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(54) Title of Invention
INFORMATION DISPLAY DEVICE
AND OPERATION INPUT DEVICE

(57) Abstract
[Problem] To provide an information display device with a small number of operating surface and display surface peripheral parts providing a reliable sense of operation and enabling a tracing operation without a push stroke.

[Resolution Means] An operating panel 10 is arranged on a liquid crystal display panel 20, and the operating panel 10 is supported by piezoelectric elements E1 through E4. Pressing an operating surface 11 of the operating panel 10 with a finger generates voltage at both ends of the piezoelectric elements E1 through E4, and an operating force and an operating position are sensed by detecting and calculating said voltage. High frequency is applied to the piezoelectric elements E1 through E4 when an operating force larger than a predetermined threshold is sensed, which thus causes the operating surface 11 to vibrate. This vibration allows an operator to obtain a reliable sense of operation. The number of parts is small because the sensing of the operating force applied to the operating surface and the application of the vibration to the operating surface 11 are performed using the common piezoelectric elements E1 through E4. Furthermore, a tracing operation is made possible because an operating force smaller than the predetermined threshold causes no reaction.
The present invention relates to an information display device and an operation input device used in, for example, factory automation (FA) devices, automatic vending machines, automatic ticket vending machines, automatic teller machines, home appliances, medical operating equipment, information equipment, handheld terminals, game devices, and the like.

Devices where a touch panel is arranged on a display are in wide use as one type of information display device having an operation input function. Touch panels are extremely thin, and have the advantage of providing a high degree of freedom for selecting an area that can be used as a switch.

Conversely, however, because the push stroke of touch panels is nearly zero, said panels lack a sense of touch (sense of operation) for indicating that operation inputs have been performed, such that operators are often left with a sense of doubt over whether operation inputs have actually been received on a device side.

To counter such circumstances, schemes have been devised whereby a visual reaction, such as changing or flashing a display color of an operation location, or an auditory reaction, such as generating an electronic sound, is generated when an operation input is actually received.

However, there is a problem with devices using visual reactions in that the display color change cannot be seen due to being hidden by a finger of an operator. Furthermore, visually impaired individuals, like as those suffering from amblyopia, and the like, will find it difficult to confirm changes if the display color change is subtle.

Moreover, with devices using auditory reactions, electronic sounds can be drowned out by ambient noise and go unheard. The electronic sound can be made louder to remedy this; however, if this is done, for example, in a location where a plurality of automatic ticket vending machines are lined up together, it can be impossible to tell which automatic ticket vending machine the sound is coming from. Additionally, making the electronic sound excessively loud in the case of a mobile phone can be an imposition on individuals in the vicinity of said phone. Furthermore, deaf people cannot hear reactions created using electronic noises.

While cases of devices using touch panels were described above, these problems are common to all information display devices having operating units that lack substantive push strokes, and are thus not limited to information display devices using touch panels.
The present invention was created to solve conventional technical problems like those described above, and thus a first object thereof is to provide an information display device able to give a reliable sense of operation even though an operating unit lacks a substantive push stroke. [0009]

A second object of the present invention is to realize a simple information display device where the number of parts in the vicinity of a display surface or an operating surface have been reduced. [0010]

Furthermore, a third object of the present invention is to permit an operating method (tracing operation) for reaching a target operating region by sliding a finger on the display surface, and to make it so that a device side does not erroneously display a reaction before an actual pressing operation can be performed in the target operating region during such a tracing operation. [0011]

Additionally, a fourth object of the present invention is to differentiate between a reaction from a location where a pressing operation was performed and a reaction from a device side caused by an operating force, to thus provide a varied sense of operation. [0012]

Moreover, a fifth object of the present invention is to provide a device having a large area for a display surface and an operating surface. [0013]

Finally, one object of the present invention is to provide an operation input device that uses the principle of realizing an information display device like that described above.

[FUNDAMENTAL PRINCIPLE OF THE INVENTION]

[0014]

In response to the first object described above, the present invention uses a mechanical reaction such as a vibration or a small displacement, and the like, of an operating surface as a response to an operation input from a device side. For example, the operating surface can be vibrated using a piezoelectric element (that is, a piezoelectric vibrator or a piezo element) to thus give an operator a reliable sense of operation. [0015]

By the way, sensing an operation input to an operating surface is a fundamental requirement for an information display device having an operation input function. Therefore, a device configured to generate a mechanical reaction like a vibration, and the like, in an operating surface must have a function for sensing an operation input and a function for generating the mechanical reaction. [0016]

Thus, the inventors of the present invention focused on the fact that a piezoelectric element is a function means (hereinafter referred to as a bi-directional function means) able to convert a mechanical action and an electrical signal in two directions. That is, a mechanical reaction such as a vibration, and the like, is generated when an electrical signal is applied to such a bi-directional function means while, on the other hand, an electrical reaction such as voltage, and the like, is generated when a pressing force is applied to said bi-directional function means. [0017]

Thus, realizing both an operation sensing function and a mechanical reaction generating function through one (or one set of) bi-directional function means through an aggressive use of the characteristics of such bi-directional function means is a fundamental principle of the present invention. [0018]
That is, with the present invention, of the various functions of the bi-directional function means, an operation input is sensed through a “function for converting mechanical pressure into voltage (or current),” and a mechanical reaction is generated in an operating surface through a “function for converting voltage (or current) into a mechanical reaction.”

By this, a reliable sense of operation can be given without increasing the number of parts.

[SPECIFIC CONFIGURATION FOR SOLVING THE PROBLEM]

The information display device of the invention according to claim 1 configured in accordance with the principle described above provides; (a) an information display surface, (b) a transparent or semi-transparent operating unit having a predetermined operating surface arranged on the information display surface, (c) bi-directional function means coupled with the operating unit able to convert a mechanical action and an electrical signal in two directions, (d) operating signal extracting means for extracting an electrical signal generated by the bi-directional function means through an operating force applied to the operating surface as an operating signal; and (e) drive control means for sending an electric drive signal to the bi-directional function means in response to the operating signal.

Furthermore, a mechanical reaction generated by the bi-directional function means through the drive signal is transmitted to the operating surface and is captured as a sense of touch of an operator.

In the invention according to claim 2, the drive control means in the information display device according to claim 1 has (e-1) operating signal determining means for comparing the operating signal to a predetermined threshold and sending the drive signal to the bi-directional function means when the operating signal exceeds the threshold.

In the invention according to claim 3, the operating signal determining means in the information display device according to claim 2 changes the mode of the drive signal in accordance with the size of the operating signal.

In the invention according to claim 2, the bi-directional function means in the information display device according to claims 1 through 3 has, (c-1) a plurality of unit function means spatially arranged mutually separated from one another each able to convert a mechanical action and an electrical signal in two directions, and the information display device also has, (f) position signal generating means for generating a position signal expressing an operating position on the operating surface based on a plurality of electrical signals generated by the plurality of unit function means through an operating force applied to the operating unit.

In the invention according to claim 5, the information display device according to claim 4 has three or more unit function means arranged and dispersed two-dimensionally as the plurality of unit function means.

In the invention according to claim 6, the operating surface in the information display device according to claim 5 is a rectangular surface, and the information display device has four unit function means arranged more or less at the four corners of the rectangular surface as the plurality of unit function means.
The invention according to claim 7 is the information display device according to any one of claims 1 through 3, where the operating means has, (b-1) a touch panel for generating a position signal corresponding to an operating position on the operating surface.

[0028] The invention according to claim 8 is the information display device according to any one of claims 4 through 7 where the drive control means changes the threshold for the operating signal based on the position signal.

[0029] The invention according to claim 9 is the information display device according to any one of claims 4 through 7 where the drive control means changes the mode of the drive signal based on the position signal.

[0030] The invention according to claim 10 is the information display device according to any one of claims 2 through 9 also having, (g) logic gate means for transmitting the generation of the position signal to predetermined information processing means when the operating signal exceeds the threshold.

[0031] The invention according to claim 11 is the information display device according to any one of claims 1 through 10 where the bi-directional function means includes a piezoelectric element.

[0032] In the invention according to claim 12, the information display device according to any one of claims 1 through 10 is housed in a portable housing having a predetermined main surface, and the operating surface is exposed on the main surface and is made portable.

[0033] The invention according to claim 13 is the information display device according to claim 12 also having one or a plurality of operating switches arranged securely on a surface other than the main surface of the housing for receiving an operation based on content displayed on the display surface.

[0034] The invention according to claim 14 was configured with a focus on the characteristics of an operating position caused by the detection of a pressing force in the inventions according to claims 1 through 13.

[0035] That is, the information display device of the invention according to claim 14 has, (a) an information display surface, (b) a transparent or semi-transparent operating unit having a predetermined operating surface arranged on the information display surface, (c) a plurality of unit function means arranged spatially dispersed in a range so as to be coupled with the operating unit, each capable of converting a mechanical action into an electrical signal, (d) operating signal extracting means for extracting an electrical signal generated by the plurality of unit function means through an operating force applied to the operating surface as a plurality of operating signals, and (e) position signal generating means for generating a position signal expressing an operating position on the operating surface based on the plurality of operating signals.

[0036] Furthermore, the invention according to claim 15 was configured with a focus on the detection of a pressing force and a portion of a mechanical reaction caused thereby without regard to the presence or absence of a display surface in the inventions according to claims 1 through 13.

[0037] That is, the operation input device has, (a) an operating unit having a predetermined operating surface, (b) bi-directional function means coupled with the operating unit able to
convert a mechanical action and an electrical signal in two directions, (c) operating signal extracting means for extracting an electrical signal generated by the bi-directional function means through a pressing force applied to the operating surface, and (d) drive control means for sending a drive signal to the bi-directional function means in response to the operating signal.

Furthermore, a mechanical reaction of the bi-directional function means caused by the drive signal is transmitted to the operating surface as a sense of touch of an operator.

Moreover, the invention according to claim 16 is an invention where the configuration of the invention according to claim 14 has been added to the invention according to claim 15. Specifically, the bi-directional function means has, (b-1) a plurality of unit function means arranged spatially dispersed in a range so as to be coupled with the operating unit, each capable of converting a mechanical action into an electrical signal. Furthermore, the operating signal is obtained as a plurality of unit operating signals generated by the plurality of unit function means, respectively, and the operation input device has, (e) position signal generating means for generating a position signal expressing an operating position on the operating surface based on the plurality of operating signals.

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 is a drawing illustrating an example of a system incorporating an information display device 100 of a first embodiment according to the present invention.
FIG. 2 is a view of the exterior of the information display device 100.
FIG. 3 is a partially omitted cross sectional view illustrating a portion corresponding to the display operating unit DP in cross section III - III in FIG. 2.
FIG. 4 is a see-through plan view seen from direction IV in FIG. 3.
FIG. 5 is a view of a basic model for describing the principle of sensing a pressed operating region using piezoelectric elements.
FIG. 6 is a view of a model for describing the principle of sensing a pressed operating region in a first embodiment using piezoelectric elements.
FIG. 7 is a block diagram of a control circuit CT in the first embodiment.
FIG. 8 is an internal block diagram of an operation unit 51.
FIG. 9 is a descriptive drawing of the apex coordinates of an operating region.
FIG. 10 is an internal block diagram of a comparing and determining unit 52a.
FIG. 11 is a descriptive diagram of operating force classifications F0 through F4.
FIG. 12 is an internal block diagram of an operating force determining unit 54.
FIG. 13 is an internal block diagram of a drive mode selecting unit 72.
FIG. 14 is a diagram schematically illustrating a variety of modes stored in a drive mode storage unit 73.
FIG. 15 is a partially omitted cross sectional view illustrating a portion equivalent to a display operating unit DP of an information display device that is a second embodiment of the present invention.
FIG. 16 is a configuration diagram of a control circuit CT using the display operating unit DP in FIG. 15.
FIG. 17 is a perspective drawing of the exterior of an information display device 200 according to a third embodiment of the present invention.
FIG. 18 is a plan view of the information display device 200.
FIG. 19 is a rear view of the information display device 200.
FIG. 20 is a diagram illustrating another example that can be used as the information display device according to the present invention.
[DESCRIPTION OF THE PREFERRED EMBODIMENTS]

<1. First Embodiment>

<1-1. Device Overview>

FIG. 1 is a perspective view of an automatic teller machine (ATM) 1 as an example of a system incorporating an information display device 100 of a first embodiment of the present invention. The automatic teller machine 1 is provided with a cashier section 3 and a card and bank passbook insertion section 4 on a front surface of a chassis 2. The machine is also provided with an information input and output section 5, and the information display device 100 is used in the information input and output section 5.

FIG. 2 is a view of the exterior of the information display device 100. In the use example illustrated in FIG. 1, the information display device 100 is arranged with a main surface thereof facing substantially upward, however, FIG. 2 illustrates a view of the information display device 100 in a standing state.

In FIG. 2, the information display device 100 is provided with a substantially box-like housing 101, and the portion housed in this housing 101 is divided mainly into a display operating unit DP facing an operator side, and a control circuit unit CT on the back side thereof.

A substantially rectangular operating surface 11 is exposed on a main surface MS of the housing 101. The operating surface 11 is either transparent or semi-transparent, and thus contents displayed on an information display surface 21 (see FIG. 3) can be viewed through the operating surface 11. Furthermore, a fixed push button switch 102 is also arranged on the main surface MS.

FIG. 3 is a partially omitted cross sectional view illustrating a portion corresponding to the display operating unit DP in cross section III - III in FIG. 2. Furthermore, FIG. 4 is a see-through plan view seen from direction IV in FIG. 3. In FIG. 3, the display operating unit DP houses a liquid crystal display panel 20 in a case 40 having a window 41, and the main surface of the liquid crystal display panel 20 serves as the information display surface 21.

As illustrated in FIG. 4, four piezoelectric elements E1 through E4 are arranged, one adjacent to each of the four corners of the liquid crystal display panel 20. The piezoelectric elements E1 through E4 are unit function means serving as elements of bi-directional function means able to convert mechanical actions and electrical signals in two directions. These piezoelectric elements E1 through E4 are fixed to a bottom surface of the case 40 in FIG. 3, and the apex portions thereof provide support at areas near the four corners of a transparent or semi-transparent operating panel 10. The operating panel 10 is, for example, a glass plate, an acrylic plate, or the like, having a substantially rectangular planar shape.

While a variety of information can be displayed on the liquid crystal display panel 20, the example in FIG. 4 illustrates menus of a bank automatic cashier. Regions R1 through R7 displayed by these menus serve as operating regions for bank users. For example, when a bank user presses on region R1 displaying “Deposit” with his or her finger using at least a
predetermined amount of force, the information display device 100, through an operation
described below, senses that “Deposit” has been selected, notifies the bank host computer of this,
and then assumes a state in which cash can be accepted. Furthermore, at the same time, the
information display surface 21 changes to a screen displaying guidance and a new operating
menu for accepting the cash. Note that the size and placement of these operating regions R1
through R7 can be set randomly. Furthermore, region R0 in FIG. 4 illustrates a region in the
information display surface 21 that is outside the operating regions R1 through R7.

Moreover, the piezoelectric elements E1 through E4 in FIG. 3 are used in the device
of the first embodiment as elements combining both sensing means for sensing whether a
bank user has pressed any of the operating regions R1 through R7, and driving means for
gently vibrating the operating panel 10 based on said pressing.

<1-2. Principles for Sensing the Operating Position>

Before describing the rest of the configuration of this device, the principles by
which the piezoelectric elements E1 through E4 are used to sense which of the operating
regions R1 through R7 have been pressed will be described.

FIG. 5 is the diagram of a model for describing this principle, where FIG. 5(a) illustrates
an operating panel 10M having any two-dimensional shape, and n number of piezoelectric
elements E1 through En arrayed near the periphery of said operating panel. Furthermore, FIG.
5(b) is an elevation of the operating panel. Here, the number n is an integer of at least 3.

Furthermore, a rectangular coordinate system XYZ is defined with any point being a
point of origin O such that a plane parallel to the plate surface of the operating panel 10M
becomes surface XY. Moreover, a case is imagined where the operating panel 10M is pressed
downward at a position at point P (x and y) with a pressing force F. At this time, the principle
for sensing (x and y), which are the XY coordinates of point P, using the function of the
piezoelectric elements E1 through En, is as described below. Note that it is self evident that
the Z coordinate for point P is above the plate surface of the operating panel 10M, and that it
is not necessary to specifically derive the Z coordinate for point P because it is enough to
know the XY direction operating position in the operating panel 10M.

First, when the XY coordinates of a piezoelectric element Ek (k = 1 to n) are
assumed to be (xk and yk), these are known values based on the design. Furthermore,
because voltage is generated at both ends of each piezoelectric element E1 through En
when pressure is applied through the bi-directional conversion function thereof, a force k (k
= 1 to n) applied to these piezoelectric elements E1 through En can be known. When seen
from the operating panel 10M, this force f1 to fn is a reaction that works upward.

At this time, from a Z direction force equilibrium taking into account a pressing
force F with respect to the operating panel 10M having a weight W and a force f1 to fn
applied to the piezoelectric elements E1 through En,

\[ F + W - \sum f_k = 0 \]

is established. However, the summation symbol \( \Sigma \) in this equation and in each of the
following equations indicates the sum of 1 through n for subscript k.

Next, from an equilibrium of a force momentum around the X axis and around the Y axis,
When Number 1 and Number 2 are transformed, they become

Number 4: \[ x = - \frac{\sum f_k \cdot x_k + W \cdot x_0}{F}, \]

Number 5: \[ y = - \frac{\sum f_k \cdot y_k + W \cdot y_0}{F}, \]

respectively, however, based on Number 1,

Number 6: \[ F = \sum f_k - W, \]

and thus,

Number 7: \[ x = - \frac{\sum f_k \cdot x_k + W \cdot x_0}{\sum f_k - W}, \]

Number 8: \[ y = - \frac{\sum f_k \cdot y_k + W \cdot y_0}{\sum f_k - W} \]

are obtained in place of Number 4 and Number 5.

Furthermore, because \( x_0 = 0 \) and \( y_0 = 0 \) when the center of gravity of the operating panel 10M is set at the point of origin of a coordinate system XYZ,

Number 9: \[ x = - \frac{\sum f_k \cdot x_k}{\sum f_k - W}, \]

Number 10: \[ y = - \frac{\sum f_k \cdot y_k}{\sum f_k - W}. \]

Furthermore, when the operating panel 10M is inclined at an angle of just \( \theta \) (not illustrated in the figure) from a horizontal plane, Number 1 becomes

Number 11: \[ F + W \cdot \cos \theta - \sum f_k = 0, \]

and, based on this, Number 9 and Number 10 become

Number 12: \[ x = - \frac{\sum f_k \cdot x_k}{\sum f_k \cdot \cos \theta}, \]

Number 13: \[ y = - \frac{\sum f_k \cdot y_k}{\sum f_k \cdot \cos \theta}. \]

Number 12 and Number 13 (or Number 7, Number 8, Number 9 and Number 10) are general equations for deriving XY coordinates (x and y) for an operating point (pressing point) P based on the force of a detected value k (k = 1 to n) of the forces at the piezoelectric elements E1 through En.

These general equations are as given below when realized with respect to the operating panel 10 of the present embodiment. That is, because \( n = 4 \) in the case of the present embodiment, when a coordinate point of origin 0 is set in a central (center of gravity) position of
a rectangle, with the side lengths of said rectangle, which defines the arrangement of the piezoelectric elements E1 through E4 as illustrated in FIG. 6, set as 2a and 2b, respectively,

[0073] 
[Number 14] is \( x = a \cdot \frac{(f_1 + f_3) - (f_2 + f_4)}{(f_1 + f_3 + f_2 + f_4 - W \cdot \cos \theta)} \), and

[0074] 
[Number 15] is \( y = b \cdot \frac{(f_1 + f_2) - (f_3 + f_4)}{(f_1 + f_3 + f_2 + f_4 - W \cdot \cos \theta)} \) based on Number 12 and Number 13.

[0075] 
Thus, while a dead weight component \( W \cdot \cos \theta \) of the operating panel 10 can be measured and calculated in advance when said panel is used in the information display device 100 spatially fixed as in the present embodiment, an incline angle \( \theta \) can be changed in various ways when said panel is used in a portable information display device like that in another example described below. While the dead weight component \( W \cdot \cos \theta \) cannot be fixed in such a case, such a case does allow an operator to define a pressing operation position. The reasons for this are as given below.

[0076] 
(1) First, a control unit is configured so that the sum of sensed amounts \( f_1 \) through \( f_4 \) of the force from the piezoelectric elements E1 through E4 described above is only assumed to be effective when in excess of a predetermined threshold. If, at this time, a value considerably larger than the dead weight \( W \) of the operating panel 10 is set as such a threshold \( f_h \), a portion of a sum \( (f_1 + f_3 + f_2 + f_4) \) of the right-hand denominators of Number 14 and Number 15 becomes considerably larger than a \((- W \cdot \cos \theta)\) portion, and thus, the portion of the sum \( (f_1 + f_3 + f_2 + f_4) \) of the right-hand denominators of Number 14 and Number 15 actually becomes the major portion. Therefore, with Number 14 and Number 15 as approximation equations, an error is small even when

[0077] 
[Number 16] is \( x = a \cdot \frac{(f_1 + f_3) - (f_2 + f_4)}{(f_1 + f_3 + f_2 + f_4)} \), and

[0078] 
[Number 17] is \( y = b \cdot \frac{(f_1 + f_2) - (f_3 + f_4)}{(f_1 + f_3 + f_2 + f_4)} \), and thus Number 16 and Number 17 can be used.

[0079] 
(2) With an information display device where a screen is operated using a finger, the accuracy required to define a pressing operation position is typically not very precise. That is, since it is sufficient in the example in FIG. 4 to define which of the operating regions R1 through R7 is being operated or which of these regions is not being operated, this example is sufficient for practical use even if small errors occur in the definition of an operation pressing position due to a dead weight component or other factors. Preferably, the operating regions R1 through R7 are not arranged densely but rather with a certain amount of space between them. This can prevent detection errors from occurring near the contour lines of the operating regions.

[0080] 
For the reasons given above, the aforementioned calculation principles can be applied even in a portable information display device. Note that there is no problem with using Number 9 and Number 10 or Number 16 and Number 17 as approximation equations, even in devices that are not portable, when a value that is larger than the dead weight \( W \) of the operating panel 10 is set as the pressing force threshold \( f_h \).

[0081] 
<1-3. Configuration and Operation of the Control Circuit Unit CT>

Next, the configuration and operation of the control circuit unit CT (FIG. 7) of the information display device 100 will be described based on the principles described above. Note that while an example where the control circuit unit CT is configured using a
hardware circuit is illustrated here, this circuit can also be realized with software using a microcomputer. In this case, the following circuit portions are functionally realized using the MPU and memory of said microcomputer.

[0082] <1-4. Pressing Force Sensing by the Piezoelectric Elements E1 through E4>

In FIG. 7, the element voltages $e_k$ ($k = 1$ to $4$) of each of the piezoelectric elements E1 through E4 coupled with the operating panel 10 are applied in parallel to an operation unit 51.

[0083] FIG. 8 illustrates the internal configuration of the operation unit 51. A numerical relationship between the force applied to the piezoelectric elements E1 through E4 and the terminal voltage is preset in a signal converter 51a inside the operation unit 51. The terminal voltages $e_k$ of the piezoelectric elements E1 through E4 are each converted by the signal converter 51a into signals $Sf_k$ for expressing forces $f_k$ ($k = 1$ to $4$) applied to the piezoelectric elements E1 through E4, and these signals $Sf_k$ are applied in parallel to a position computing unit 51b and an operating force detecting unit 51c.

[0084] Distance constants a and b (see FIG. 6) saved in advance in a constant storage unit 51c are also applied to the position computing unit 51b, and the position computing unit 51b calculates the position coordinates (x and y) for an operating point using Number 16 and Number 17 described above. Note that when Number 14 and Number 15 are used instead of Number 15 and Number 16, a value relating to the dead weight component ($W \cdot \cos \theta$) is also stored in the constant storage unit 51c, and used.

[0085] On the other hand, the summation $\Sigma f_k$ of the forces $f_k$ ($k = 1$ to $4$) is derived by the operating force detecting unit 51d. When the dead weight of the operating panel 10 is also taken into consideration, the value ($W \cdot \cos \theta$) from the constant storage unit 51c is taken into consideration as well, and the operating force $F$ is derived from Number 11. Note that if the value of the operating force $F$ derived by the operating force calculating unit 51d is used as the value of the denominator of the calculation (for example, Numbers 16 and 17), it is not necessary for both the position calculating unit 51b and the operating force calculating unit to calculate the sum $\Sigma f_k$.

[0086] As a result, an operating position signal SP showing the operating position P (x and y) and an operating force signal SF showing the operating force F are both output from the operation unit 51. The operating position signal SP has two components (x and y).

[0087] <1-5. Operating Position (Operating Region) Determination>

The operating position signal SP obtained by the operation unit 51 is applied to a region determining unit 52 in accordance with FIG. 7. Information (xi-, xi+, yi-, yi+: where $i = 1$ to $7$) expressing the apex coordinates (see FIG. 9) of each of the operating regions R1 through R7 in FIG. 4 is input from a region classification storage unit 53 into the region determining unit 52. The information of these apex coordinates is loaded from an information processing unit 60 (FIG. 7) described below in accordance with the content displayed at the time the information is loaded.

[0088] The region determining unit 52 uses a comparing and determining unit 52a (FIG. 10) to compare the coordinates (x and y) of the operating point P to the apex coordinates of the operating regions R1 through R7 obtained as described above, and then determines whether the operating point P is in the region R0 or one of the operating regions R1 through R7. For example, if, in the comparing and determining unit 52a, a comparison and calculation is performed at a portion relating to the region R2 with regard to whether,
[Number 18] is \( x^2 - \leq x \leq x^2 + \) and \( y^2 - \leq y \leq y^2 + \)
or not, and the Number 18 is established, it is determined that the current operating point P is inside the operating region R2.

It is also determined whether or not the coordinates (x and y) of the operating point P are in the region (non operating region) R0, which is the region outside the operating regions R1 through R7 on the liquid crystal display screen.

Accordingly, a signal SR that classifies operating regions R1 through R6 in order to express whether to denote an operating region R1 through R7 or the non operating region R0, is output from the comparing and determining unit 52a in FIG. 10. Note that when the operator is not touching any part of the operating surface 11, the operating position signal SP is considered to be at a non active level and, based on this, a region determining signal SR is also considered to be at a non active level. To distinguish the plurality of regions R1 through R0 and non active levels, the region determining signal SR is assumed to be a multi level signal carrying a plurality of bits.

<1-6. Determination of the Operating Force>

On the other hand, in FIG. 7, an operating force signal SF indicating the operating force F is applied to an operating force determining unit 54. A plurality of thresholds Fh1 through Fh4 for defining the operating force classifications F0 through F4 in FIG. 11 are input from an operating force classification storage unit 55 into the operating force determining unit 54. The information of these thresholds Fh1 through Fh4 is also loaded at a given time from an information processing unit 60 described below, based on displayed content. Furthermore, while operating force classifications F0 through F4 have been defined for this example, the number of force classifications can be changed based on the displayed content at a given time.

The region determining signal SR from the region determining unit 52 is also input into the region classification storage unit 55. Finally, the thresholds Fh1 through Fh4 can be changed based on which region the operating position P belongs to at a given time (hereinafter referred to as “in-operation region R”). Accordingly, for example, the values of the thresholds Fh1 through Fh4 can be made small for the operating regions R1 through R6, and the values of the thresholds Fh1 through Fh4 can be made large for the operating region R7. These corresponding relationships are stored in advance in the information processing unit 60 in FIG. 7, and the specific method for changing the thresholds is described below.

In all cases, however, the minimum threshold Fh1 of the thresholds Fh1 through Fh4 is a threshold that makes the tracing operation possible by ensuring that pressing at an operating force F that is smaller than this minimum threshold is not interpreted as a menu selection operation. That is, because next to no operating force is applied by the simple act of moving a finger on the operating surface 11, as in the case of the tracing operation, operating errors can be prevented during tracing by discerning the operating force using the minimum threshold Fh1. Given that this is what the minimum threshold Fh1 means, it is preferable that the minimum threshold Fh1 be given a fixed value regardless of the operating region or displayed content.

With the four operating force classifications F1 through F4, in ranges at or above the minimum threshold Fh1, referred to as “effective operating force classifications,” the operating force determining unit 54 uses the comparing and determining unit 54a housed therein (FIG. 12) to compare the operating force F, denoted at a given time by the operating force signal SF, to the operating force thresholds Fh1 through Fh4 to determine which of the effective operating force classifications F1 through F4 the operating force F is in at a given time. For example, if
[0096] [Number 19] is \( F_{h1} \leq F < F_{h2} \),
the operating force is determined to be pressing at effective operating force
classification \( F_1 \), and if
[0097] [Number 20] is \( F_{h4} \leq F \),
the operating force is determined to be pressing at effective operating force
classification \( F_4 \).
[0098] So, in other words, when the operating force \( F \) is not in either of the operating force
classifications \( F_1 \) through \( F_4 \), and
[0099] [Number 21] is \( F < F_{h1} \),
the operation force is determined to be pressing at operating force classification \( F_0 \)
(“no actual pressing operation”).
[0100] Furthermore, an activation signal is generated when the operating force \( F \) at a given
time belongs to effective operating force classifications \( F_1 \) through \( F_4 \). When none of the
signals from the effective operating force classifications \( F_1 \) through \( F_4 \) are active, it means
that the operating force is smaller than the minimum threshold \( F_{h1} \).
[0101] All of the signals from the determining unit 54a for these effective operating force
classifications \( F_1 \) through \( F_4 \) are applied to a logical sum circuit 54b, and then an operation
enabling signal \( FC \) is generated as a logical sum signal for said classifications. Accordingly,
the operation enabling signal \( FC \) is activated when it has been determined, at a given time,
that the operating force \( F \) is at or above the smallest determining threshold \( F_{h1} \), and that the
operator has actually performed a pressing operation in the operating surface 11. Conversely,
if the operator is not pressing the operating surface 11 at all, or if the operator is touching the
operating screen 11 but has not yet performed a final selection operation (such as during a
tracing operation, and the like), the operation enabling signal \( FC \) stays at a non active level.
[0102] Furthermore, a signal is output from each determining unit for the effective
operating force classifications \( F_1 \) through \( F_4 \) to a drive mode selecting unit 72 in FIG. 7, as
an operating force determining signal \( FB \). This signal is used as information for selecting
the operating surface 11 drive mode using the piezoelectric elements \( E_1 \) through \( E_4 \), based
on what classification the operating force \( F \) is in.
[0103] By the way, as is illustrated in FIG. 7, the region determining signal \( SR \) from the region
determining unit 52 is also input to the operating force classification storage unit 55. As has
already be mentioned, this is to enable changes to the values of the thresholds \( F_{h1} \) through \( F_{h4} \)
based on the in-operation region \( R \). Specifically, a plurality of combinations of the thresholds
\( F_{h1} \) through \( F_{h4} \) are input to and stored in the operating force classification storage unit 55
from the information processing unit 60 based on the screen being displayed at a given time,
and the threshold of one of these combinations is selected based on a region classifying signal
\( R \). Therefore, if the threshold for the operating force \( F \) is changed for every in-operation region
\( R \) (or for the operating position at a given time) in this way, the operating force determination
in the operating force determining unit 54 can be performed after the region determining signal
\( SR \) is generated from the region determining unit 52. This can be achieved by, for example,
delaying the timing of the operation of the comparing and determining unit 54a in FIG. 12 a
very short period of time with respect to the operation timing of the region determining unit 52, or by inserting a delay circuit in front of the comparing and determining unit 54a.

[0104]

<1-7. Gate of the Region Determining Signal R>

In FIG. 7, the region determining signal SR output from the region determining unit 52 is output to the information processing unit 60, a gate circuit 56, and an AND circuit 57. Furthermore, the operation enabling signal FC is also input to the AND circuit 57.

[0105]

The AND circuit 57 derives the logical product of the region determining signal SR and the operation enabling signal FC, and then applies the value of said logical product to the gate circuit 56 as a gate control signal G. The region determining signal SR is only allowed to pass through the gate circuit 56 when the gate control signal G is activated, that is, only when any portion of the operating surface 11 is operated with a force larger than the minimum threshold Fh1.

[0106]

A region determining signal SR allowed to pass through the gate circuit 56 is input to a first processing unit 61 inside the information processing unit 60. The first processing unit 61 performs information processing and generates control signals for each device unit based on the menu item selected by the operator, and conveys the facts of this action to an external device (for example, a host computer) as necessary. For example, when “Withdrawal,” which corresponds to region R2 in FIG. 3, is selected, the screen is switched to an input operation screen for withdrawing money by driving the liquid crystal display panel 20 through a display driver 71.

[0107]

On the other hand, a region determining signal SR that circumvents the gate circuit 56 and is input into the information processing unit 60, is input into a second processing unit 62 inside the information processing unit 60. The second processing unit 62 performs a predetermined process when a finger of the operator touches any region of the operating surface 11, even when the operator has not yet performed an actual pressing operation with a force at or above the minimum threshold Fh1. For example, by changing the display color of the region being touched by a finger at a given time, the operator can be informed of “which region an operation will take place in if he/she presses down in a given position.” Furthermore, an audio assist that says “make a ‘Withdrawal’” may be provided.

[0108]

<1-8. Drive Mode Selection>

On the other hand, the drive mode selecting unit 72 in FIG. 7, which inputs the region determining signal SR and an operating force determining signal FB, selects a drive mode based on the classifications of the in-operation region and the operating force. The drive mode defines how the operating surface 11 will be vibrated.

[0109]

Specifically, as is illustrated in FIG. 13, with which region, R1 through R0, the region determining signal SR belongs to as a first index, and which of the operating force classifications, F1 through F4, a classification expressed by the operating force determining signal FB belongs to as a second index, the drive modes that should be selected for combinations of the first and second indices are stored in Table 72a in advance. Signals S11, S12, ... in FIG. 13 are codes for selecting and defining any of a variety of drive modes like, for example, that illustrated in FIG. 14.

[0110]

FIG. 14 schematically illustrates a variety of drive modes stored in a drive mode storage unit 73. For example, FIG. 14 (a) illustrates a mode for performing a continuous vibration having a small amplitude, while FIG. 14 (b) is a vibration mode having a large
amplitude. FIG. 14 (c) illustrates a vibration mode having a different frequency than FIG. 14 (a) and (b), while FIG. 14 (d) and (e) illustrate examples where vibration is performed for a short period of time once or twice. Furthermore, FIG. 14 (f) is a vibration mode for applying only a single vibration (one shot pulse). Note that examples of other modes are described below.

These drive modes can be identified using predetermined parameter codes, and in the example in FIG. 14 (d), these parameters are a vibration frequency VF, a vibration amplitude VD, and a vibration time VT.

Returning to FIG. 13, variations can be introduced with respect to how the operating surface 11 is driven by changing the content stored in the table 72a. For example, when weak vibration is to be applied to operating regions R1 through R6, codes in the range of S11 through S64 can be determined to specify the vibration mode in FIG. 14 (a). Furthermore, when a stronger vibration is to be applied as the operating force F gets larger, the vibration mode in FIG. 14 (a) may be specified in the operating force classifications F1 and F2 in FIG. 13, and the vibration mode in FIG. 14 (b) may be specified in the operating force classifications F3 and F4, respectively. While it is preferred that codes S01 through S04 for the non operating region R0 specify “no driving,” it is acceptable to apply weak vibrations to this region.

When one drive mode is selected using the region determining signal SR and the operating force determining signal FB in this way, the parameter values that specify drive modes in FIG. 14 are read from the drive mode storage unit 73, and then applied to a piezoelectric element drive unit 75 in FIG. 7. In response to this, a vibration voltage is applied to the piezoelectric elements E1 through E4 such that the piezoelectric elements E1 through E4 vibrate or are displaced slightly, and this vibration or slight displacement is propagated to the operating surface 11. When the operator presses down on one of the operating regions R1 through R7 with at least a predetermined force, a tactile action intended to notify the operator that the operation was received is generated by a vibration or slight sliding of the operating surface 11.

By the way, there is no example in the table 72a in FIG. 13 that specifies a drive mode for a case where the operating force F is equal to or below the minimum threshold Fh1. This is because the operating surface 11 is not driven in such a case, and thus there is no need to select a drive mode.

Through this kind of configuration, while a parameter signal V for a drive mode specified using a corresponding location in the table 72a is output to the piezoelectric element drive unit 75 when the operating force determining signal FB is active, no drive mode information of any kind is output to the piezoelectric element drive unit 75 when the operating force determining signal FB is not active. Therefore, the operating surface 11 is only made to vibrate or displace slightly when an operating force F equal to or greater than the minimum threshold Fh1 is applied to the operating surface 11.

Note that when a setting is made with respect to the non operating region R0 indicating there is to be “no vibration” therein regardless of the size of the operating force F, no vibration, or the like, will occur therein even if an operating force F equal to or greater than the minimum threshold is applied, as long as said operating force is applied in the non operating region R0.

Furthermore, while subsequent selection rules have been prepared in a table format for each type of vibration mode in the examples in FIG. 13 and FIG. 14, these selection rules
may be kept as a function that uses the operating region determining signal SR and the operating force determining signal FB as two input variables.

By the way, another configuration can be used in these drive mode selection operations that drives the piezoelectric elements E1 through E4 only when an operating force F equal to or greater than the minimum threshold Fh1 is applied to the operating surface 11. That is, as is illustrated by the broken line 74 in FIG. 7 and FIG. 13, a logical product signal G, which is the output of the AND circuit 57, is input to a gate circuit 72b, added and provided inside the drive mode selecting unit 72 in FIG. 13, as a gate control signal. The gate circuit 72b controls either the transmission of selected output from the table 72a to the drive mode storage unit 73, or the transmission of the drive mode parameter V signal to the drive mode storage unit 73. That is, because the logical product signal G is always inactive when the operating force F is smaller than the minimum threshold Fh1, this signal can be used to prohibit the transmission of drive modes. The table 72a only specifies this type of variation for the region determining signal SR, which is particularly useful in the case of configurations where devices do not change drive modes based on the size of the operating force F.

That is, because the only issue in such cases is whether the operating force F is larger than the minimum threshold Fh1, there is no need to determine which operating force interval F1 through F4 the force belongs to in a range equal to or larger than the minimum threshold. Therefore, there is no need to generate the operating force determining signal FB using the operating force determining unit 54 in FIG. 7, and the transmission of the operating force determining signal FB from the operating force determining unit 54 to the drive mode selecting unit 72 can also be omitted. Thus, in such cases, there are increased practical benefits in using the additional gate circuit 72b and the logical product signal G, which is the output of the AND circuit 57, to permit the generation of vibrations in the operating surface 11 only when the operating force F is larger than the minimum threshold Fh1.

Furthermore, it is preferable that the table 72a in FIG. 13 be re-written for each screen displayed on the liquid crystal display panel 20. That is, when the content displayed on the liquid crystal display panel 20 changes, each type of drive mode for the operating surface 11 can be used in a variety of ways by changing the drive mode to be selected for each operating region in the new display content or for each operating force interval to which the operating force belongs. For example, when the “Withdrawal” menu item is selected and the display changes to the withdrawal amount input screen, the operating region simulates a numeric keypad, and, for example, a one shot displacement like that in FIG. 14 (f) may be applied each time the keypad is pressed. So called click sensations can be given to the operator in the case of such one shot displacements.

Thus, in order to re-write the content of the table 72a each time the screen changes, table re-write information is input to the drive mode selecting unit 72 from the information processing unit 60. That is, when the screen displayed on the liquid crystal display panel 20 changes, the information processing unit 60 in FIG. 7 simultaneously loads, (1) coordinates for specifying a new operating region in the operating region classification storage unit 53, (2) a threshold group specifying new operating force classifications in the operating force classification storage unit 55, and (3) new content for the drive mode selecting table 72b in the drive mode selecting unit 72.

<1-9. Drive Control> In FIG. 7, the drive mode parameter signal V output from the drive mode selecting unit 72 is applied to the piezoelectric element drive unit 75. The piezoelectric element drive unit 75 has a high frequency oscillation circuit 76, which
transmits a high frequency wave specified by the parameter signal V to the piezoelectric elements E1 through E4. Thus, the piezoelectric elements E1 through E4 are vibrated or slightly displaced at a specified amplitude and timing.

[0123]

This mechanical reaction is propagated to the operating panel 10 in FIG. 3, which thus vibrates or slightly displaces the operating surface 11. This vibration is felt by an operator touching the operating surface, which thus allows said operator to know that his/her operational input has been accepted successfully.

[0124]

By the way, in FIG. 7, the piezoelectric elements E1 through E4 are connected to both the operation unit 51 and the piezoelectric element drive unit 75 by predetermined wires. Accordingly, when a high frequency wave is output from the piezoelectric element drive unit 75, said high frequency wave is also transmitted to the operation unit 51. In order to separate the voltage generated by the operating force of the piezoelectric elements E1 through E4 from this high frequency wave, a low-pass filter may be provided in, for example, the signal converter 51a in FIG. 8. Thus, a vibration high frequency wave is cut by the low-pass filter, allowing just the direct current caused by the operating force to be extracted and used in the calculation of the operating position P and the operating force F. Furthermore, by making the minimum threshold for the operating force F larger than the amplitude of the drive signal for the piezoelectric elements E1 through E4, the interference of such a signal can be prevented.

[0125]

In the case of information display where screens change in conjunction with the operational input of an operator, vibration is stopped after, for example, the operating panel 10 has been vibrated for exactly a predetermined amount of time. This can be accomplished by using a signal transmitting path from the information processing unit 60 to the drive mode selecting unit 74 to forcefully put the drive mode parameter signal V into an inactive level. Furthermore, the operation unit 51 and the piezoelectric element drive unit 75 may be integrated, and the importation of the signals from the piezoelectric elements E1 through E4 and the sending of the high frequency wave to the piezoelectric elements E1 through E4 may be switched temporally using a switching circuit. Moreover, short period vibration modes like those in FIG. 14 (d) and (e) may be selected.

[0126]

In the case of vibration modes like those in FIG. 14 (a) through (c), vibration continues as long as the operator applies an operating force F that is larger than the minimum threshold Fh1. When the operator weakens the operating force F or removes his/her finger from the operating surface 11, this is sensed by the operating force determining unit 54, and thus the operating force determining signal FB to the drive mode selecting unit 72 becomes inactive. As a result, the drive mode parameter signal V goes to an inactive level, and the operating surface 11 stops vibrating.

[0127]

<1-10. Main Advantages of the Information Display Device 100>

Because, as is described above, the piezoelectric elements E1 through E4 for giving a sense of touch to an operator through an operation are also used to sense regions selected by the operator in the information display device 100 according to this embodiment, there is no need to provide a large number of other elements.

[0128]

Accordingly, without increasing the number of parts in the vicinity of the operating surface 11 and the information display surface 21, an effective sense of operation can be provided while the device identifies which operating area has been operated.
Because this sense of operation uses the sense of touch, a clear sense of operation can be obtained even in cases where there is a lot of ambient noise or in cases where the surroundings are dark. Furthermore, this sense of operation can also be perceived not only by deaf people but also by people with visual disorders such as amblyopia, and the like.

Furthermore, a tracing operation, and the like, is made possible because pressing with an operating force $F$ smaller than the minimum threshold $F_{h1}$ is not perceived as an effective operation.

Moreover, because the drive mode applied to the operating surface 11 can be changed based on differences in operating force and operating region, the operator can be given a varied sense of operation.

Furthermore, because the minimum threshold $F_{h1}$ for the operating force $F$ can be changed, confusion caused by erroneous selections can be prevented by setting the minimum threshold $F_{h1}$ for operating regions that should be selected with care (for example, operating regions such as Call Attendant, Report Emergency, and the like) higher than for other operating regions.

<2. Second Embodiment>

FIG. 15 is a partially omitted cross sectional view illustrating a portion equivalent to a display operating unit DP of an information display device that is a second embodiment of the present invention used in place of the structure in FIG. 3. The information use aspects and appearance of the second embodiment are the same as in FIG. 1 and FIG. 2.

In FIG. 15, the display operating unit DP allows an operator to specify an operating position using a touch panel 10T. The touch panel 10T is, for example, a resistive type panel having transparent electrodes arranged in an orthogonal matrix of $M$ rows and $N$ columns in an XY plane on a transparent substrate. With this panel, the intersections of these rows and columns form switches, each cell of the matrix is considered to be a unit, and XY direction operating position signals are output.

The touch panel 10T is not limited to a resistive type panel and thus may also be a, (1) photoelectric touch panel for detecting an operating position where data light from a light emitting element incident on a light receiving element is blocked or attenuated by a finger, or the like, (2) an ultrasonic touch panel for detecting an operating position where ultrasonic waves emitted from an ultrasonic wave oscillating element that enter a geophone element are blocked or attenuated by a finger, or the like, or (3) a capacitive touch panel for detecting a position touched by a finger, or the like, based on a change in capacitance, or the like.

A touch panel support plate 42 is provided to reinforce the touch panel 10T, and said support plate may be an opaque member in cases where a part corresponding to the touch panel 10T has the shape of a hollowed out frame member like that illustrated by the example in the figure. When in the shape of a flat plate and not a frame member, it is preferable that the plate be formed using a transparent or semi-transparent material. Furthermore, the touch panel support plate 42 does not need to be provided when the touch panel 10T itself is strong enough not to deform due to a pushing operation.

While the remaining configuration of the display operating unit DP in FIG. 15 is the same as that in FIG. 3, with the display operating unit DP in FIG. 15, the touch panel
performs the detection of an operating position, and the piezoelectric elements E1 through E4 are used for the purpose of detecting an operating force on the operating surface 11 and for applying mechanical drive to the operating surface 11.

[0138] FIG. 16 is a configuration diagram of a control circuit CT using the display operating unit DP in FIG. 15, and while this circuit is described as a hardware circuit, as was the circuit in FIG. 7, the functions of these circuits can be expressed using software. While most of the elements of the control circuit CT in FIG. 16 have the same configuration and function as in FIG. 7, differences with FIG. 7 will described below by comparing FIG. 16 and FIG. 7.

[0139] In FIG. 16, the operating position of the touch panel 10T is specified using an operating position specification unit 51T. However, because the touch panel 10T is a matrix array of M rows and N columns, the operating position signal SP becomes a value where a unit is the size of the cells of the touch panel 10T.

[0140] The region determining unit 52 determines which of the operating regions R1 through R7 the operating position signal SP corresponds to, while the configuration and operation of the region determining unit 52 are fundamentally the same as in FIG. 7.

[0141] On the other hand, while the terminal voltages $e_k$ (k = 1 to 4) of the piezoelectric elements E1 through E4 are each applied in parallel to an operation unit 51F, the operation unit 51F is equivalent to a unit where the position calculating unit 51b has been omitted from the configuration in FIG. 8. That is, because the touch panel 10T specifies the operating position in the second embodiment, all that has to be calculated from the output voltage of the piezoelectric elements E1 through E4 is the total operating force F.

[0142] The operating force signal SF, which is the output of the operation unit 51F, is output to the operating force determining unit 54, where it is determined which operating force classification F0 through F4 (FIG. 11) the operating force F belongs to.

[0143] All other configurations and operations are the same as in the first embodiment. The second embodiment not only has the advantages of the device according to the first embodiment, but also the advantage that operating position detection errors are very rare. That is, as has already been mentioned, when the operating position is specified using the terminal voltages $e_k$ (k = 1 to 4) of the piezoelectric elements E1 through E4, the dead weight, and the like, of the operating panel 10 has an impact on said specification. While these errors pose little problem when the operating regions R1 through R7 are relatively big, more accurate operating position detection is required when the areas of these operating regions are particularly small. In such cases, it is preferable to use the touch panel 10T used in the second embodiment.

[0144] Furthermore, because position calculation based on the terminal voltages $e_k$ (k = 1 to 4) is not necessary to use the touch panel 10T, the second embodiment also has the additional advantage that operating regions can be specified very quickly.

[0145] <3. Third Embodiment>

FIG. 17 is an external perspective view of an information display device 200 according to a third embodiment of the present invention. The information display device 200 is a liquid crystal display type game device given as one example of a mobile information display device. With the information display device 200, the operating surface 11 is exposed on a main surface MS of a box shaped housing 201. This operating surface is equivalent to
the operating panel 10 in FIG. 3, or the touch panel 10T in FIG. 15. The display operating unit and control circuit behind the operating surface 11 are configured in the same way as the display operating unit DP in the first embodiment and the second embodiment.

[0146]

The operating regions R1 through R4 displayed by the liquid crystal display panel are visible through the operating surface 11 in FIG. 17. Typically, these operating regions R1 through R4 are displayed along both sides of the operating surface. An operator grips the housing 201 by both sides, as illustrated by the broken lines in FIG. 17, and performs operations by pressing these operating regions R1 through R4 with his/her thumbs. When the position of this pressing operation is sensed, if the pressing force thereof is larger than a predetermined threshold, the operation input is accepted, a displayed object 210 (FIG. 18) on a screen changes, and the operating surface 11 is vibrated or slightly displaced based on a predetermined mode. The operation at this point is the same as in the first and second embodiments.

[0147]

However, with the information display device 200, a fixed operating button 203 is provided on a side surface of the housing 201. Furthermore, as illustrated in the back surface view in FIG. 9, fixed operating buttons 221 and 222 and a cross shaped operating button 223 are provided on a back surface 220 of the housing 201 out of the way of a battery case cover 224. These fixed buttons 203, and 221 through 223 can be assigned, for example, to start and end games, to switch between screen display content, to move or operate objects on screen, and the like. Typically, these fixed buttons 203, and 221 through 223 are operated using the fingers gripping the housing 201 other than the thumbs.

[0148]

In conventional devices of this type, a liquid crystal display screen had only a display function, and fixed buttons were arranged on the main surface MS, which thus reduced the area of a liquid crystal display surface. However, with the information display device 200 according to the present embodiment, because operation input is also possible using the operating surface 11 on the liquid crystal display screen, most of the area of the main surface MS can be used as a display operating surface by moving the fixed buttons to surfaces other than the main surface of the housing 201.

[0149]

Additionally, while conventional devices were provided with fixed buttons only, a variety of operating input in conjunction with a variety of circumstances is made possible by the device according to the present embodiment because the display content and positions of the operating regions R1 through R4 are enabled therein.

[0150]

Note that, as is illustrated in FIG. 17, the housing 201 has a power switch 202 on top, and that such power switches 202 and volume adjusting dials were arranged on surfaces other than the main surface MS in conventional devices as well. However, given that the fixed buttons 203, and 221 through 223 in the device according to the present embodiment are operating switches for receiving operations based on the content displayed on an information display surface, said fixed buttons are thus substantively different from a power switch or a volume adjusting dial. Stated in terms of the game device, these fixed buttons 203, and 221 through 223 are buttons that relate to game content.

[0151]

If the present invention is used in this type of game device or mobile information display terminal (so-called mobile device), said invention is not only able to provide a sense of operation through the vibration of the operating surface 11, but is also able to increase the realism of a game, and the like. That is, the invention is able to vibrate the operating surface
11 to coincide with the movement of a displayed object (for example, a character) on the screen, and to synchronize the vibration of the operating surface 11 with a sound.

Furthermore, if the invention varies the phase of high frequency waves applied to the piezoelectric elements E1 through E4, it is possible to provide a vibration like a traveling wave that travels from one end of the operating surface 11 to the other, which would serve to make games, and the like, more interesting.

<4. Other Embodiments>

FIG. 20 is a drawing of another example of an available information display device according to the present invention illustrating the information display surface 21 and a portion of an overlapping operating surface 11. In this example, volume control knobs of an audio device are displayed on a liquid crystal display panel, which knobs are configured so as to be operated by the finger of an operator. Specifically, the panel displays a sliding volume knob 301 for each register, and, when a finger 303 is placed on a knob to apply a pressing force thereupon, and the finger 303 is then moved in either an “H” direction or an “L” along a volume adjusting line 302, the display of the volume knob 301 moves in conjunction the movement of the finger, to thus actually change a volume. In addition to this, the operating surface 11 vibrates to convey to the operator that the device is operating.

Furthermore, a vibration amplitude changes to coincide with the position of the volume knob 301 being operated at a given time. For example, the operating surface 11 is vibrated with a low amplitude when the volume knob 301 is in section YL, a medium amplitude when the knob is in section YM, and a high amplitude when the knob is in section YH. This gives the operator a sense of touch that coincides with the current volume. Furthermore, the amplitude can be increased continuously in conjunction with the Y coordinates of the volume knob 301.

FIG. 22 illustrates an example of a specific configuration for realizing such a function. FIG. 22 illustrates a deformed portion of part of the first embodiment in FIG. 7 or the second embodiment in FIG. 16, where information yD indicating which section, YL, YM, or YH, the displayed Y coordinate for the operated volume knob 301 belongs to at a given time is transmitted to the drive mode selecting unit 72 from the information processing unit 60. The table 72a in the drive mode selecting unit 72 stores relationships for selecting a drive mode to coincide with this Y coordinate identifying value yD in a table format and is set such that the drive mode is selected from the drive mode storage unit 73, where a vibration mode with a high amplitude is selected when the Y coordinate identifying value yD is large, and a vibration mode with low amplitude is selected when the identifier is small. Vibration modes with high amplitudes, medium amplitudes, or low amplitudes, respectively, are stored in the drive mode storage unit 73.

Furthermore, when amplitude is to be changed continuously, the value of the displayed Y coordinate for the volume knob 301 may be applied to the drive mode selecting unit 72 as the Y coordinate identifying information yD, and to the vibration amplitude determined using an increasing function for the Y coordinate identifying information yD.

In all cases, this provides for very realistic knob operation.
adjusting line 302, and the volume increases as does the vibration amplitude of the operating surface 11. In this case, information indicating either the Y coordinate itself of the slide display 301 for the volume knob 303 being operated at a given time, or which of the sections Y_L, Y_M, or Y_H the Y coordinate thereof belongs to, is used as the information y_D in FIG. 22.

All other configurations and operations are the same as those in the first embodiment and the second embodiment.

<5. Modifications>

<5-1. Bi-directional function means>

A variety of elements such as (1) a piezoelectric element, (2) a combination of an electromagnetic solenoid and a plunger, or (3) a combination of an electromagnet and a permanent magnet can be used as the unit function means used as the bi-directional function means or components thereof used in the present invention. In elements using electromagnetic effects, like (2) and (3) described above, a pressing force applied to an operating surface causes changes to a magnetic flux distribution, thus evoking voltage between the terminals of a coil. Furthermore, the size of the pressing force can be determined by amplifying said voltage. That is, this takes advantage of the fact that the functions of both a displacement sensor and electromagnetic driving means are being provided.

Ceramic piezoelectric elements and piezoelectric films, and the like, may also be used in cases where piezoelectric elements are used. FIG. 23 is a partial view illustrating an example using a piezoelectric film 310. In this example, a piezoelectric film 310 is arranged under the operating panel 10 or the touch panel 10T near each of the four corners thereof, and these piezoelectric films 310 are each supported by an elastic body 311 such as a spring, a piece of rubber, or the like. Screen display is performed using a liquid crystal display panel (not illustrated) arranged under the operating panel 10 or the touch panel 10T, just as in the embodiments described above. When an operator presses a desired location on the operating panel 10 or the touch panel 10T, the elastic bodies 311 contract and voltage is generated on both sides of the piezoelectric film corresponding to a related pressing force and pressing location, and then a pressing force and a pressing location are detected through the detection of this voltage.

<5-2. Extension to an Operation Input Device>

FIG. 24 is a cross sectional view illustrating a switch as an example of an operation input device that realizes the fundamental principle of the present invention in the simplest form. In this switch, a piezoelectric element ES is arranged in the bottom of a case 321, and then a recording faceplate 322 and a transparent or semi-transparent operating plate 323 are arranged thereupon. The upper surface of the operating plate 323 serves as an operating surface 324.

A wire 327 stretches out from the piezoelectric element ES, and then said wire 327 is connected to a press sensing unit 325 and a drive unit 326. The press sensing unit 325 senses a pressing force on the operating surface 324, caused by an operator, by sensing a terminal voltage of the piezoelectric element ES through a low-pass filter, and the like. When the terminal voltage of the piezoelectric element ES is larger than a predetermined threshold, the press sensing unit 325 sends a switching signal to an external device and a sensing command signal to a piezoelectric element drive unit 326, based on this, the piezoelectric element drive unit 326 generates a high frequency wave having a predetermined vibration pattern and sends said wave to the piezoelectric element, thus causing the piezoelectric element ES to vibrate. By this, the operating surface 324 is vibrated through the recording faceplate 322 to thus give an operator a sense of touch to the effect that the operation input has been accepted.
By following the principle of the present invention in this way, it is possible to use just one piezoelectric element ES, or just one set of piezoelectric elements, to sense a pressing operation and apply vibration to an operating surface without providing separate means for doing so, even in a switch that does not have a variable display surface.

The switch in FIG. 24 does not require the recording faceplate 322. In this case, a fixed display may be used on the front surface of the operating plate 324 itself, and display may be also be provided outside the switch. That is, the present invention can be extended to an operation input device that does not have a display surface of its own.

<6. Other Modifications>

Modifications like those described below are also possible in addition to each of the configurations described as embodiments and modifications according to the present invention.

In the case where detection of an operating position on an operating panel is through a plurality of unit function means (piezoelectric elements, and the like), as in the first embodiment, it is preferable that at least three unit function means be distributed and arranged two dimensionally. This is because an operating position in a two dimensional plane can be specified accurately by detecting a pressing force in at least three locations.

On the other hand, in the case of a device having a use method where locations of operating regions are aligned one dimensionally, operating positions can be specified one dimensionally by arranging piezoelectric elements on each of two opposing sides. Accordingly, while at least three, and preferably four or more, unit function means are typically arranged in a rectangular operating panel, the number of unit function means can be increased or reduced based on the shape and use state of the operating panel, and the like.

Modes for applying a mechanical reaction to an operating surface include, (1) sliding the operating panel sideways in one shot, (2) suddenly sliding the operating panel sideways and then holding the panel there as long as the operating surface 11 is being pressed, (3) sliding the operating panel down in one shot, (4) suddenly sliding the operating panel down and then holding the panel there as long as the operating surface 11 is being pressed, (5) sliding the operating panel up in one shot (equivalent to FIG. 14 (f)), (6) suddenly sliding the operating panel up and then holding the panel there as long as the operating surface 11 is being pressed, and the like, and these modes can be stored in the drive mode storage unit 73 in FIG. 14.

While, of these modes, (1), (3), and (5) are acceptable if pulse-like drive signals are generated, because modes (2), (4), and (6) generate DC like drive signals, it is necessary to avoid picking up drive signals when detecting terminal voltage $e_k$ (direct current) generated in piezoelectric elements E1 through E4. In the case of modes (2) and (6) described above, because the displacement directions of the piezoelectric elements are different than the displacement direction (facing down from the operating surface) caused by the operating force, putting the terminal position for applying the drive signal and the terminal position for extracting the signal $e_k$ in different locations, as well as also using a different wire, allows the drive signals of the piezoelectric elements and the terminal voltage caused by the operating force to be separated from one another.

By contrast, in the case of mode (6), the voltage caused by the drive signal and the terminal voltage caused by the operating force appear in the same location, and thus must
be differentiated from one another. This can be solved by setting the minimum threshold for the operating force larger than, for example, the value of the DC drive voltage.

[0172]

In the present invention, a member other than the operating panel 10 or the touch panel 10T may be interposed between the piezoelectric elements E1 through E4. That is, the coupling between the operating unit and the bi-directional function means may be either direct or indirect.

[0173]

The variable information display means is not limited to a liquid crystal display panel, and thus an electroluminescent (EL) display, a plasma display, a thin CRT, an LED array, a combination of a liquid crystal shutter, a light emitter to illuminate the shutter, and a reflecting plate, and the like, may be used as said display means.

[0174]

In a case using fixed display means, paper or a sheet may be affixed thereto instead of the recording faceplate.

[0175]

In a case where the present invention is implemented as an operation input device that has no information display surface, a plurality of unit function means may be distributed and arranged two dimensionally as in the first embodiment, and then a function can be provided whereby an operating position is detected based on the output thereof. Such an operation input device can be used as a sliding pad, which is one type of pointing device used in, for example, portable personal computers (so-called notebook computers). Because the movement of a finger on the operating surface in such a case can be visually verified as the movement of a cursor on a screen such as a liquid crystal display of a personal computer, the operation input device itself does not need to have a display function.

[0176]

Furthermore, in such a case, a plurality of operating force thresholds are set, where an operating force within a range between a minimum threshold and a maximum threshold is imported as a cursor movement command, and an operation equal to or exceeding the maximum threshold is imported as an operation equivalent to the click of a mouse. Doing this eliminates the need to provide a separate button for clicking on the main body of a notebook computer, and a clicking operation can be easily achieved by means of a sliding pad alone in cases where a button for clicking has already been provided separately.

[0177]

Conductive rubber or a load cell can be used as function means in cases where the present invention is used only to detect the presence or absence of an operation, or as unit function means in cases where the present invention is applied only to the detection of operating positions.

[EFFECT OF THE INVENTION]

[0178]

As has been described above, with the invention according to claim 1 through claim 12, an operating force applied to an operating screen can be sensed by using bi-directional function means able to convert a mechanical reaction and an electrical signal in two directions, and an operating surface can be moved mechanically and a sense of operation given to an operator by applying an electrical drive signal to the bi-directional function means based on an operating signal.

[0179]

Therefore, a reliable sense of operation can be provided even if an operating means does not have a substantial push stroke. This sense of operation is tactile and does not use vision or hearing such that perception thereof is possible even in noisy and dark
surroundings. Thus, even visually impaired and deaf people can clearly perceive the mechanical reaction of the operating surface.

Furthermore, because the sensing of the operating force and the mechanical reaction of the operating surface can be realized with a single means, a simple information display device that reduces the number of parts in the vicinity of an information display surface and the operating surface can be achieved.

With the invention according to claim 2, because a drive signal is applied to the bi-directional function means when an operating signal exceeds a predetermined threshold, a drive signal is not generated by a small operating force alone, and thus a tracing operation is possible, and no reaction is erroneously displayed by a device side before a pressing operation is actually performed in a target operating region.

With the invention according to claim 3, because a drive signal mode changes based on the size of the operating signal, a sense of operation can be varied.

With the invention according to claim 4, it is possible to generate a position signal that expresses the operating position on the operating surface using a plurality of unit function means that configure the bi-directional function means, without requiring the addition of other means for specifying the operating position on the operating surface.

With the invention according to claim 5, it is possible to detect the operating position on a planar operating surface using three or more unit function means.

With the invention according to claim 6, the operating position on the operating surface can be detected using a rectangular operating surface having a wide range of use.

With the invention according to claim 7, because the operating position is specified using a touch panel, operating position specification accuracy is high, and only a short period of time is required to specify a position.

With the invention according to claim 8, because a threshold of the operating force is changed by the operating position, sensitivity can be changed based on a position that has been pressed and operated, thus allowing the sense of operation to be varied.

With the invention according to claim 9, because the drive mode is changed, the sense of operation can also be varied.

With the invention according to claim 10, because the position signal becomes substantially effective when the operating force exceeds a predetermined threshold, the tracing operation will not cause erroneous input.

With the invention according to claim 11, because the function means for detecting the operating force and applying the mechanical reaction to the operating surface is configured using a piezoelectric element, the device can easily be made smaller and the operating force can be detected with high accuracy.
With the invention according to claim 12, because the information display device is housed in a housing and thus made portable, the information display surface can be used effectively, and an adequate sense of operation can be applied.

With the invention according to claim 13, because one or a plurality of operating switches for accepting an operation based on the displayed content on the information display surface of a portable information display device are provided on a surface other than a housing main surface, most of the housing main surface can be used as the information display surface and an overlapping operating surface.

Furthermore, because an input operation is also possible using the operating surface, the housing main surface can be used effectively thus enabling a variety of inputs in conjunction with the operating switches not on the main surface.

With the invention according to claim 14, because the operating position is specified using the output signals of the plurality of unit function means, the operating position can be specified without using the touch panel. While dirt, and the like, on the touch panel can cause erroneous operation, the risk of such erroneous operation is reduced in the present invention because the operating force is converted into an electrical signal.

With the invention according to claim 15, the fundamental principle of the present invention is extended to configure an operation input device where a reliable sense of operation can be obtained without a stroke, thus becoming an operation input device with a small number of parts.

Finally, the invention according to claim 16 combines the advantages of the invention according to claim 14 and the advantages of the invention according to claim 15.

[Reference Numerals]

E1 - E4 Piezoelectric elements (unit function means)
e_k Terminal voltage of the kth piezoelectric element
R1 - R7 Operating regions
P (x and y) Operating position
R In-operation region
F Operating force
SF Operating force signal
SP Operating position signal
FC Operation enabling signal
FD Operating force determining signal
G Gate signal
V Drive mode parameter signal
F1 - F4 Operating force intervals
Fh1 - Fh4 Operating force thresholds
Fh1 Minimum operating force threshold
DP Display operating unit
CT Control circuit
MS Housing main surface
10 Operating panel
10T Touch panel
*11 Operating surface
20 Liquid crystal display panel
21 Display surface (information display surface)
30 Bi-directional conversion function means
51 Operation unit
52 Region determining unit
54 Operating force determining unit (operating signal determining means)
56 Gate circuit
57 AND circuit
60 Information processing unit
72 Drive mode selecting unit
73 Drive mode storage unit
75 Piezoelectric element drive unit
100, 200 Information display devices
*101, 201 Housings
[Scope of Claims]

[Claim 1]
An information display device, comprising:
(a) an information display surface;
(b) a transparent or semi-transparent operating unit having a predetermined operating surface arranged on the information display surface;
(c) bi-directional function means coupled with the operating unit able to convert a mechanical action and an electrical signal in two directions;
(d) operating signal extracting means for extracting the electrical signal generated by the bi-directional function means through an operating force applied to the operating surface as an operating signal; and
(e) drive control means for sending an electric drive signal to the bi-directional function means in response to the operating signal,
wherein
a mechanical reaction generated by the bi-directional function means through the drive signal is transmitted to the operating surface and is captured as a sense of touch of an operator.

[Claim 2]
The information display device according to claim 1, wherein
the drive control means has,
(e-1) operating signal determining means for comparing the operating signal to a predetermined threshold and sending the drive signal to the bi-directional function means when the operating signal exceeds said threshold.

[Claim 3]
The information display device according to claim 2, wherein
the operating signal determining means changes the mode of the drive signal in accordance with the size of the operating signal.

[Claim 4]
The information display device according to claims 1 through 3, wherein
the bi-directional function means has,
(c-1) a plurality of unit function means arranged mutually separated from one another each able to convert a mechanical action and an electrical signal in two directions, and
the information display device is a device, further comprising:
(f) position signal generating means for generating a position signal expressing an operating position on the operating surface based on a plurality of electrical signals generated by the plurality of unit function means through an operating force applied to the operating unit.

[Claim 5] The information display device according to claim 4, further comprising:
three or more unit function means arranged and dispersed two-dimensionally as the plurality of unit function means.

[Claim 6]
The information display device according to claim 5, wherein
the operating surface is a rectangular surface has,
four unit function means arranged more or less at the four corners of the rectangular surface as the plurality of unit function means.

[Claim 7]
The information display device according to any one of claims 1 through 3, wherein
the operating means has,
(b-1) a touch panel for generating a position signal corresponding to an operating
position on the operating surface.

[Claim 8]
The information display device according to any one of claims 4 through 7, wherein
the drive control means changes the threshold for the operating signal based on the
position signal.

[Claim 9]
The information display device according to any one of claims 4 through 7, wherein
the drive control means changes the mode of the drive signal based on the position signal.

[Claim 10]
The information display device according to any one of claims 2 through 9, further
comprising:
(g) logic gate means for transmitting the generation of the position signal to
predetermined information processing means when the operating signal exceeds the threshold.

[Claim 11]
The information display device according to any one of claims 1 through 10, wherein
the bi-directional function means includes a piezoelectric element.

[Claim 12]
The information display device according to any one of claims 1 through 10 housed
in a portable housing having a predetermined main surface, wherein the operating surface is
exposed on the main surface and is made portable.

[Claim 13]
The information display device according to claim 12, further comprising:
one or a plurality of operating switches arranged securely on a surface other than the
main surface of the housing for receiving an operation based on content displayed on the
display surface.

[Claim 14]
An information display device, comprising:
(a) an information display surface;
(b) a transparent or semi-transparent operating unit having a predetermined
operating surface arranged on the information display surface;
(c) a plurality of unit function means arranged spatially dispersed in a range so as to
be coupled with the operating unit, each capable of converting a mechanical action into an
electrical signal;
(d) operating signal extracting means for extracting electrical signals generated by
the plurality of unit function means through an operating force applied to the operating
surface as a plurality of operating signals; and
(e) position signal generating means for generating a position signal expressing an
operating position on the operating surface based on the plurality of operating signals.

[Claim 15]
An operation input device, comprising:
(a) an operating unit having a predetermined operating surface;
(b) bi-directional function means coupled with the operating unit able to convert a mechanical action and an electrical signal in two directions;
(c) operating signal extracting means for extracting an electrical signal generated by the bi-directional function means through a pressing force applied to the operating surface; and
(d) drive control means for sending a drive signal to the bi-directional function means in response to the operating signal,
wherein
a mechanical reaction of the bi-directional function means caused by the drive signal is transmitted to the operating surface as a sense of touch of an operator.

[Claim 16]
The operation input device according to claim 15, wherein
the bi-directional function means has,
(b-1) a plurality of unit function means arranged spatially dispersed in a range so as to be coupled with the operating unit, each capable of converting a mechanical action into an electrical signal;
the operating signal is obtained as a plurality of unit operating signals generated by the plurality of unit function means, respectively, and
the operation input device is a device further comprising:
(e) position signal generating means for generating a position signal expressing an operating position on the operating surface based on the plurality of operating signals.
Abstract

[Problem] To provide an information display device with a small number of operating surface and display surface peripheral parts providing a reliable sense of operation and enabling a tracing operation without a push stroke.

[Resolution Means] An operating panel 10 is arranged on a liquid crystal display panel 20, and the operating panel 10 is supported by piezoelectric elements E1 through E4. Pressing an operating surface 11 of the operating panel 10 with a finger generates voltage at both ends of the piezoelectric elements E1 through E4, and an operating force and an operating position are sensed by detecting and calculating said voltage. High frequency is applied to the piezoelectric elements E1 through E4 when an operating force larger than a predetermined threshold is sensed, which thus causes the operating surface 11 to vibrate. This vibration allows an operator to obtain a reliable sense of operation. The number of parts is small because the sensing of the operating force applied to the operating surface and the application of the vibration to the operating surface 11 are performed using the common piezoelectric elements E1 through E4. Furthermore, a tracing operation is made possible because an operating force smaller than the predetermined threshold causes no reaction.
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Jeremy Coombs
Vice President, International Operations

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On this 13 day of September 2016 before me, the undersigned Notary Public, personally appeared Jeremy Coombs, who proved on the basis of satisfactory evidence to be the person whose name is subscribed to this Translator’s Certificate of Translation and who acknowledged that he or she executed the same for the purposes stated therein.

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