actuators. The term "force information" can include both commands/parameters and streamed data. The touchpad microprocessor can implement haptic sensations independently after receiving a host command by controlling the touchpad actuators; or, the host processor can maintain a greater degree of control over the haptic sensations by controlling the actuators more directly. In other embodiments, logic circuitry such as state machines provided for the touchpad **16** can handle haptic sensations as directed by the host main processor. Architectures and control methods that can be used for reading sensor signals and providing haptic feedback for a device are described in greater detail in U.S. Pat. No. 5,734,373 and copending application Nos. 60/156,354, 60,133,208, 09/376,649, and 60/160,401, all incorporated herein by reference.

[**0033**] **FIG. 2** is a perspective view of another embodiment of a device which can include the active touchpad **16** of the present invention. The device can be a handheld remote control device **30**, which the user grasps in one hand and manipulates controls to access the functions of an electronic device or appliance remotely by a user (such as a television, video cassette recorder or DVD player, audio/video receiver, Internet or network computer connected to a television, etc.). For example, several buttons **32** can be included on the remote control device **30** to manipulate functions of the controlled apparatus. A touchpad **16** can also be provided to allow the user to provide more sophisticated directional input. For example, a controlled apparatus may have a selection screen in which a cursor may be moved, and the touchpad **16** can be manipulated to control the cursor in two dimensions. The touchpad **16** includes the ability to output haptic sensations to the user as described herein, based on a controlled value or event. For example, a volume level passing a mid-point or reaching a maximum level can cause a pulse to be output to the touchpad and to the user.

[**0034**] In one application, the controlled apparatus can be a computer system such as Web-TV from Microsoft Corp. or other computing device which displays a graphical user interface and/or web pages accessed over a network such as the Internet. The user can control the direction of the cursor by moving a finger (or other object) on the touchpad **16**. The cursor can be used to select and/or manipulate icons, windows, menu items, graphical buttons, slider bars, scroll bars, or other graphical objects in a graphical user interface or desktop interface. The cursor can also be used to select and/or manipulate graphical objects on a web page, such as links, images, buttons, etc. Other force sensations associated with graphical objects are described below with reference to **FIG. 7**.

[**0035**] **FIG. 3** is a perspective view of a first embodiment **40** of a touchpad **16** of the present invention for providing haptic feedback to the user. In this embodiment, one or more piezoelectric actuators **42** are coupled to the underside of the touchpad **16**. The piezoelectric actuator **42** is driven by suitable electronics, as is well known to those skilled in the art. In one embodiment, a single piezoelectric actuator **42** is positioned at or near the center of the touchpad **16**, or off to one side if space constraints of the housing require such a position. In other embodiments, multiple piezoelectric actuators **42** can be positioned at different areas of the touchpad; the dashed lines show one configuration, where an actuator **42** is placed at each corner of the pad **16** and at the center of the pad.

[**0036**] The piezoelectric actuators **42** can each output a small pulse, vibration, or texture sensation on the touchpad **16** and to the user if the user is contacting the touchpad. The entire touchpad **16** is preferably moved with the forces output by actuator(s) **42**. Preferably, the forces output on the touchpad are linear (or approximately linear) and along the z-axis, approximately perpendicular to the surface of the touchpad **16** and the top surface of computer **10**. In a different embodiment, as mentioned above, forces can be applied to the touchpad **16** to cause side-to-side (e.g., x-y) motion of the pad in the plane of its surface in addition to or instead of z-axis motion. For example, one linear actuator can provide motion for the x-axis, and a second linear actuator can provide motion for the y-axis and/or the x-axis.

[**0037**] The frequency of a vibration output by an actuator **42** can be varied by providing different control signals to an actuator **42**. Furthermore, the magnitude of a pulse or vibration can be controlled based on the applied control signal. If multiple actuators **42** are provided, a stronger vibration can be imparted on the touchpad by activating two or more actuators simultaneously. Furthermore, if an actuator is positioned at an extreme end of the touchpad and is the only actuator that is activated, the user may experience a stronger vibration on the side of the touchpad having the actuator than on the opposite side of the touchpad. Different magnitudes and localized effects can be obtained by activating some but not all of the actuators. Since the tip of a user's finger that is touching the pad is fairly sensitive, the output forces do not have to be of a high magnitude for the haptic sensation to be effective and compelling.

[**0038**] Besides using a finger to contact the touchpad, the user may also hold other objects that directly contact the touchpad. Any haptic sensations output on the pad can be transmitted through the held object to the user's hand. For example, the user can hold a stylus having a point that contacts the touchpad **16** more precisely than a finger. Other objects may also be used. In some embodiments, specialized objects can be used to enhance the haptic sensations. For example, a stylus or other object having a flexible portion or compliance may be able to magnify at least some of the touchpad haptic sensations as experienced by the user.

[**0039**] The piezoelectric actuators **42** have several advantages for the touchpad **16**. These actuators can be made very thin and small, allowing their use in compact housings that are typical for portable electronic devices. They also require very low power, and are thus suitable for devices with limited power (e.g., powered by batteries). In some embodiments described herein, power for the actuators can be drawn off a bus connecting the computer to the touchpad (or touch screen). For example, if the touchpad **16** is provided in a separate housing, a Universal Serial Bus can connect the pad to the computer and provide power from the computer to the pad as well as data (e.g. streaming force data, force commands, etc.).

[**0040**] **FIG. 4** is a side elevational view of the embodiment **40** of the touchpad **16** of the present invention as shown in **FIG. 3**. Touchpad **16** is directly coupled to a grounded piezoelectric actuator **42** which operates to produce a force on the touchpad **16** when an electrical signal is input to the actuator. Typically, a piezoelectric actuator includes two layers which can move relative to each other when a current is applied to the actuator; here, the grounded