

a human interface control device, such as a button or a controller, and a system including the tactile feedback apparatus as a human interface control apparatus.

[0016] It is a further object of the present invention to provide a tactile feedback apparatus that is able to present a larger force feedback that may readily be recognized by the user.

[0017] It is yet another object of the present invention to provide a tactile feedback apparatus in which the tactile feedback presented may be correlated with the force applied from the user.

MEANS FOR SOLVING THE PROBLEMS

[0018] The present invention provides a tactile feedback apparatus comprising an interfacing element acted on by a user, and a piezo actuator arranged on the interfacing element for presenting tactile feedback to a user acting on the interfacing element. The piezo actuator has a circular-shaped multi-layered structure and has a shape changed to an upturned dome shape or to a downturned dome shape on application of voltages of opposite polarities to a plurality of layers in an upper portion of the multi-layered structure and to a plurality of layers in a lower portion of the multi-layered structure.

[0019] At least one of the amplitude and the frequency in a change between the upturned dome shape and the downturned dome shape is determined depending on a user's input mediated by the interfacing element.

[0020] The tactile feedback apparatus may further include a force sensor for detecting the force applied at the time of the inputting operation by a user. Preferably, the tactile feedback presented to the user is correlated with the force detected. Specifically, it is more preferred that at least one of the amplitude and the frequency in a change between the upturned dome shape and the downturned dome shape is determined depending on the force as detected by the force sensor or on the user's input applied via the interfacing element. Hence, with the tactile feedback apparatus according to the present invention, the user can feel the tactile response changing with the magnitude of the force applied by the user.

[0021] The interfacing element, used in the tactile feedback apparatus according to the present invention, may be exemplified by a joystick type operating device of a controller for playing a game, and a button or a switch provided to a large variety of consumer apparatus in need of such button or switch.

[0022] The present invention also provides a system comprising a main body part executing an application program and a user interface program and a control device mounted in separation from the main body part and adapted for controlling the state of the application program. In the system of the present invention, the control device includes an interfacing element acted on by a user and a piezo actuator arranged on the interfacing element for presenting tactile feedback to a user acting on the interfacing element. The piezo actuator has a circular-shaped multi-layered structure and has a shape changed to an upturned dome shape or to a downturned dome shape on application of voltages of opposite polarities to a plurality of layers in an upper portion

of the multi-layered structure and to a plurality of layers in a lower portion of the multi-layered structure.

[0023] The tactile feedback apparatus according to the present invention has the following configuration.

[0024] That is, the tactile feedback apparatus includes

(a) a human interface controller directly acted on by a user's finger, such as a switch, button or a joystick;

(b) a circular-shaped single-layer or multi-layer piezo actuator mounted to the human interface controller;

(c) a hardware component and a software system for generating driving signals of an optional waveform for generating optional vibrations in the piezo actuator; and

[0025] (d) another software system for accepting inputs from the human interface controller and for controlling the hardware component and the software system, responsive to the current status of the user interface/application program for presenting proper tactile feedback to the user.

[0026] The above software systems may be implemented by a computer executing a proper application program.

FAVORABLE EFFECT OF THE INVENTION

[0027] According to the present invention, there may be provided a tactile feedback apparatus, particularly applicable to a human interface control device, such as a button or a controller, and a system including this tactile feedback apparatus as a human interface control apparatus.

[0028] According to the present invention, there may be provided a tactile feedback apparatus that is able to present larger tactile feedback that may readily be recognized by the user.

[0029] According to the present invention, there may be provided a tactile feedback apparatus in which the force applied by the user may be correlated with the tactile feedback.

[0030] Other objects and specified advantages of the present invention will become more apparent from the following explanation of preferred embodiments thereof especially when read in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. 1 is a schematic block diagram showing a system employing a tactile feedback apparatus according to the present invention.

[0032] FIG. 2 is a schematic block diagram showing another example of the system employing a tactile feedback apparatus according to the present invention.

[0033] FIG. 3A is a perspective view showing a piezo actuator according to the present invention, FIG. 3B is a perspective view showing the state in which the piezo actuator according to the present invention is bowed upwards and FIG. 3B is a perspective view showing the state in which the piezo actuator according to the present invention is bowed downwards.

[0034] FIG. 4 is a cross-sectional view showing an example of an operating unit used in the tactile feedback apparatus according to the present invention.