or different materials (e.g., soft rubber, hard rubber) from one another. Moving mass **94** may impact bumpers **96**, thereby causing a haptic effect.

In some embodiments, cavity **93** may include or otherwise be coupled with bumps **97**, which may each be made of the same material (e.g., soft rubber) as one another or different materials (e.g., soft rubber, hard rubber) from one another. Bumps **97** may stop, slow down, or otherwise cause friction on moving mass **94**, thereby causing a haptic effect as moving mass **94** moves within cavity **93**.

In the embodiment illustrated in FIG. **9***a*, moving mass **94** may move freely within cavity **93** (notwithstanding bumpers **96** and/or bumps **97**). In other embodiments, moving mass **94** may be coupled to a shaft, a spring, or other component (not otherwise illustrated in FIG. **9***a*) that constrains the movement of moving mass **94**.

In some embodiments, cavity **93**, moving mass **94**, bumpers **96**, and/or bumps **97** may be configured such that only force provided by a user that exceeds a predefined threshold will cause moving mass **94** to move. Thus, only force that exceeds the predefined threshold will cause moving mass **94** to impart a haptic effect.

Although illustrated in FIG. **9***a* as a single moving mass **94**, two or more moving masses **94** may be used as would be appreciated by those having skill in the art.

FIG. **9***b* is a cut-away view of handheld computer interface **15** that illustrates reflex component **80**, according to an embodiment. According to the embodiment illustrated in FIG. **9***b*, reflex component **80** includes a fan component **98**, which may be disposed inside handheld computer interface **15**. Fan component **98** may spin in one or both directions illustrated by arrows in response to the user-generated force. In this embodiment, handheld computer interface **15** may include vents that allow air to pass through housing **81**, thereby causing fan component **98** to move. In some embodiments, fan component **98** may impact an inner portion of handheld computer interface **15** (such as an inner wall of housing **81**), thereby causing the reflex haptic effect. In some embodiments, a motor may be coupled to fan component **98** (not otherwise illustrated in FIG. **9***b*). The motor may assist or resist the motion of fan component **98**, thereby enhancing or muting the reflex haptic effect caused by fan component **98**.

FIG. **9***c* is a cut-away view of handheld computer interface **15** that illustrates reflex component **80**, according to an embodiment. According to the embodiment illustrated in FIG. **9***c*, reflex component **80** includes a linkage portion **99** that separates one or more portions **81***a* and **81***b* of housing **81**. In some embodiments, linkage portion **99** is a hinge or other flexible component that movably couples housing portions **81***a* and **81***b* to one another. In this manner, the user-generated force causes housing portions **81***a* and **81***b* to impact one another and/or other component of handheld computer interface **15**, thereby causing the reflex haptic effect.

FIG. **9***d* is a cross-sectional view of handheld computer interface **15** that illustrates reflex component **80**, according to an embodiment. According to the embodiment illustrated in FIG. **9***d*, reflex component **80** includes a flexible member **100**. In this embodiment, the user-generated force may be a squeezing force exerted on handheld computer interface **15** by the user, thereby deforming flexible member **100**. Flexible member **100** may be configured to provide a returning force indicated by arrows that returns flexible member **100** toward an equilibrium position, thereby generating the reflex haptic effect. The equilibrium position is a position and/or orientation in which flexible member **100** exists when the user-generated force is not exerted on flexible member **100**. In some embodiments (not otherwise illustrated in FIG. **9***d*), a motor or other device may be coupled to flexible member **100** to assist or resist the reflex haptic effect provided by flexible member **100**.

Those having skill in the art will appreciate that various components illustrated in FIGS. **9***a*, **9***b*, **9***c*, and **9***d* may differ in number, position, and/or orientation according to particular needs.

As disclosed, a handheld computer interface generates haptic feedback from an impact actuator as well as from other actuators. The haptic effects generated by the impact actuator, other actuators, and/or components described herein provide effective and realistic sensations to simulate the impact from a ball or other object.

Several embodiments are specifically illustrated and/or described herein. However, it will be appreciated that modifications and variations of the disclosed embodiments are covered by the above teachings and within the purview of the appended claims without departing from the spirit and intended scope of the invention.

What is claimed is:

1. A handheld computer interface comprising:

a handle; and

an impact actuator coupled to the handle, wherein the impact actuator comprises a movable mass and an end stop, wherein the impact actuator is adapted to receive a haptic effect signal and in response cause the movable mass to contact the end stop to generate a haptic effect,

wherein the end stop is adapted to be movably inserted into a travel path of the movable mass, and

wherein the movable mass rotates greater than 360° before contacting the end stop.

2. The handheld computer interface of claim **1**, wherein the movable mass contacts the end stop through a bumper coupled to the mass.

3. The handheld computer interface of claim **1**, wherein the end stop is coupled to a first bumper having first impact properties and a second bumper having second impact properties.

4. The handheld computer interface of claim **1**, further comprising:

an end piece coupled to the handle, the end piece having a shape that simulates an object.

5. The handheld computer interface of claim **1**, further comprising:

a smart material that outputs a surface haptic effect, wherein the smart material is coupled to a surface of the handle, thereby directly imparting the surface haptic effect substantially from the smart material rather than the handle.

6. The handheld computer interface of claim **1**, wherein the movable mass moves in response to a user-generated motion of the handheld computer interface, thereby supplementing the haptic effect caused by the impact actuator.

7. A handheld computer interface comprising;

a housing; and

a reflex component coupled to the housing, wherein the reflex component is configured to cause a first haptic effect to the housing in response to a user-generated force on the handheld computer interface, wherein the reflex component comprises a movable mass disposed within a cavity of the housing, wherein the user-generated force causes the movable mass to move linearly within the cavity from a resting position towards an end of the cavity, and wherein the first haptic effect is caused by the movable mass striking a bump projecting from an inner surface of the housing into the cavity.

8. The handheld computer interface of claim **7**, further comprising an actuator coupled to the housing, wherein the actuator is configured to impart a second haptic effect to the housing.

9. The handheld computer interface of claim **8**, wherein the actuator comprises at least one coil surrounding the movable mass, wherein the movable mass is magnetic and the coil is adapted to be energized in response to receiving a haptic effect signal to move the mass along the guide shaft, wherein the actuator supplements the user-generate force.

10. The handheld computer interface of claim **8**, further comprising:

a sensor configured to output sensor information that describes a force of the handheld computer interface, wherein the actuator varies the second haptic effect based on the sensor information.

11. The handheld computer interface of claim **10**, wherein the sensor information describes one or more forces imparted on or by the reflex component.

12. The handheld computer interface of claim **10**, wherein the sensor information describes a motion of the handheld computer interface.

13. The handheld computer interface of claim **7**, further comprising a bumper coupled to the end of the cavity such that the movable mass contacts the bumper to cause a second haptic effect.

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