text, or a magnifying icon is selected to enable zooming. However, these graphical metaphors can often be awkward, especially in view of the ease of such rate control tasks when using an isometric or elastic controller. Indeed, some users who have a great need for rate control tasks such as scrolling and zooming may simultaneously use both an isotonic controller such as a mouse and an isometric controller such as a Space Ball to allow maximum ease of use in interacting with the computer environment. However, the use of two separate controllers for computer interactions is often awkward and inconveniencing for the user.

In addition, existing isometric controllers are limited in that they are only input devices and are not able to provide active force feedback to a user. The user is thus not able to experience force feedback when manipulating the isometric controller which can be provided when manipulating an isotonic controller such as a joystick. The user is therefore missing potentially valuable and interesting force information and assistance in executing tasks in a graphical environment when using a traditional isometric controller.

There are a few commercial examples of isotonic controllers that have additional control modes usable for rate control tasks. One example is the SoftMouse from Immersion Corporation that has been available for a number of years. This is a standard mouse controller that has an additional thumb wheel that can be rotated to control zoom functions. Another example is the forthcoming Intellimouse from Microsoft®, which is a standard mouse controller having a finger wheel that may be rotated to control scrolling functions. Both of these are examples of poorly integrated multi-modal controllers because the additional modes are just add-ons to standard controllers. For example, add-on sensors are used to track the thumb wheels independently of standard mouse sensors. Also, different finger actions are required for each mode, e.g., moving a mouse to control one mode and turning a wheel to control another mode. And, like the isometric controllers, these types of controllers are input only controllers and are not able to provide computer-controlled output forces to a user.

What is needed is an integrated multi-modal controller where the same sensor and the same hand activities are used to implement multiple control modes. In addition, a seamless method to switch between modes is desirable to provide ease of use. Finally, a multi-modal device having force feedback provided by computer-controlled actuators in all available modes is needed for interactions of a user in a computer environment.

SUMMARY OF THE INVENTION

The present invention is directed to a force feedback interface which allows a user to provide both isotonic and isometric input to a host computer system. Isotonic input and force feedback is provided for position control tasks such as positioning a cursor or other graphical object, while isometric input is provided for easily performing rate control tasks.

More specifically, the present invention includes an interface device for providing isotonic and isometric input to a host computer system from a user. An interface device includes a user manipulatable physical object contacted by a user and movable in physical space. In the preferred embodiment, the physical object is a puck or mouse that can be moved in a planar workspace. A sensor detects the movement of the physical object in physical space and, preferably, an actuator applies output forces on the physical object. A mode selector is provided to select an isotonic control mode and an isometric control mode of the interface device. The isotonic mode provides input to the host computer system based on a position of the physical object in physical space with respect to a ground. The isometric mode provides input to the host computer system based on an input force applied by the user to the same physical object with respect to the same ground, where the input force is determined based on the movement detected by the sensor. In isometric mode, the input force applied by the user preferably opposes the output force applied by the actuator, and is preferably detected based on a measured deviation of the physical object in physical space from a locally-defined origin.

A method of the present invention similarly provides isotonic and isometric input from a user using a single interface device coupled to a host computer system that displays a graphical environment such as a graphical user interface (GUI). A selection of a control mode of the interface device is received, where the control mode is either isotonic control mode or isometric control mode. Isotonic input is provided to the host computer if the interface device is in isotonic mode, where the isotonic input is used by the host computer to update a position of a user-controlled graphical object in the graphical environment to correspond to a position of a user-manipulated physical object (such as a cursor) in provided degrees of freedom. The interface device is preferably in isotonic mode when the isometric mode is not active. Preferably, force sensations are applied to the physical object in isotonic mode based on interactions of the user-controlled graphical object in the graphical environment, where the force sensations assist and/or inform the user of interaction with graphical objects. A program function may be performed as indicated by the location of the cursor and a command gesture from the user.

Isometric input is provided to the host computer if the interface device is in isometric mode, where the isometric input is used by the host computer to control an isometric function of the graphical environment based on an input force applied by the user to the physical object. In a preferred embodiment, an indication is received to engage the isometric mode of the interface device. A local origin is defined with reference to a current position of the physical object in provided degrees of freedom. A deviation of the physical object from the local origin is determined, where this deviation is indicative of the user's input force, and a resistive force is applied to the physical object opposing the deviation. The resistive force is preferably a restoring force having a magnitude proportional to a magnitude of the deviation from the local origin and a direction towards the local origin. The determined deviation is used to control an isometric function of an application program or operating system implemented by the host computer. The isometric function can include such tasks as scrolling a displayed document, panning a displayed view, or zooming a displayed view. Optionally, in isometric mode, the host computer may display movement of the user-controlled graphical object corresponding to the deviation of the physical object.

In one embodiment, the control mode may be selected by the user activating an input device such as a physical button provided on the physical object. Alternatively, the control mode can be selected based on an interaction between a user-controlled graphical object, such as a cursor, and a different graphical object displayed by the host computer in a graphical environment. This interaction can include moving the user-controlled graphical object against an "isometric surface" of another graphical object. An indexing feature of the present invention allows the user to change the offset