position when a user-controlled graphical object is moved over a selectable graphical object, to make the selection easier. Or, the direction pad can be moved to different positions on an axis approximately perpendicular to a top surface of the direction pad, the different positions based on a desired 3-D elevation of an object or area displayed in the graphical environment. A method for providing haptic feedback to a direction pad of an interface device includes similar features.

The present invention advantageously provides haptic feedback device to a direction pad of an interface device. The direction pad haptic feedback can be independent of any other haptic feedback provided for the device, allowing a greater variety of tactile sensations and different tactile sensations to be output simultaneously. The haptic feedback direction pad is significantly lower in cost than many other types of haptic feedback devices and is thus quite suitable for home consumer applications. The embodiments described allow crisp forces and a variety of sensations to be output to enhance the user's interaction and experience with a computer application or electronic device.

These and other advantages of the present invention will become apparent to those skilled in the art upon a reading of the following specification of the invention and a study of the several figures of the drawing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1***a* is a perspective view of a gamepad control including the directional pad of the present invention;

FIG. **1***b* is a perspective view of a remote control device including the directional pad of the present invention;

FIGS. **2***a* and **2***b* are perspective exploded view and side elevational views, respectively, of a first embodiment of a direction pad of the present invention for providing haptic feedback to the user;

FIG. **3***a* is a perspective view of a different embodiment of the direction pad of the present invention, which is integrated with an elastomeric layer and a printed circuit board in a sub-assembly;

FIGS. **3***b*, **3***c*, **3***d*, and **3***e* illustrate different actuators for use with the direction pad of the present invention;

FIG. **4** is a side elevational view of a different embodiment of the direction pad of the present invention in which a linear actuator is used to provide linear motion along an axis different from the z-axis;

FIG. **5** is a side elevational view of a different embodiment of the direction pad of the present invention in which the direction pad provides analog input based on the amount it is moved;

FIG. **6** is a perspective view of a different embodiment of the direction pad of the present invention in which a coil routed around the direction pad and multiple magnets provide haptic feedback on the direction pad; and

FIG. **7** is a side elevational view of a different embodiment of the present invention in which a piezo-electric actuator is directly coupled to the direction pad of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1***a* is a perspective view of one example of a force feedback interface device **10** including the active tactile direction pad of the present invention. The device is used for interfacing a user with a computer generated environment implemented by a host computer **12**.

Interface device **10** of the described embodiment is in the form of a handheld controller, of similar shape and size to many "gamepads" currently available for video game console systems. A housing **14** of the interface device **10** is shaped to easily accommodate two hands gripping the device at the gripping projections **16***a* and **16***b*. In the described embodiment, the user accesses the various controls on the device **10** with his or her fingers. In alternate embodiments, the interface device can take a wide variety of forms, including devices that rest on a tabletop or other surface, stand-up arcade game machines, laptop devices or other devices worn on the person, handheld or used with a single hand of the user, etc.

A direction pad ("d-pad" or "joypad") **18** is included on device **10** to allow the user to provide directional input to the host computer **12**. In its most common implementation, the direction pad **18** is approximately shaped like a cross or disc having four extensions or directional positions (all referred to as "extensions" herein) radiating from a central point at a 90-degree spacing, where the user can press down on one of the extensions **20** to provide a directional input signal to the host computer for the corresponding direction. Typically, the direction pad **18** is tilted approximately about a pivot point, e.g. when one of the extension is pressed, the entire pad tilts as a single unit. In other embodiments, just the extension portion **20** that is pressed can move relative to the other parts of pad **18**. In yet other embodiments, a contact sensor can be provided in the pad **18** at each extension **20** so that the presence of a finger is detected with mechanical switches and no tilting motion or pressing motion is required.

Two adjacent extensions **20** can be simultaneously pressed to provide input for the appropriate diagonal direction between the extensions. In other embodiments, the direction pad **18** can include eight extensions or other number of extensions. The directional input is most commonly used to move a user-controlled graphical object in the direction corresponding to the direction of the extension, e.g. pressing on the "up" extension moves a cursor or character up or forward, pressing "left" moves the cursor or character left, etc. Also, in some embodiments, the direction pad **18** can be pressed down as a single piece (e.g., from the center) to provide a different input signal than the signals provided when pressing the extensions **20**. For example, the entire pad **18** can be pressed to provide the equivalent of a single mouse-click to select an object pointed to by a cursor. A contact switch can be positioned at the end of the downward travel of the pad to provide the signal, or other types of switches or sensors can be used (optical, magnetic, etc.).

In the present invention, the direction pad **18** is provided with the ability to output haptic feedback such as tactile sensations to the user who is contacting the direction pad **18**. Various embodiments detailing the structure of the haptic feedback direction pad are described in greater detail below. Preferably, the forces output on the pad are linear and along the z-axis, approximately perpendicular to the top surface of the pad **18**. Herein, the "top surface" of the pad is generally meant to refer to the overall x-y orientation of the surface of the pad, since there may be several actual top surfaces, e.g. on a pad having bumps or ridges on its top surface. Using one or more actuators and sensors coupled to the direction pad (or other controls), a variety of force sensations can be output to the user who is contacting the button. For example, jolts, vibrations (varying or constant amplitude), and textures can be output. Forces can be at least in part based on the position of the direction pad in a degree of freedom, and/or on the location or state of a controlled object in the