

[0036] FIG. 21 is an elevational diagram illustrating alternative electromagnetic components for generating attractive magnetic force in an actuator in accordance with one embodiment of the present invention;

[0037] FIG. 22 is an elevational diagram of an alternative embodiment of an actuator in accordance with the present invention;

[0038] FIG. 23 is an elevational diagram of another embodiment of an actuator in accordance with the present invention;

[0039] FIG. 24 is an elevational diagram of a system employing an actuator in accordance with one embodiment of the present invention;

[0040] FIG. 25 is an elevational diagram illustrating a second equilibrium position of an actuator in accordance with one embodiment of the present invention;

[0041] FIG. 26 is a front perspective diagram of a system configured with a plurality of actuators in accordance with one embodiment of the present invention;

[0042] FIG. 27 is a flow diagram illustrating a method for generating haptic effects in accordance with one embodiment of the present invention;

[0043] FIG. 28 is a block diagram illustrating a system having an actuator in accordance with one embodiment of the present invention; and

[0044] FIGS. 29, 30 and 31 are diagrams illustrating areas of a touch input device which may be used for particular inputs.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0045] Embodiments of the present invention are described herein in the context of a system of touch input devices with haptic feedback. Sometimes these are referred to herein as touch control devices. Those of ordinary skill in the art will realize that the following detailed description of the present invention is illustrative only and is not intended to be in any way limiting. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of the present invention as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

[0046] In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

[0047] In accordance with the present invention, the components, process steps, and/or data structures may be implemented using various types of operating systems, computing platforms, computer programs, and/or general purpose machines. In addition, those of ordinary skill in the art will recognize that devices of a less general purpose nature, such as hardwired devices, field programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), or the like, may also be used without departing from the scope and spirit of the inventive concepts disclosed herein.

[0048] FIG. 1 is a perspective view of a portable computer 10 including a haptic touchpad of the present invention. Computer 10 is preferably a portable or "laptop" computer that can be carried or otherwise transported by the user and may be powered by batteries or other portable energy source in addition to other more stationary power sources. Computer 10 preferably runs one or more host application programs with which a user is interacting via peripherals. Some display devices 12 for computers are display-only devices—in other cases the display devices incorporate a touch-sensitive surface and may themselves be used for touch input. Such screens are frequently seen in kiosks, automatic teller machines, automated vending machines of various types, and the like.

[0049] Computer 10 may include the various input and output devices as shown, including a display device 12 for outputting graphical images to the user, a keyboard 14 for providing character or toggle input from the user to the computer, and a touchpad 16 of the present invention. Display device 12 can be any of a variety of types of display devices; flat-panel displays are most common on portable computers. Display device 12 can display a graphical environment 18 based on application programs and/or operating systems that are running, such as a graphical user interface (GUI), that can include a cursor 20 that can be moved by user input, as well as windows 22, icons 24, and other graphical objects well known in GUI environments. Other devices may also be incorporated or coupled to the computer 10, such as storage devices (hard disk drive, DVD-ROM drive, and the like), network server or clients, game controllers, and the like. In alternate embodiments, the computer 10 can take a wide variety of forms, including computing devices that rest on a tabletop or other surface, stand-up arcade game machines, automatic teller machines (ATMs), automatic vending machines, other portable devices or devices worn on the person, handheld or used with a single hand of the user, and the like. For example, host computer 10 can be a video game console, personal computer, workstation, a television "set top box" or a "network computer", or other computing or electronic device.

[0050] Touchpad device 16 of the present invention preferably appears externally to be similar to the touchpads of the prior art. Pad 16 includes a planar, rectangular smooth surface that can be positioned below the keyboard 14 on the housing of the computer 10, as shown, or may be positioned at other areas of the housing. When the user operates the computer 10, the user may conveniently place a fingertip or other object on the touchpad 16 and move the fingertip to correspondingly move cursor 20 in the graphical environment 18.

[0051] In operation, the touchpad 16 inputs coordinate data to the main microprocessor(s) of the computer 10 based