displays images of a game environment, operating system application, simulation, etc. Audio output device **164**, such as speakers, is preferably coupled to host microprocessor **160** provides sound output to user when an "audio event" occurs during the implementation of the host application program. Other types of peripherals can also be coupled to host processor **160**, such as storage devices (hard disk drive, CD ROM drive, floppy disk drive, etc.), printers, and other input and output devices.

[**0054**] The interface device, such as mouse **12**, is coupled to host computer system **14** by a bi-directional bus **20** The bi-directional bus sends signals in either direction between host computer system **14** and the interface device. Bus **20** can be a serial interface bus, such as an RS232serial interface, RS-422, Universal Serial Bus (USB), Firewire (1394), MIDI, or other protocols well known to those skilled in the art; or a parallel bus or wireless link. For example, the USB standard provides a relatively high speed interface that can also provide power to the actuator of actuator assembly.

[**0055**] Device **12** can include a local microprocessor **170**. Processor **170** is considered local to device **12**, where "local" herein refers to processor **170** being a separate microprocessor from any processors in host computer system **14**. Microprocessor **170** can be provided with software instructions to wait for commands or requests from computer host **14**, decode the command or request, and handle/control input and output signals according to the command or request. In addition, processor **170** can operate independently of host computer **14** by reading sensor signals and/or calculating appropriate forces from sensor signals, time signals, and stored or relayed instructions selected in accordance with a host command. Microprocessor **170** can include one microprocessor chip, multiple processors and/or co-processor chips, and/or digital signal processor (DSP) capability, or can be implemented as digital logic, state machines, ASIC, etc.

[**0056**] Microprocessor **170** can receive signals from sensor(s) **172** and provide signals to actuator assembly **174** in accordance with instructions provided by host computer **14** over bus **20**. For example, in a local control embodiment, host computer **14** provides high level supervisory commands to microprocessor **170** over bus **20**, and microprocessor **170** decodes the commands and manages low level force control loops to sensors and the actuator in accordance with the high level commands and independently of the host computer **14**. This operation is described in greater detail in U.S. Pat. No. 5,734,373, incorporated by reference herein. In the host control loop, force commands are output from the host computer to microprocessor **170** and instruct the microprocessor to output a force or force sensation having specified characteristics. The local microprocessor **170** reports data to the host computer, such as locative data that describes the position of the device in one or more provided degrees of freedom. The data can also describe the states of buttons, switches, etc. The host computer uses the data to update executed programs. In the local control loop, actuator signals are provided from the microprocessor **170** to actuator assembly **54** and sensor signals are provided from the sensor **172** and other input devices **184** to the microprocessor **170**. Herein, the term "tactile sensation" or "tactile effect" refers to either a single force or a sequence of forces output by the actuator assembly **54** which provide a sensation to the user. For example, vibrations, a single jolt or pulse, or a texture sensation are all considered tactile sensations. The microprocessor **170** can process inputted sensor signals to determine appropriate output actuator signals by following stored instructions. The microprocessor may use sensor signals in the local determination of forces to be output on the user object, as well as reporting locative data derived from the sensor signals to the host computer.

[**0057**] In a different, host-controlled embodiment, host computer **14** can provide low-level force commands over bus **20**, which are directly transmitted to the actuator assembly **54** via microprocessor **170** or other (e.g. simpler) circuitry. Host computer **14** thus directly controls and processes all signals to and from the device **12**, e.g. the host computer directly controls the forces output by actuator assembly **54** and directly receives sensor signals from sensor **172** and input devices **184**. In host control embodiments, the signal from the host to the device can be a single bit that indicates whether to pulse the actuator at a predefined frequency and magnitude; or can include a magnitude; and/or can include a direction; or, a local processor can be used to receive a simple command from the host that indicates a desired force value to apply over time; or a highlevel command with tactile sensation parameters can be passed to the local processor on the device which can then apply the full sensation independent of host intervention. A combination of numerous methods described above can also be used for a single device **12**.

[**0058**] Local memory **176**, such as RAM and/or ROM, is preferably coupled to microprocessor **170** in device **12** to store instructions for processor **170** and store temporary and other data. In addition, a local clock **178** can be coupled to the microprocessor **170** to provide timing data.

[**0059**] Sensors **172** sense the position or motion of the device (e.g. the housing or a manipulandum) in its degrees of freedom and provides signals to microprocessor **170** (or host **14**) including information representative of the position or motion. Sensors suitable for detecting motion of the device include digital optical encoders, other optical sensors, linear optical encoders, potentiometers, optical sensors, magnetic sensors, velocity sensors, acceleration sensors, strain gauge, or other types of sensors can also be used, and either relative or absolute sensors can be provided. Optional sensor interface **180** can be used to convert sensor signals to signals that can be interpreted by the microprocessor **170** and/or host computer system **14**, as is well known to those skilled in the art.

[**0060**] Actuator assembly **54** transmits forces to the housing of the device as described above with reference to **FIG. 3** in response to signals received from microprocessor **170** and/or host **14**. In the described embodiment, actuator assembly **54** is provided to generate inertial forces by moving an inertial mass; tactile forces can be generated in other ways in other embodiments. Actuator interface **182** can be optionally connected between actuator assembly **54** and microprocessor **170** to convert signals from microprocessor **170** into signals appropriate to drive actuator assembly **54**. Interface **182** can include power amplifiers, switches, digital to analog controllers (DACs), analog to digital controllers (ADCs), and other components, as is well known to those skilled in the art.

[**0061**] Other input devices **184** are included in device **12** and send input signals to microprocessor **170** or to host **14**