the button is moved to different elevations in correspondence with simulated elevations of graphical objects, displayed terrain features, etc.

Furthermore, the magnitude of output forces can depend on the event or interaction in the graphical environment. For example, the force jolt can be a different magnitude of force depending on the type of graphical object encountered by the cursor. For example, a jolts of higher magnitude can be output when the cursor moves over windows, while jolts of lower magnitude can be output when the cursor moves over icons. The magnitude of the jolts can also depend on other characteristics of graphical objects, such as an active window as distinguished a background window, file folder icons of different priorities designated by the user, icons for games as distinguished from icons for business applications, different menu items in a drop-down menu, etc.

User-independent events can also be relayed to the user using force sensations. An event occurring within the graphical user interface, such as an appointment reminder, receipt of email, etc., can be signified using a vibration, jolt, or other time-based force. The force sensation can be varied to signify different events of the same type. For example, vibrations of different frequency can each be used to differentiate different events or different characteristics of events, such as particular users sending email, the priority of an event, or the initiation or conclusion of particular tasks (e.g. the downloading of a document or data over a network).

The above-described force sensations can also be used in games or simulations where the mouse **12** is used as the primary input device. For example, a vibration can be output when a user-controlled racing car is driving on a dirt shoulder of a displayed road, and a jolt can be output when the car collides with another object. The magnitude of jolts can be based on the severity of a collision or explosion, the size of the controlled graphical object or entity (and/or the size of a different graphical object/entity that is interacted with), the velocity or acceleration of the mouse **12**, etc. Force sensations can also be output based on user-independent events in the game or simulation, such as jolts when bullets are fired at the user's character.

FIGS. **6***a* and **6***b* are perspective and side views, respectively, of another embodiment **200** of the force feedback pointing device of the present invention. In this embodiment, a cylinder controller is provided for a user to control a cursor or other graphical object or entity displayed on a computer screen. Controller **200** is preferably coupled to a host computer **14** as shown in FIG. **1** by a interface bus similar to bus **20** described above. Controller **200** can be mounted on a grounded surface or base **202**, which can be a keyboard housing allowing easy access to the controller when operating the keyboard. Or the surface can be a different base separate from the keyboard.

A switchbar **204** is flexibly coupled to the base **202** at a leg **203** so as to allow the switchbar to flex downward toward the base **202**. A contact switch **206** is provided on the base **202** and detects when the switchbar **204** is pressed downward by the user. Switch **206** can be any type of sensor as described for sensor **113** above. In addition, an actuator **208** is provided having a grounded portion **210** coupled to the base **202** (or ground) and a moving portion **212** coupled to the switchbar **204**. Actuator **208** is similar to actuator **18** described above, and can output forces on the switchbar in the degree of freedom along the Z axis, similar to the mouse button **16**. A local microprocessor **110** and the other components of FIG. **4** may also be included for embodiment **200**.

A bar **212** is slidably coupled to the base **202** and may translate left and right along the x-axis as shown by arrow **214**. The movement of bar **212** may be detected using a grounded sensor **216** which detects the motion of a member **218** that is rigidly coupled to the bar **214** and which is frictionally engaged with a rotating wheel **220** coupled to the sensor shaft. Barrier bar **215** is provided as a stationary surface with respect to the base **202**. A cylinder **222** is rotatably coupled between the base **202** and the switchbar **202**, and is preferably journalled in a U-shaped groove in the switchbar **202**. Cylinder **222** may rotate about axis A as shown by arrow **228** and may also translate along axis A parallel to the x-axis as shown by arrow **230**. The rotation of cylinder **222** can be detected by a sensor **224** that is connected to the cylinder **222** by a shaft **226**. The cylinder **222** can be provided with a member and sensor (not shown) similar to sensor **216** and member **218** to measure translatory movement of the cylinder shown by arrow **230**.

Controller **200** is preferably used as a pointing device to control the position of a cursor or other graphical object on a display device. In a preferred embodiment, the rotation of cylinder **222** causes a user-controlled cursor displayed by the computer **14** to be moved vertically in the host frame (on the computer screen), while translation of bar **214** or cylinder **222** causes the cursor to be moved horizontally in the host frame. Preferably, bar **214** can be translated independently of cylinder **222** to allow horizontal motion of the cursor without undesired vertical motion. The operation and structure of controller **200** to control a cursor is described in greater detail with respect to U.S. Pat. Nos. 4,896,554 and 5,235,868 of Culver, incorporated herein by reference.

Furthermore, the base **202** is preferably pressed downward by the user as a command gesture to send a command signal to the computer with similar effect as if a mouse button had been pressed as described above. Thus, if the user presses on base **202** directly, or presses on bar **214**, barrier bar **215**, or cylinder **222** to indirectly cause the base **202** to activate switch **206**, then a signal is sent to the host computer or local microprocessor. Buttons **232** can also be pressed by the user as second and third buttons to provide additional input signals to the host computer, as detected by switch **234**. These buttons can be provided with force feedback, if desired, using an actuator similar to actuator **208**, for example.

Using the actuator **18**, forces can be output on base **202**, cylinder **222**, and bar **214** similar to the forces output on mouse button **16***a* as described with respect to FIG. **5**. This allows bumps, jolts, textures, and other force sensations to enhance the user's interaction with graphical objects in a graphical user interface, game, or simulation while using the controller **200** at a low cost and complexity. In alternate embodiments, force feedback can also be added to one or more of the other degrees of freedom for the control of the cursor as shown by arrows **214**, **228**, and **230**.

While this invention has been described in terms of several preferred embodiments, it is contemplated that alterations, permutations and equivalents thereof will become apparent to those skilled in the art upon a reading of the specification and study of the drawings. For example, many different types of force sensations can be provided with the actuator of the present invention. Furthermore, certain terminology has been used for the purposes of descriptive clarity, and not to limit the present invention. It is therefore intended that the following appended claims include all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

What is claimed is:

1. A force feedback mouse coupled to a host computer implementing a host application program, said mouse physi-