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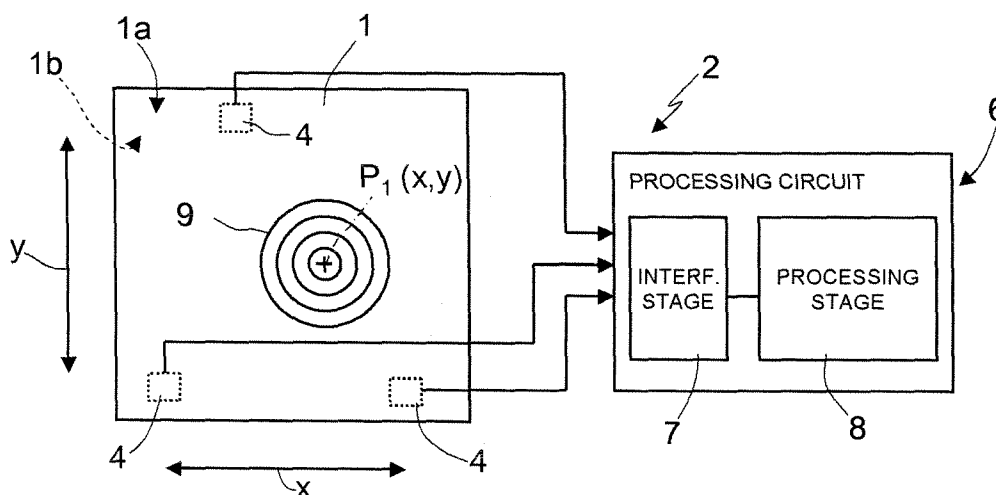
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(54) Title: TOUCH POSITION DETERMINING DEVICE AND METHOD, AND ELECTRONIC TOUCH-SENSITIVE DEVICE



(57) Abstract: In a device (2) for determining the position ($P_1(X, y)$) of a touch on a contact surface (1a), a plurality of vibration sensors (4) are configured to detect mechanical vibrations (9) generated by the touch on the contact surface (1a) and to generate corresponding vibration signals, and a processing circuit (6) is connected to the vibration sensors (4) and is configured to determine the touch position ($P_1(x, y)$) via a time-of-flight algorithm, based on differences between times of detection (t_1, t_2, t_3) of the mechanical vibrations (9) by the vibration sensors (4).

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TOUCH POSITION DETERMINING DEVICE AND METHOD, AND ELECTRONIC TOUCH-SENSITIVE DEVICE

TECHNICAL FIELD

The present invention relates to a touch position determining device and method, and to an electronic touch-sensitive device. In the ensuing treatment, particular reference will be made, without this implying any loss of generality, to the field of touch-sensitive display devices (touch displays), i.e., devices where functions are activated by mere physical contact.

BACKGROUND ART

As is known, the use of electronic devices provided with touch displays, which enable a user to activate given functions via a physical contact (touch) on pre-set points of a corresponding display screen, is increasing. The contact can be originated directly by the touch of a user's finger, or else can occur via a purposely provided input device, such as for example a stylus. Touch displays are provided with touch position determining devices, configured to determine the position of contact in terms of co-ordinates in the plane in which the display screen lies, and to transmit the position to the corresponding electronic device, in such a manner that it will issue a command for activation of corresponding functions.

A wide range of touch position determining devices are currently known, which are based principally on three technologies: capacitive technology, resistive technology, and ultrasound technology. In any case, the production of the determining devices involves complex additional processing steps in the manufacturing process of the display devices, with considerable repercussions on the manufacturing costs.

In detail, in the case of capacitive technology, an array of

electrostatic capacitances is formed together with a pixel array of the display device. The array of electrostatic capacitances is constituted by electrodes made of transparent metallic material (for example, ITO - Indium Tin Oxide) so as not to be evident to the user. The physical contact on the screen causes a local variation of the capacitance value in the area in which the contact has occurred. An electronic circuit detects the capacitance variation and determines the position of contact. This solution is expensive, and is not in any case altogether invisible to the user, who perceives, in fact, a certain degradation in the quality of the images displayed. Consequently, this solution can be implemented only in applications in which image resolution and quality are not constraining design characteristics.

Resistive technology envisages formation of an array of transparent metallic wires (made, for example, of ITO), whose resistance value is altered by a touch on the display screen. The determining devices employing this technology are widely used, for example, in the aeronautic sector, but the array of metallic wires is visible to the naked eye, and consequently also in this case a non-negligible degradation in the quality of the displayed images occurs.

Ultrasound technology envisages generation of surface acoustic waves with a frequency equal to some tens of megahertz, which distribute with a given pattern over the surface of the display screen. The physical contact determines a local variation of this pattern, from which it is possible, by means of appropriate algorithms, to trace the position at which the contact has occurred. The acoustic waves are generated by a first set of piezoelectric transducers, whilst a second set of piezoelectric transducers, located in appropriate positions of the display screen, detects the pattern of acoustic waves and its alterations. This solution, unlike the ones previously described, is of an active type; i.e., it requires continuous

generation of a pattern of acoustic waves on the surface of the display screen, with a consequent considerable expenditure in terms of energy.

DISCLOSURE OF INVENTION

The aim of the present invention is consequently to provide a touch position determining device and method which is free from the drawbacks outlined above and, in particular, which is simple to produce at contained costs and, at the same time, has a high degree of precision in determining the position of contact.

According to the present invention, a touch position determining device and method are consequently provided, as defined in claims 1 and 13, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, preferred embodiments thereof are now described purely by way of non-limiting example, with reference to the attached drawings, wherein:

- Figure 1 is a schematic illustration of a touch position determining device according to an aspect of the present invention;
- Figure 2 is a flowchart corresponding to processing operations executed by the device of Figure 1;
- Figure 3 shows schematic diagrams illustrating the principle of operation of the device of Figure 1;
- Figure 4 is a partially exploded perspective view of an electronic device including the device of Figure 1; and
- Figure 5 shows an electronic alarm system including the device of Figure 1.

BEST MODE FOR CARRYING OUT THE INVENTION

Figure 1 shows a touch panel 1, and a touch position determining device 2 according to an aspect of the present

invention and configured to determine the position of a physical contact on the touch panel 1. It is emphasized that by the term "touch panel" is meant in what follows a rigid element designed for contact by a user, which can have any shape and size. For example, the touch panel 1 can be associated to the screen of a liquid-crystal-display (LCD) device of an electronic device, which displays icons, menus or other graphic signs, in positions at which a user can exert a contact in order to activate corresponding functions of the electronic device and/or cause new visualizations.

The touch panel 1 is made of a rigid material, for example glass, wood or plastic, and has an outer contact surface 1a, on which contacts are generated, and an inner surface 1b. The outer contact surface 1a lies in a plane xy, and the points belonging to the outer contact surface 1a are univocally defined in a two-dimensional co-ordinate system (x, y). In particular, the mechanical characteristics of the touch panel 1 are such as to enable propagation of mechanical vibrations, advantageously in an isotropic manner (i.e., irrespective of the direction of propagation).

The touch position determining device 2 comprises a plurality of vibration sensors 4, in particular accelerometer sensors, fixedly coupled to the touch panel 1, and a processing circuit 6, of an electronic type, connected to the vibration sensors 4. Conveniently, the vibration sensors 4 are fixed (for example bonded) to the inner surface 1b of the touch panel 1 so as to not be accessible to the user and so as to prevent any risks of manipulation and failure. In particular, for reasons that will be clarified hereinafter, the number of vibration sensors 4 is not less than three.

The processing circuit 6 comprises an interface stage 7, configured to acquire vibration signals generated by the vibration sensors 4, and a processing stage 8, connected to

the interface stage 7 and configured to carry out, as will be described in detail hereinafter, appropriate processing operations from the vibration signals, in order to determine the position of the contact on the outer contact surface 1a.

General operation of the touch position determining device 2 is described in what follows (reference is made also to Figures 2 and 3).

A touch in a point of contact $P_1(x, y)$ of the outer contact surface 1a generates a pattern of mechanical vibrations, designated as a whole by 9 in Figure 1, which propagate at a constant speed starting from the point of contact $P_1(x, y)$ in an equivalent manner in all the directions of the plane xy , given the isotropy of the touch panel 1. In particular, the speed of propagation of the mechanical vibrations 9 depends only on the material of which the touch panel 1 is made, and varies in a known way as a function of temperature.

The vibration sensors 4 detect (block 10) the mechanical vibrations 9 generated by the touch. In particular, detection of the mechanical vibrations 9 by the various vibration sensors 4 occurs at detection times that differ according to the position of the vibration sensors 4 and to their distance from the point of contact $P_1(x, y)$ (in particular, the term "detection time" is used to indicate the instant at which a vibration sensor 4 detects the mechanical vibrations 9).

The processing stage 8 receives the vibration signals generated by the vibration sensors 4, processes them (blocks 11-13) using an appropriate algorithm based on the time of flight, i.e., on the difference between the detection times of the various vibration sensors 4 (or, in a similar manner, between the times of arrival of the mechanical vibrations 9 in positions corresponding to the vibration sensors 4), and determines the position of the contact (block 14), in terms of

co-ordinates (x, y) within the outer contact surface 1a.

In detail, at least three vibration sensors 4 are used to univocally obtain the position of the contact by means of an algorithm based on the time of flight.

Let $P_1(x, y)$ (see, in particular, Figure 3) be the point of contact on the outer contact surface 1a, and d_1 , d_2 and d_3 the distances of the point of contact $P_1(x, y)$, respectively, from a first vibration sensor 4', a second vibration sensor 4'', and a third vibration sensor 4''' fixed to the outer contact surface 1a (assume for example $d_1 < d_2 < d_3$). At a detection time t_1 , the first vibration sensor 4' detects the mechanical vibrations 9 generated by the contact, which are detected by the second vibration sensor 4'' at a detection time t_2 , and by the third vibration sensor 4''' at a detection time t_3 . Given that the propagation of the mechanical vibrations 9 through the touch panel 1 occurs isotropically, the following relation applies: $t_3 > t_2 > t_1$. Then, the processing stage 8 calculates (block 11) the temporal differences (in absolute value, i.e., without the information of sign) $t_2 - t_1$, $t_3 - t_1$ and $t_3 - t_2$ between the detection times of all the possible pairs formed by the vibration sensors 4. From these temporal differences, given that the speed of propagation of the mechanical vibrations 9 is known, the processing stage 8 calculates the corresponding distance differences $d_2 - d_1$, $d_3 - d_1$ and $d_3 - d_2$ between the distances of the point of contact $P_1(x, y)$ from the vibration sensors 4 belonging to each pair. Then, the processing stage 8 associates to each of the distance differences (block 12) a locus of points in the plane xy that are equivalent as regards the time of flight (i.e., they give rise to the same temporal difference between the times of detection of the mechanical vibrations 9 by the vibration sensors 4 of the pair). In particular, the locus of points is a hyperbola having as focuses the positions of the two respective vibration sensors 4', 4'', 4''' of the pair. The hyperbola is in fact by definition the locus of the points whereby the difference of

the distances from two fixed points referred to as focuses is constant. Accordingly, the processing stage 8 identifies: a first hyperbola I_1 having as focuses the first vibration sensor 4' and the second vibration sensor 4''; a second hyperbola I_2 having as focuses the first vibration sensor 4' and the third vibration sensor 4'''; and a third hyperbola I_3 having as focuses the second vibration sensor 4'' and the third vibration sensor 4'''. As illustrated in Figure 3, the three hyperbolas I_1 - I_3 intersect in two points: the point of contact $P_1(x, y)$ belonging to the contact surface 1a, and a further point of intersection $P_2(x, y)$. It is sufficient to arrange the vibration sensors 4 in the proximity of the peripheral edges of the touch panel 1 for the further point of intersection $P_2(x, y)$ to be located outside of the contact surface 1a (as illustrated in Figure 3). Then, the processing stage 8 determines (block 13) the co-ordinates of the intersections of the three hyperbolas I_1 - I_3 , rejects the point of intersection falling outside the contact surface 1a, and considers the co-ordinates of the point of intersection belonging to the contact surface 1a. These co-ordinates correspond to the position of the point of contact $P_1(x, y)$, which can thus be univocally determined by the processing stage 8 (block 14). In fact, the intersection is the single point of the contact surface 1a that satisfies the relations of time of flight associated to the detection times t_1 , t_2 , t_3 of the vibration sensors 4', 4'', 4'''.

In particular, just two vibration sensors 4', 4'' are not sufficient to univocally determine the point of contact $P_1(x, y)$: in fact, the algorithm described, on the basis of the only difference $t_2 - t_1$ between the detection times of the two vibration sensors, would lead in this case to determination of a locus of points (i.e., the hyperbola having as focuses the positions of the two vibration sensors 4', 4'') that are absolutely equivalent, and hence are indistinguishable as regards the time of flight.

Furthermore, the effective position of the vibration sensors 4 with respect to the touch panel 1 is not a determining factor for the purposes of the algorithm described, and consequently the vibration sensors 4 can be arranged at arbitrary positions (provided that they are arranged, however, in the proximity of the periphery of the touch panel 1), according, for example, to specific production requirements.

Advantageously, the number of vibration sensors 4 used for determining the point of contact $P_1(x, y)$ can be greater than three. In particular, if at least four vibration sensors 4 are used, the intersection of the hyperbolas identified as previously described is just one (in a position corresponding to the point of contact $P_1(x, y)$). In this case, consequently, it is not necessary to arrange the vibration sensors 4 in the proximity of the edges of the touch panel 1 (thus, the vibration sensors 4 can be arranged in an altogether arbitrary manner with respect to the touch panel 1), and the processing stage 8 does not carry out any further processing operations beyond determination of the intersection, in order to identify the point of contact $P_1(x, y)$.

Figure 4 shows an electronic device 15, in particular a PDA (Personal Digital or Data Assistant), provided with a touch display 16, for example of the liquid-crystal type (LCD), and with the touch position determining device 2 described above. In detail, the touch display 16 has a touch screen, comprising: a display screen 17; a frame 18, surrounding the display screen 17 and having a supporting function; and the touch panel 1, which is transparent, is preferably made of glass, and is superimposed on the display screen 17 and supported by the frame 18. The vibration sensors 4 (as has been said, not less than three in number) are fixed, for example bonded or carried by suction caps (not shown), to the touch panel 1. In use, the vibration sensors 4 are arranged

between the touch panel 1 and the frame 18. The processing circuit 6, connected to the vibration sensors 4 for determining the position of contact, is in this case conveniently integrated in the control electronics (not shown) that supervises general operation of the touch display 16.

Texts, icons, or other graphic signs are displayed on the display screen 17, and to each of them is associated a given function of the electronic device 15 or a given visualization on the display screen 17. A touch on the outer contact surface 1a generates mechanical vibrations which propagate towards, and are detected by, the vibration sensors 4. The processing circuit 6 (Figure 1) thus determines univocally the position at which the touch has occurred on the basis of the differences between the times of arrival of the mechanical vibrations to the various vibration sensors 4, and transmits this position to the control electronics of the electronic device 15, which activates the corresponding functions/visualizations.

Figure 5 shows a further application of the touch position determining device 2 as alarm system, for example for the protection of a show case 20. In this case, the touch panel 1 is constituted by a glass plate of the show case 20, and the vibration sensors 4 are fixed to the inner surface 1b of the touch panel 1. The processing circuit 6 (Figure 1) is connected to an alarm device 22 (for example, a siren), which activates upon detection of a theft attempt (i.e., upon detection of a contact on the touch panel 1). In particular, the processing circuit 6, via the algorithm described above, enables univocal identification of the co-ordinates of the point at which the theft attempt has been made.

The touch position determining device has the following advantages.

In the first place, it does not entail any complex and costly

additional manufacturing steps, in so far as the vibration sensors 4 can be applied in a simple manner at the end of the manufacturing process of any display device or of a generic electronic device. Furthermore, the presence and provision of electrodes and/or wires that would be visible to the naked eye, thus jeopardizing the quality of display of the images, is not necessary.

The spatial resolution with which the position of contact is determined is high. In fact, considering a typical speed of propagation of mechanical vibrations of 3.5 km/s, to have a spatial resolution Δx of 1 mm, it is necessary for the electronic circuit 6 to appreciate a temporal difference Δt between the detection times of the various vibration sensors 4 of:

$$\Delta t = \frac{\Delta x}{v} = \frac{10^{-3}}{3 \cdot 10^3} = 0.3 \mu s$$

It is consequently necessary to discriminate the time of flight with a precision in the region of a microsecond, a temporal difference that is altogether compatible with the electronics available on the market.

The power consumption is reduced, in so far as the determining device is of a passive type and does not envisage continuous generation of a pattern of acoustic waves. The determining device is sturdy and not easily subject to damage.

In addition, use of a number of vibration sensors 4 greater than three (for example, four vibration sensors) is advantageous in so far as the point of intersection between the various hyperbolas is unique.

Finally, it is clear that modifications and variations may be made to what is described and illustrated herein without thereby departing from the scope of the present invention, as

defined in the annexed claims.

In particular, if a number of vibration sensors 4 equal to three is used, the problem of the non-uniqueness of the intersection between the various hyperbolas I_1 - I_3 can be solved in an alternative way, without arranging the vibration sensors 4 in the proximity of the edges of the control panel 1. In detail, the processing stage 8 can be configured to determine also the information of sign of the temporal differences between the detection times of the mechanical vibrations 9, and to use this information of sign in order to discriminate the point of contact $P_1(x, y)$ between the two resulting intersection points. In fact, only one of the two intersection points (i.e., the point of contact $P_1(x, y)$) satisfies the conditions on the temporal differences, if it is considered with sign, whereas the further point of contact $P_2(x, y)$ is rejected by the processing stage 8.

The vibration sensors 4 may be microphones or piezoelectric sensors, instead of accelerometer sensors, or in any case sensors of movement capable of detecting the presence of the vibrations generated by the touch on the contact surface.

The described device can advantageously be applied in numerous other applications, for example in the field of toys, for making a light-up board that changes colour or lights up where a contact has occurred (the co-ordinates of contact being determined as previously described). In this case, the touch panel 1 is constituted by the same light-up board, or by an outer casing thereof.

The touch position determining device can advantageously be used not only in display devices of an LCD type, but also to make touch sensitive display devices of any other type (for example, Cathode Ray Tube - CRT, Organic Light Emitting Diode - OLED, etc.).

The arrangement of the vibration sensors 4 can be different; for example, they can be fixed to the outer contact surface 1a, instead of to the inner surface 1b. The vibration sensors 4 can also be directly fixed to the screen 17 of the display device 16, without any need for providing any additional touch panel.

CLAIMS

1. A device (2) for determining the position ($P_1(x, y)$) of a touch on a contact surface (1a) characterized by:
 - a plurality of vibration sensors (4) configured to detect mechanical vibrations (9) generated by said touch on said contact surface (1a) and to generate corresponding vibration signals; and
 - a processing circuit (6) connected to said vibration sensors (4) and configured to determine said touch position ($P_1(x, y)$) based on said vibration signals.
2. The device according to claim 1, wherein said processing circuit (6) is configured to determine said touch position ($P_1(x, y)$) via a time-of-flight algorithm, on the basis of times of detection (t_1, t_2, t_3) of said mechanical vibrations (9) by said vibration sensors (4).
3. The device according to claim 1 or 2, wherein said contact surface (1a) lies in a plane (xy), and said processing circuit (6) is configured to determine temporal differences between times of detection (t_1, t_2, t_3) of said mechanical vibrations (9) by vibration sensors (4) belonging to pairs of said vibration sensors (4), and to identify loci of points (I_1-I_3) of said plane (xy) corresponding to said temporal differences; said touch position ($P_1(x, y)$) being determined as the point of intersection of said loci of points (I_1-I_3) belonging to said contact surface (1a).
4. The device according to claim 3, wherein each of said loci of points (I_1-I_3) is a hyperbola having as focuses positions of the vibration sensors (4) of a respective one of said pairs.
5. The device according to any one of the preceding claims, wherein the number of said vibration sensors (4) is not less than three.

6. The device according to any one of the preceding claims, wherein said vibration sensors (4) are accelerometer sensors.

7. The device according to any one of the preceding claims, wherein said vibration sensors (4) are rigidly coupled to said contact surface (1a).

8. The device according to claim 7, wherein said contact surface (1a) is an outer surface (1a) of a touch panel (1), and said touch panel (1) has an inner surface (1b) opposite to said contact surface (1a); said vibration sensors (4) being fixed to said inner surface (1b).

9. An electronic touch-sensitive device (15), comprising a contact surface (1a) and a device (2) for determining the position ($P_1(x, y)$) of a touch on said contact surface (1a), said device (2) being made according to any one of the preceding claims.

10. The electronic device according to claim 9, wherein said contact surface (1a) is made of a rigid material, configured to transmit at least partially and isotropically mechanical vibrations (9).

11. The electronic device according to claim 9 or 10, wherein said electronic device is a touch display (16).

12. The electronic device according to claim 11, comprising a display screen (17), a frame (18) surrounding said display screen (17), and a touch panel (1) made of a rigid material configured to transmit at least partially and isotropically said mechanical vibrations (9) and including said contact surface (1a); said touch panel (1) being superimposed on said display screen (17) and supported by said frame (18), and said vibration sensors (4) being arranged between said frame (18) and said touch panel (1).

13. The electronic device according to claim 11 or 12, wherein the touch display (16) comprises one of an LCD, CRT and OLED display.

14. The electronic device according to any one of claims 9-13, wherein the device comprises a personal digital assistant.

15. A method for determining the position ($P_1(x, y)$) of a touch on a contact surface (1a) characterized by:

- detecting vibration signals at a plurality of detection points fixed to said contact surface (1a), said vibration signals being a function of mechanical vibrations (9) generated by said touch on said contact surface (1a); and
- processing said vibration signals for determining said touch position ($P_1(x, y)$).

16. The method according to claim 15, wherein said processing step comprises determining said touch position ($P_1(x, y)$) via a time-of-flight algorithm, on the basis of times of detection (t_1, t_2, t_3) of said mechanical vibrations (9) at said detection points.

17. The method according to claim 15 or 16, wherein said contact surface (1a) lies in a plane (xy), and said processing step comprises:

- determining temporal differences between times of detection (t_1, t_2, t_3) of said mechanical vibrations (9) at detection points belonging to pairs of said detection points;
- identifying loci of points (I_1-I_3) belonging to said plane (xy) corresponding to said temporal differences; and
- determining said touch position ($P_1(x, y)$) as the point of intersection of said loci of points (I_1-I_3) belonging to said contact surface (1a).

18. The method according to claim 17, wherein each of said loci of points (I_1-I_3) is a hyperbola having as focuses the

detection points of a respective one of said pairs of detection points.

19. The method according to any one of claims 15-18, wherein the number of said detection points is not less than three.

20. The method according to any one of claims 15-19, further comprising providing vibration sensors (4) at said detection points in such a manner that said vibration sensors (4) are sensitive to mechanical vibrations (9) generated by said touch on said contact surface (1a); providing vibration sensors comprising mechanically coupling said vibration sensors (4) to said contact surface (1a).

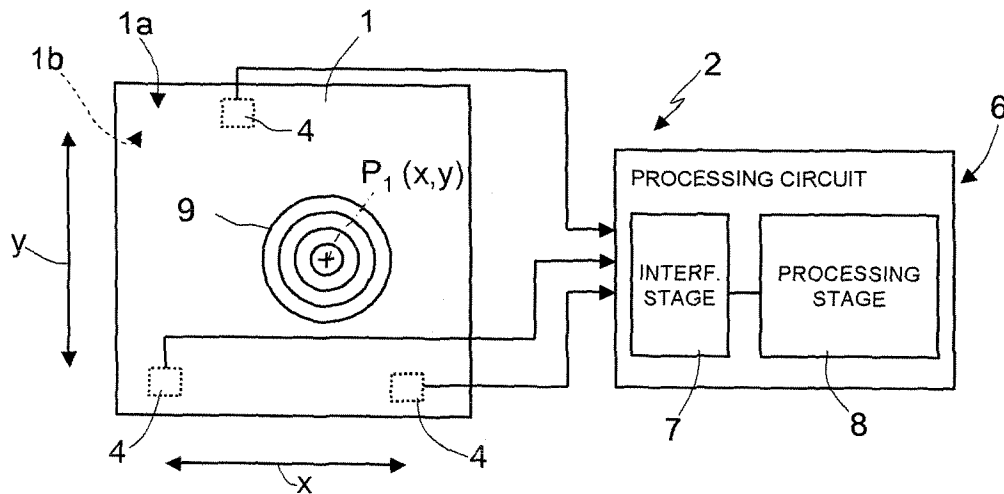


Fig.1

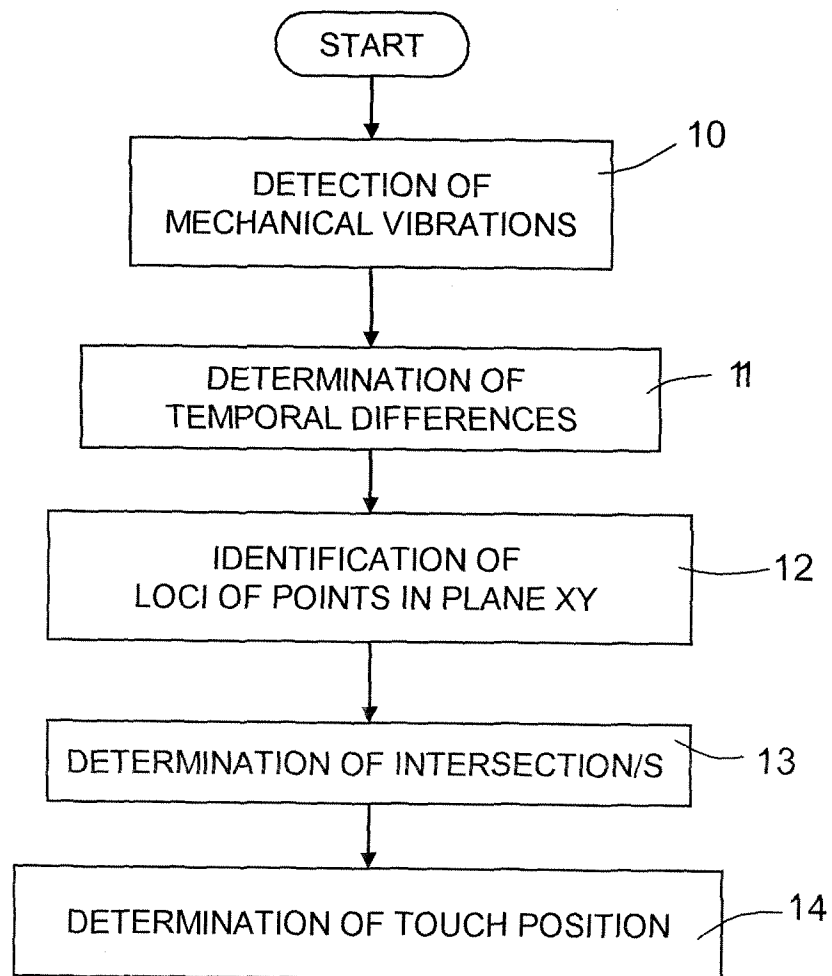


Fig.2

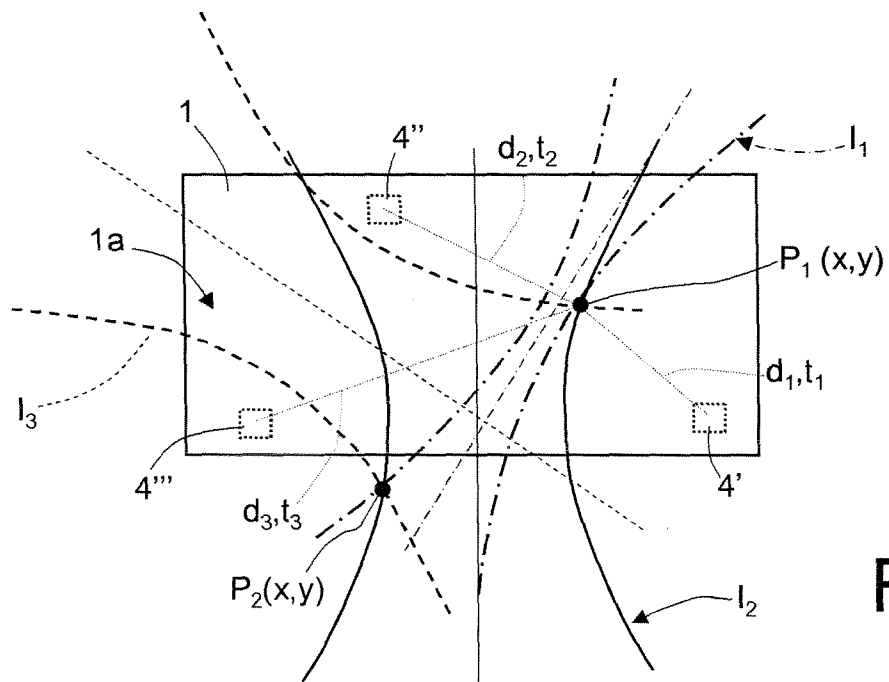


Fig.3

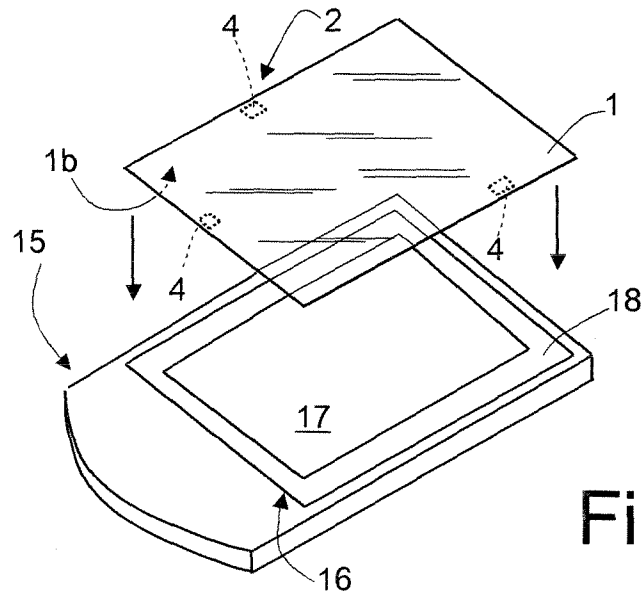


Fig.4

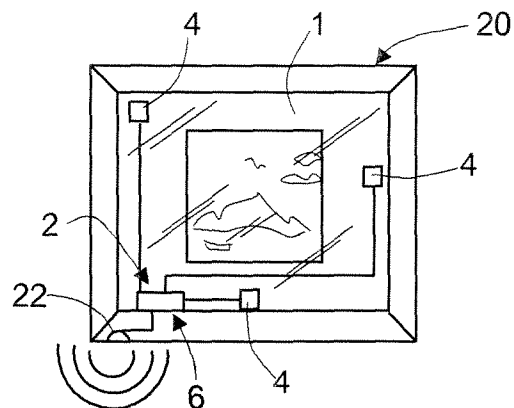


Fig.5