

[0035] FIG. 5 is a perspective view showing another example of an operating unit used in the tactile feedback apparatus according to the present invention.

[0036] FIG. 6 is a perspective view showing an example of a control device for a game according to the present invention.

#### BEST MODE FOR CARRYING OUT THE INVENTION

[0037] Referring to the drawings, preferred embodiments of the present invention will be explained in detail.

##### (1) System Structure

[0038] Referring to FIG. 1, an example of system structure employing the present invention will be explained. As shown in FIG. 1, the present system includes a main body part 10, an operating unit 20 on which a user acts by way of an inputting operation for interfacing with the main body part 10, and a display part 30 for demonstrating an image consistent with the current state of the interface and the application program.

[0039] The operating unit 20 includes an interfacing element 22, accepting the user's inputting operation, and a piezo actuator 21 for generating tactile feedback for a user performing an inputting operation on the operating unit 20. Details and a concrete structure of the piezo actuator 21 will be explained subsequently. The interfacing element 22 is any optional user interface controller, such as a button or a joystick.

[0040] It is more preferred that the piezo actuator 21 is mounted on the interfacing element 22. However, the structures of the piezo actuator 21 and the interfacing element 22 are not limited to any particular structures and may be of any suitable type on the condition that tactile feedback such as mechanical vibrations generated in the piezo actuator 21 may thereby be transmitted to the user's finger or hand performing an inputting operation on the operating unit 20.

[0041] The main body part 10 includes an interface controller 12, receiving a signal output from the interfacing element 22 responsive to the user's inputting operation, a tactile feedback controller 11 for driving controlling the piezo actuator 21, and an application program-user interfacing unit 13 for executing an application program and a user interface program and for outputting a control signal controlling the movement of the piezo actuator 21 to the tactile feedback controller 11 responsive to the user's inputting operation. The application program-user interfacing unit 13

[0042] In the system shown in FIG. 1, in case a user performs an inputting operation on the interface controller 12, via interfacing element 22, such as by pressing a button or causing movement of the joystick, the user is provided with a tactile feedback from the piezo actuator 21. This piezo actuator 21 is controlled by the tactile feedback controller 11 generating a control signal. This control signal is a voltage signal, which is a function of time, and which may be of an amplitude, a waveform and a period as determined by an interface implementer determining which tactile feedback is to be presented to different inputting operations. The control signal may, for example, be a rectangular wave or a sine wave.

[0043] The control signal may be generated from the application program and from the user interface program, responsive to an input signal from the interface controller 12. The control signal is generated in keeping with the current state of the application program and the user interface program exploited in the present system.

[0044] FIG. 2 shows a modification of the system embodying the present invention. The system shown in FIG. 2 includes, in addition to the elements included in the system of FIG. 1, a force sensor 23 and a force measurement unit 14, for detecting the force applied to the interfacing element 22 by the user. The force sensor 23 may be comprised of a pressure sensor or any other suitable sensor capable of directly or indirectly detecting the user's force.

[0045] In the system of FIG. 2, the force at the time of the inputting operation is measured by the force measurement unit 14 and sent to the application program-user interfacing unit 13 along with the signal from the interface controller 12. The tactile feedback, presented by the system of the present invention, is correlated with the force applied by the user to the operating unit 20, such as a button or a joystick for playing a game.

##### (2) Components and Structure of the Tactile Interface

[0046] The piezo actuator 21 is a source of motive power for tactile feedback and includes a single layer or plural layers of piezoelectric elements having a shape corresponding or conforming to the shape of the interfacing element 22.

[0047] FIG. 3A shows an example of the piezo actuator 21. In this particular example, the main component of the piezo actuator 21 is a bowed circular multi-layered piezo actuator having a multi-layered structure of a thin-filmed piezo-ceramic material, with electrodes sandwiched between neighboring actuator layers.

[0048] The piezo actuator 21, shown in FIG. 3A, is e.g. of the bimorph type, made up by an upper actuator unit 21a and a lower actuator unit 21b, each having an electrode sandwiched in-between.

[0049] The piezoelectric material is expanded or contracted, depending on the direction of the voltage applied. When the voltages of opposite polarities are applied to the upper actuator unit 21a and to the lower actuator unit 21b, one of the units is contracted, while the other is expanded, as a result of which the piezo actuator 21 has its upper section or lower section expanded on the whole to assume a dome-like shape. In FIG. 3A, the piezo actuator 21 is shown in a neutral state in which no voltage is applied to the piezo actuator 21. In FIGS. 3B and 3C, the piezo actuator 21 is shown in a bowed state in which it is bowed responsive to application of voltages of opposite polarities.

[0050] The piezo actuator 21, shown in FIGS. 3A to 3C, is of a circular shape. However, the piezo actuator 21 of the present invention is not limited to this particular shape. The piezo actuator 21 may be of an elliptical or any other suitable shape, if the piezo actuator may be mounted on the interfacing element 22 as later explained and may be changed in shape to present an upwardly or downwardly bowed dome shape responsive to a driving signal applied.

[0051] The electrodes for supplying driving signals to the respective layers of the piezo actuator 21 are mounted on a peripheral or central area of the circular piezo actuator 21,