sensing device. In other embodiments, such as a gamepad, the device **12** may be held by the user.

[**0034**] Computer **14** is coupled to the device **12** by a bus **20**, which communicates signals between device **12** and computer **14** and may also, in some preferred embodiments, provide power to the device **12**. Components such as the actuator assembly require power that can be supplied from a conventional serial port or through an interface such as a USB or Firewire bus. In other embodiments, signals can be sent between device **12** and computer **14** by wireless transmission/reception. In some embodiments, the power for the actuator can be supplemented or solely supplied by a power storage device provided on the device, such as a capacitor or one or more batteries. Some such embodiments are disclosed in U.S. Pat. No. 5,691,898, incorporated herein by reference.

[**0035**] Host computer **14** can be a personal computer or workstation, such as a PC compatible computer or Macintosh personal computer, or a Sun or Silicon Graphics workstation. For example, the computer **14** can operate under the Windows™, MacOS, Unix, or MS-DOS operating system. Alternatively, host computer system **14** can be one of a variety of home video game console systems commonly connected to a television set or other display, such as systems available from Nintendo, Sega, or Sony. In other embodiments, host computer system **14** can be a "set top box" or a "network-" or "internet-computer" which allows users to interact with a local or global network such as the Internet. Host computer preferably includes a host microprocessor, random access memory (RAM), read only memory (ROM), input/output (I/O) circuitry, and other components of computers well-known to those skilled in the art.

[**0036**] Host computer **14** preferably implements a host application program with which a user is interacting via device **12** and other peripherals, if appropriate, and which may include force feedback functionality. For example, the host application program can be a video game, word processor or spreadsheet, Web page or browser that implements HTML or VRML instructions, scientific analysis program, virtual reality training program or application, or other application program that utilizes input of device **12** and outputs force feedback commands to the device **12**. Herein, for simplicity, operating systems such as Windows™, MS-DOS, MacOS, Linux, Be, etc. are also referred to as "application programs." In one preferred embodiment, an application program utilizes a graphical user interface (GUI) to present options to a user and receive input from the user. Herein, computer **14** may be referred as providing a "graphical environment,", which can be a graphical user interface, game, simulation, or other visual environment. The computer displays "graphical objects" or "computer objects," which are not physical objects, but are logical software unit collections of data and/or procedures that may be displayed as images by computer **14** on display screen **26**, as is well known to those skilled in the art. A displayed cursor or a simulated cockpit of an aircraft might be considered a graphical object. The host application program checks for input signals received from the electronics and sensors of device **12**, and outputs force values and/or commands to be converted into forces output for device **12**. Suitable software drivers which interface such simulation software with computer input/output (I/O) devices are available from Immersion Corporation of San Jose, Calif.

[**0037**] Display device **26** can be included in host computer **14** and can be a standard display screen (LCD, CRT, flat panel, etc.), 3-D goggles, or any other visual output device. Typically, the host application provides images to be displayed on display device **26** and/or other feedback, such as auditory signals. For example, display screen **26** can display images from a GUI.

[**0038**] In alternative embodiments, the device **12** can instead be a different interface device or control device. For example, handheld devices are very suitable for the actuator assemblies described herein. A hand-held remote control device used to select functions of a television, video cassette recorder, sound stereo, internet or network computer (e.g., Web-TV™). Furthermore, a gamepad controller for video games or computer games can be used with the tactile feedback components and methods described herein, where the user grips the gamepad housing while operating buttons, joysticks, dials, spheres, or other controls on the gamepad. Other interface devices may also make use of the actuator assemblies described herein. For example, a joystick handle can include an actuator assembly, where tactile sensations are output on the joystick handle as the sole tactile feedback or to supplement kinesthetic force feedback in the degrees of freedom of the joystick. Trackballs, steering wheels, styluses, rotary knobs, linear sliders, gun-shaped targeting devices, medical devices, spheres, grips, etc. can also make use of the actuator assemblies described herein to provide haptic sensations.

[**0039**] **FIG. 2** is a side cross-sectional view of one embodiment of device **12** of **FIG. 1**. Device **12** includes one or more actuator assemblies for imparting haptic feedback such as tactile sensations to the user of the device. The actuator assembly outputs forces on the device which the user is able to feel.

[**0040**] Device **12** includes a housing **50**, a sensing system **52**, and an actuator assembly **54**. Housing **50** is shaped to fit the user's hand, in the example shown, like a standard mouse while the user moves the mouse in the planar degrees of freedom and manipulates the buttons **16**. Other housing shapes can be provided in many different embodiments.

[**0041**] Sensor **52** detects the position of the mouse in its planar degrees of freedom, e.g. along the X and Y axes. In the example shown, sensor **52** includes a standard mouse ball **64** for providing directional input to the computer system. Ball **64** is a sphere that extends partially out the bottom surface of the mouse and rolls in a direction corresponding to the motion of the mouse on a planar surface **22**. The ball motion can be tracked by cylindrical rollers **60** which are coupled to sensors, such as sensor **62**, for detecting the motion of the cylinders corresponding to x and y motion of the mouse. Other types of mechanisms and/or electronics for detecting planar motion of the device **12** can be used in other embodiments. For example, an optical sensor can be used to detect motion of the device relative to the planar support surface by optically taking and storing a number of images of the surface and comparing those images over time to determine if the mouse has moved, as is well known in the art.

[**0042**] Buttons **16** can be selected by the user as a "command gesture" when the user wishes to input a command