

## TACTILE FEEDBACK INTERFACE DEVICE INCLUDING DISPLAY SCREEN

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 09/203,908, filed Dec. 1, 1998 now U.S. Pat. No. 6,256,011, which claims priority to provisional applications No. 60/067,382, filed Dec. 3, 1997 by Craig F. Culver, entitled "An Improved Multi-Function Control with Feedback," and No. 60/067,381, filed Dec. 3, 1997 by Craig F. Culver, entitled "Interactive Panels for Instrument Control," all of which are incorporated herein by reference.

### BACKGROUND OF THE INVENTION

This invention relates generally to control devices, and more particularly to force feedback control devices.

Control devices can be used for a variety of different control tasks. A user can conveniently select or operate different functions and features of a device using the control device. In some cases, the control device allows a user to operate or interface with a device remotely, without having to operate controls located on the housing of the device itself. For example, signals can be sent from the remote control device to the controlled apparatus. In addition, the control device preferably offers a more intuitive and easy-to-use way of interfacing with a device than using other inconvenient, bulky, or unintuitive controls.

Control devices can be implemented in a variety of forms. In hand-held embodiments, it is desirable for control devices to be lightweight and convenient to hold, and to include controls that are straightforward to use, comfortable, and effective in controlling the features or operation of a device. Typical control devices of the prior art, however, may not include all these features. For example, a standard joystick device may not be very convenient for use in controlling functions since it either requires two hands to operate (one hand holding the device, the other hand operating the joystick), or it requires a table top or other surface on which to rest the joystick. Some attempts have been made to develop one-handed joysticks, but these devices often end up clumsy and ineffective. Similarly, gamepad controllers, commonly used to interface with video games provided by game consoles, require the use of two hands and are thus inconvenient in many applications.

In embodiments where a device is not hand-held, there is still a need for a controller device having superior precision, ergonomics, and convenience. Furthermore, such a device that can readily include force feedback functionality is also desirable.

### SUMMARY OF THE INVENTION

The present invention provides a control device that allows a user to interface with an apparatus in a convenient and effective manner. The control device can also be provided with force feedback for added functionality and efficiency.

More particularly, a control device of the present invention includes a housing and a carrier coupled to the housing and operative to move with respect to the housing in a first rotary degree of freedom. A first sensor senses the movement of the carrier and outputs a first control signal. A roller rotatably coupled to the carrier rotates with the carrier in the first degree of freedom and rotates independently of the

carrier in a second rotary degree of freedom. A second sensor senses rotary motion of the roller and outputs a second control signal. Preferably, an arm member is coupled between the carrier and the housing, where the arm member pivots about an axis and where the first sensor senses rotation of the arm member. The roller rotates about an axis that is parallel to a plane of rotation of the arm member. The arm member can be positioned in the housing, where the housing includes an aperture through which the carrier and roller are accessible to a user of the control device. Preferably, a third sensor is also included to detect when the carrier has been pushed in a direction substantially orthogonal to a plane of rotation of the arm member.

In another embodiment, force feedback functionality is preferably included in the control device. For example, a first actuator is preferably coupled to the arm and outputs a force on the arm in its degree of freedom. A second actuator can be coupled to the roller to output a force to the roller in its rotary degree of freedom. The first and second actuators are controlled by first and second actuator signals. The control device interfaces with an apparatus; the apparatus, for example, can be a host computer that provides force feedback signals to the control device based at least in part on the first and second sensor signals received from the control device. For example, the host computer can display a graphical environment, such as graphical user interface or game environment, in which a user-controlled graphical object is displayed, such as a cursor, having a position determined by the first and second sensor signals. Other graphical objects may also be displayed. In one embodiment, the first and second force feedback signals are determined at least in part based on an interaction of the cursor with a displayed graphical object.

A number of alternate embodiments of the control device are also provided. A second roller can be coupled to the carrier and rotate with respect to the carrier independently of the first roller. Another sensor is provided to sense rotary motion of the second roller. The second roller can be oriented in the same direction as the first roller, or can be oriented orthogonally or in other configurations. Furthermore, a belt can be coupled between the first and second rollers which is accessible to be contacted and moved by the user. A rotating member, such as a cylinder or sphere, can be coupled to the housing and extend from a bottom plate of the housing, such that the rotating member contacts a flat surface and rotates when the control device is moved over the flat surface. The carrier can alternatively be coupled to the housing by contact bearings which sit in tracks on the housing and allow the carrier to move along the tracks.

The device and method of the present invention provide an interface to an apparatus that provides greater control functionality and convenience for the user. The arcuate or linearly moving carrier portion is easily moved by a user's thumb, providing horizontal control over a cursor or other input. The rotatable wheel provided in the carrier allows the same finger of the user to control vertical motion of a cursor or control a different function of an apparatus. However, since the wheel rotates in a single position, the length of the carrier arm need not be adjusted greatly for differently-sized hands. Force feedback may also be added to the control device to provide the user with greater control and to inform the user of options and selections through the sense of touch.

These and other advantages of the present invention will become apparent to those skilled in the art upon a reading of the following specification of the invention and a study of the several figures of the drawing.