

MEMORY AND FORCE OUTPUT MANAGEMENT FOR A FORCE FEEDBACK SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of co-pending parent patent application Ser. No. 08/970,953, filed Nov. 14, 1997 on behalf of Braun et al., assigned to the assignee of this present application, and which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates generally to interface devices for allowing humans to interface with computer systems, and more particularly to computer interface devices that allow the user to provide input to computer systems and provide force feedback to the user.

[0003] Computer systems are used extensively to implement many applications, such as word processing, data management, simulations, games, and other tasks. A computer system typically displays a visual environment to a user on a display screen or other visual output device. Users can interact with the displayed environment to perform functions on the computer, play a game, experience a simulated environment, use a computer aided design (CAD) system, etc. One visual environment that is particularly common is a graphical user interface (GUI), and include such systems as the Windows™ operating system from Microsoft Corporation, the MacOS operating system from Apple Computer, Inc., and X-Windows for the Unix operating system. Most GUI's are currently 2-dimensional as displayed on a computer screen; however, three dimensional (3-D) GUI's with 3-D environments can also be provided. Other graphical environments include games, simulations, CAD environments, World Wide Web/Internet interfaces, etc. which present 2-D or 3-D interactive environments manipulatable by the user.

[0004] The user interaction with and manipulation of the computer environment is achieved using any of a variety of types of human-computer interface devices that are connected to the computer system controlling the displayed environment. In most systems, an application program running on the host computer updates the environment in response to the user's manipulation of a user manipulandum that is included in the interface device, such as a mouse, joystick handle, track ball, steering wheel, etc. The computer provides feedback to the user utilizing the display screen.

[0005] Force feedback interface devices allow a user to experience forces on the manipulandum based on interactions and events within the displayed graphical environment. Force feedback devices can be implemented in many forms, such as a joystick, mouse, steering wheel, etc. Typically, computer-controlled actuators are used to output forces on the user object in provided degrees of freedom to simulate various sensations, such as an obstruction force when moving a cursor into a wall, a vibration force when a virtual race car drives off a race track, or a spring force to bias a cursor to move back toward a starting position of the spring.

[0006] Force sensations are usually commanded to be output on the device by the application program running on the host computer. Most consumer-market force feedback

devices include a microprocessor and memory to parse host commands and store and manage various force feedback effects local to the device. The device microprocessor can check user input and other conditions based on commands from the host, and can output force sensations using the force sensation data stored in local memory. The local management of force sensations on the device greatly increases the realism of generated force sensations due to the responsiveness of the device processing; if the host had to process all input and generate all forces, the transmission of data between host and device would cause delays in responsiveness that would seriously degrade the quality of force sensations. Thus, the ability of the device to store force sensation data and independently command those force sensations when conditions warrant is critical to realistic force feedback.

[0007] When providing force feedback sensations on a force feedback device, several issues arise as to the management of force feedback sensations. One problem is that the memory on the force feedback device is limited due to cost concerns. A device may only be able to store a certain limited number of force sensation data ("force effects") before the local memory is filled. An application program, however, may require a large number of different force effects to be output during different conditions and events in the program. For example, a racing game program may wish to output 20 different force effects for various racing conditions during a game; however, the device may only be able to store data for 10 force effects at a time.

[0008] Since data for a force effect should be stored local to the device before the force is output, the application program must first attempt to store effect data to the device. One existing way to store force effects on a device is for the host application to send a request to the device to store a specified force effect in device memory. The device determines if sufficient memory is available and responds to the host that either the requested force effect has been stored in device memory, or that the requested force effect could not be stored due to lack of sufficient space. If the effect could not be stored, the host application can send a "destroy" command to the device to remove a currently-unused force effect from device memory to free up sufficient room for the requested force effect, and then send the request again to store the new force effect. However, this method can cause some degradation in force quality on the device since the device and host must transmit data several times back and forth to free up device memory and store a new force effect.

[0009] In addition, since the device memory usually cannot store all the force effects which a host application wishes to use, the host application must spend processing time for memory management tasks. For example, the host application must determine whether to swap out an old force effect in device memory with a new force effect and then command that such a swap take place. The application must keep track of how much space is available in device memory and which force effects are currently being output. Such extra processing by the host application can degrade the overall performance of the application and compels the designer of the application to focus on low-level processing, thereby detracting from the higher-level force design process.

SUMMARY OF THE INVENTION

[0010] The present invention is directed to memory management of force effects and other management of force