

FIG. 3 is a side cross-sectional view of a mouse embodiment of the haptic feedback device suitable for use with the present invention;

FIG. 4 is a perspective view of another embodiment 150 of interface device 12 suitable for use with the present invention.

FIG. 5 is a flow diagram of a method for pre-processing sound data in accordance with the present invention;

FIG. 6 is a diagrammatic illustration of a sound waveform and haptic sensations correlated with the sound waveform;

FIG. 7 is a flow diagram illustrating a process for playing back pre-processed sound data and haptic sensations in accordance with the present invention;

FIG. 8 is a flow diagram illustrating a real-time playback process of outputting haptic sensations in accordance with sound playback according to the present invention;

FIGS. 9a and 9b are diagrammatic illustrations showing sound and haptic waveforms in basic time vs. amplitude form for continuous haptic output in direct and inverse outputs, respectively;

FIG. 10 is a diagrammatic illustration of a graphical user interface which can allow the user to input preferences and settings as well as control sound playback for the present invention; and

FIG. 11 is a diagrammatic illustration of another graphical user interface which can allow the user to input preferences and settings for the present invention.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a block diagram illustrating a system 10 for providing sound data manipulation capabilities for the user enhanced with haptic feedback. A host computer 14 runs a sound data manipulation application program that allows a user 16 to manipulate sound data 15 by inputting commands to the host computer. To input these commands, the user 16 manipulates a haptic feedback interface device 12. Haptic feedback interface devices allow the user to input commands and data and also provide kinesthetic force feedback or tactile feedback to the user, more generally known herein as "haptic feedback." Using motors or other types of actuators, these interface devices can provide physical sensations which are felt by the user contacting the device or manipulating a user manipulandum of the device. For example, the device 12 can be a knob, a mouse, a trackball, a joystick, or other device which the user moves in provided degrees of freedom to input direction, value, magnitude, etc. While the user physically contacts the device 12 to provide input, he or she also can experience haptic sensations output by the haptic device 12. In the present invention, the haptic sensations are related to the editing and other sound manipulation features occurring in the application program of the host computer and allow the user to more easily perform the manipulation tasks and work with the sound data.

The host computer 14 also outputs signals to the audio speakers 24 to allow the user 16 to hear sound data that the user has selected to be played. The output of the sound data from the speakers, coordinated with a visual display of the host computer and the output of haptic sensations from the haptic device 12 allows the user to experience and note particular or preselected events in the sound data more easily. This allows the user to edit sound more easily by discerning such events through the sense of touch in addition to auditory and visual senses.

A haptic feedback device can handle input and output to a computer interface. This is very powerful for real-time

tasks in which quick and efficient human physical reactions are critical to success. Haptic feedback interfaces can improve user efficiency and accuracy while decreasing the cognitive load required to accomplish computer tasks. These types of results can be greatly beneficial to music creation and editing since one of the critical characteristics of an effective musical interface is that it allow the user to become immersed in the musical experience without being overly conscious of specific physical gestures. The present invention allows inexpensive haptic devices to be integrated into computer-assisted musical and sound editing and creation.

FIG. 2 is a block diagram illustrating one embodiment of the haptic feedback system of FIG. 1 including haptic feedback interface device 12 in communication with a host computer 14.

Host computer 14 preferably includes a host microprocessor 20, a clock 22, a display screen 26, and an audio output device 24. The host computer also includes other well known components, such as random access memory (RAM), read-only memory (ROM), and input/output (I/O) electronics (not shown). The host computer 14 is a computing device that can take a wide variety of forms. For example, in the described embodiments computer 14 is a personal computer or workstation, such as a PC compatible computer or Macintosh personal computer, or a Sun or Silicon Graphics workstation. Such a computer 14 can operate under the Windows™, MacOS™, Unix, MS-DOS, or other operating system. Alternatively, host computer 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, Sony, or Microsoft. In other embodiments, host computer system 14 can be a "set top box", a "network-" or "internet-computer", a portable computer or game device, a consumer electronics device (stereo component, etc.), PDA, etc.

Host computer 14 preferably implements a host application program with which a user is interacting via device 12 and other peripherals, if appropriate. In the context of the present invention, the host application program is a digital audio editing program, as described in greater detail below. Other application programs that utilize input of device 12 and output haptic feedback commands to the device 12 can also be used. The host application program preferably utilizes a graphical user interface (GUI) to present options to a user and receive input from the user. This application program may include the haptic feedback functionality described below; or, the haptic feedback control can be implemented in another program running on the host computer, such as a driver or other application program. 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. Suitable software drivers which interface software with haptic feedback devices are available from Immersion Corporation of San Jose, Calif.

Display device 26 can be included in host computer system 14 and can be a standard display screen (LCD, CRT, flat panel, etc.), 3-D goggles, projection device, or any other visual output device. Display device 26 displays images as commanded by an operating system application, simulation, game, etc. Audio output device 24, such as speakers, provides sound output to user. In the context of the present invention, other audio-related devices may also be coupled