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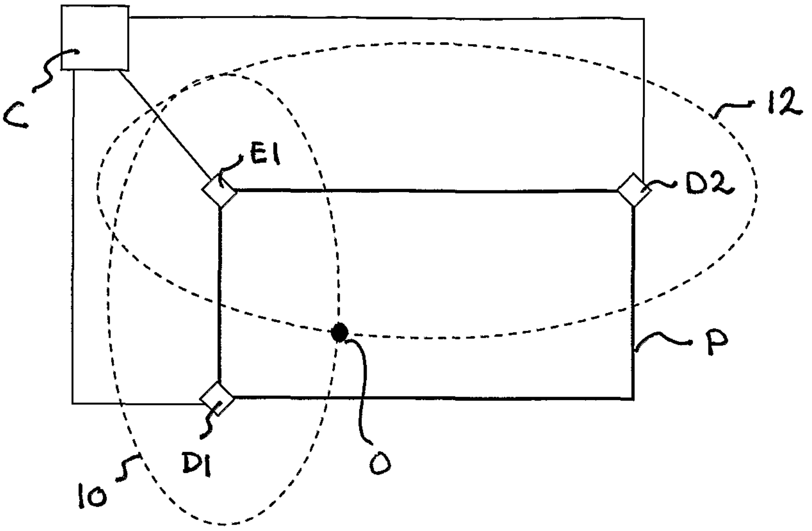

(57) **Abstract:** An optical interface system, such as a touch pad or a touch screen, includes an optical waveguide (P) having a first surface adapted to be engaged by an object in a point-of-touch (O) so as to reflect/scatter radiation into the waveguide (P). The system includes at least one emitter (E1) for injecting radiation into the waveguide (P) and at least one detector (D1, D2) for detecting injected radiation that has been reflected/scattered by the object. The emitter(s) and detector(s) form part of at least one range-finder of the system for determining the distance to the point-of-touch by comparing emitted and detected radiation. The system further includes means (C) for determining the position of the point-of-touch (O) on the waveguide (P). Such determining means (C) may operate on a plurality of distances determined by a plurality of range-finders or on at least one distance determined by a range-finder and a direction/angle for the emitted radiation and/or the detected radiation in a plane parallel to the first surface of the waveguide.

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POSITION DETERMINATION IN OPTICAL INTERFACE SYSTEMS

Cross-Reference to Related Applications

The present application claims the benefit of U.S. provisional patent application No. 60/873,594, filed on December 8, 2006 and incorporated herein by reference.

Field of the Invention

The present invention relates to optical interface systems, such as touch pads and touch screens, comprising a radiation-transmissive element that guides radiation by internal reflection, and in particular to techniques for determining the position of a point-of-touch on such an element based on radiation reflected/scattered/emitted into the element at the point of touch.

Background of the Invention

Optical interface systems are previously known. For example, WO 03/0077192, WO 2005/026938 and WO 2007/003196 describe different techniques for determining the position of the point-of-touch on an optical touch pad.

Summary of the Invention

It is an object of the present invention to provide one or more alternative techniques for determining the position of the point-of-touch of an object on an optical interface system.

This and other objects, which will appear from the description below, are at least partly achieved by means of systems for determining the position of an object, an optical interface system, and a method of determining the position of an object according to the independent claims, embodiments thereof being defined by the dependent claims.

In a first aspect, the present invention relates to a system for determining the position of an object adapted to reflect/scatter radiation, the system comprising:

- a radiation-transmissive element having a first surface being adapted to be engaged by the object so as to reflect/scatter radiation into the element and a second surface opposite the first surface, the radiation-transmissive element being adapted to guide radiation by internal reflection;
- a first radiation emitter being arranged to emit a pulse of radiation into the element and towards the first/second surface;

- a first detector arranged to detect radiation emitted into the radiation-transmissive element and reflected/scattered by the reflecting/scattering object, the first detector being adapted to output a first signal relating to the detected radiation;
- at least one of:
  - a second radiation emitter being arranged to emit a pulse of radiation into the element and towards the first/second surface, and
  - a second detector arranged to detect radiation emitted into the radiation-transmissive element and reflected/scattered by the reflecting/scattering object, the second detector being adapted to output a second signal relating to the detected radiation; and
- a determining means being adapted to determine the position of the reflecting/scattering object on the first surface on the basis of:
  - point(s) in time of emission of a pulse of radiation by the radiation emitter(s), and
  - point(s) in time of outputting of said signal(s).

In the first aspect, radiation is emitted into the radiation-transmissive element by means of the first (and possibly the second) emitter, such that the radiation propagates inside the radiation-transmissive element by being reflected between the first and the second surface. An object touching the first surface at a point-of-touch may reflect/scatter said radiation such that it propagates in a plurality of different angles relative to the normal of the first and/or second surface. Radiation propagating above a predetermined angle relative to the normal of the first and/or second surface will be reflected by said surfaces whereby the radiation will bounce between the first and second surface. A part of said radiation may propagate in the direction of the first (and possibly the second) detector, which may detect the radiation.

By determining the point in time of emission of radiation by the first (and possibly the second) emitter and by determining the point in time of detection of the reflected/scattered radiation by the first (and possibly the second) detector, it is possible to determine the time elapsed between emission and detection. The elapsed time corresponds to the distance from the emitter to the detector via the point-of-touch. Accordingly, for each combination of an emitter and a detector it is possible to determine a plurality of possible positions of the point-of-touch.

If the emitter and the detector are provided in substantially the same spot, the possible points of touch define a circle with the emitter/detector in the centre. If the emitter and the detector are spaced apart the possible points-of-touch define an ellipse, as the sum of the distance from the emitter to the point-of-touch and the distance from the point-of-touch to the detector is constant, as the sum is determined by the time between emission and detection. Accordingly, the emitter and detector are located in the focus-points of the ellipse.

By providing a first emitter and detector, and at least a second emitter or detector, it is possible to determine at least two ellipses (circles), as will be further described below with reference to Fig. 4A-4C. The point-of-touch may be determined as the point(s) of intersection of the ellipses.

In one embodiment, exemplified in Fig. 4A, the system comprises a first emitter E1 and a first and second detector D1,D2, directly or indirectly connected to a determining means C. At least a part of the radiation emitted by the first emitter E1, will propagate in the radiation-transmissive element P towards the reflecting/scattering object O which reflects/scatters the radiation. The first and the second detector D1,D2 may subsequently detect the reflected/scattered radiation.

Accordingly, a first ellipse 10 having the first emitter E1 and the first detector D1 in the focus-points may be determined and a second ellipse 12 having the first emitter E1 and the second detector D2 in the focus-points may be determined. The point-of-touch may be determined as the point(s)-of-intersection of the first and the second ellipses 10,12.

In a second embodiment, exemplified in Fig. 4B, the system comprises a first and second emitter E1,E2 and a first detector D1, directly or indirectly connected to a determining means C. At least a part of the radiation emitted by the first emitter E1 will propagate towards the reflecting/scattering object O which reflects/scatters the radiation which, subsequently, may be detected by the first detector D1. Analogously, at least a part of the radiation emitted by the second emitter E2 will propagate towards the reflecting/scattering object O which reflects/scatters the radiation which, subsequently, may be detected by the first detector D1.

A first ellipse 14 having the first emitter E1 and the first detector D1 in the focus-points may be determined and a second ellipse 16 having the second emitter E2 and the first detector D1 may be determined. Again, the point-of-touch may be determined as the point(s)-of-intersection of the first and second ellipses 14,16.

In a third embodiment, exemplified in Fig. 4C, the system comprises a first and a second emitter E1, E2 and a first and second detector D1,D2, directly or indirectly connected to a determining means C. From the above, it will be appreciated that the first and second detector D1,D2 each may detect radiation emanating from the first and the second emitter E1,E2, whereby four ellipses 18,20,22,24 may be determined on the basis of one point-of-touch. In order to differentiate the radiation originating form the first emitter E1 from radiation originating from the second emitter E2, the two emitters may be operated out of phase and/or emit radiation at different frequencies as will be described in further detail below.

In the first aspect, the determining means together with the arrangement of the emitter(s) and the detector(s) defines a plurality of range-finders. Based on a plurality of distances to the point-of-touch given by the range-finders, the system may be capable of determining the position of the point-of-touch for the object on the radiation-transmissive element. The determining means may be implemented by hardware calculation circuitry, optionally in combination with controlling software. In one specific embodiment, the determining means is a software-controlled computer.

A first type of range-finder is one emitting a single pulse or a number of individual pulses, and which determines the range or distance by the time-of-flight of the pulse. Determining the point in time of emission of a pulse and the point in time of receipt of the reflected pulse automatically provides an estimate of the distance from the emitter to the target and further to the detector.

A second type of range-finder is one emitting a continuous signal, such as a sine-wave which may be seen as a number of identical pulses equally spaced in time. This range-finder receives the reflected signal and compares the phase (the position of the peaks, valleys or other easily determinable positions) of the detected signal and that emitted by the emitter. This phase difference relates to a time-of-flight and will relate to the distance from the emitter to the target and further to the detector.

A third type of range-finder is also one emitting a continuous signal, such as a sine wave, but this range-finder varies the frequency of the signal in order to obtain a resonance between the emitted and the received signals. When the resonance occurs (no phase difference exists between the emitted and received signals), the distance from the emitter to the detector via the target will be an integer times the wavelength of the sine wave. From this frequency, an estimate of the distance may be derived.

The first and the second surfaces may be parallel or substantially parallel, and the distance there-between may be known. This distance may be used in the determination the point-of-touch, as the time elapsing between emission of a radiation pulse and the detection of its reflection/scattering by the object, depends on the distance between the first and the second surface and the bouncing angle.

For the same distance between the first and the second surface, the distance covered by radiation propagating at a large angle (relative to the normal of the first and/or second surface) between two points, is shorter than the distance covered by radiation propagating at a small angle (relative to the normal of the first and/or second surface) between the same two points.

The radiation-transmissive element may comprise an edge portion interconnecting the first and the second surface. The radiation-transmissive element may define a plurality of corners such as three corners (triangular) or four corners (quadrangular). The radiation-transmissive element may be a solid radiation-transmissive element made from a radiation-transmissive material such as glass or plastic or any material suitable for use in fibre optics or windows.

The first and/or the second surface may be coated e.g. with an antiglare coating or a protecting layer suitable for limiting scratches caused by mechanical engagement with the first and/or the second surface. At least one surface of the radiation-transmissive element may be adapted to be engaged by an object adapted to reflect/scatter radiation. The object may take the form of a finger, a pen, a stylus, a credit cart or the like.

The radiation-transmissive element may be an optical waveguide adapted to guide radiation by Total Internal Reflection (TIR), whereby at least a part of the radiation will propagate inside the transmissive element by bouncing between the first and the second surface. The first and/or the second surface may have a small critical TIR-angle. The TIR-angle being defined as, the critical angle relative to the normal of a surface, above which TIR occurs.

In the context of the present invention, radiation subject to internal reflection such as TIR, is said to propagate in a plane parallel with the first and/or second surface despite the fact that it naturally will propagate in directions transverse to said plane as it is reflected by the two surfaces.

In the context of the present invention, the terms "first/second emitter" and "first/second detector" shall be understood as "the first and/or second and/or one or more further radiation emitter(s)" and "the first and/or second and/or one or more further detector(s)", respectively.

The first/second emitter is adapted to emit radiation into the radiation-transmissive element. Said radiation may be emitted into the element through the first and/or second surface of the transmissive element. Alternatively, or as a supplement, the radiation may be emitted into the element through the edge of the transmissive element.

The first/second emitter may be configured and/or arranged with respect to neighbouring/adjacent edges, such that said edges cannot be irradiated/illuminated directly. Thereby, the neighbouring/adjacent edges are shielded from direct illumination.

The first/second emitter may comprise an LED, a laser diode, a VCEL laser diode, an OLED, a micro bulb or any other suitable radiation providing means. In one embodiment the radiation emitted by the first/second emitter is guided into the radiation-transmissive element by means of a wave guide. The wave guide and the corresponding emitter may be manufactured as a separate element adapted to be attached to a radiation-transmissive element, such as a shop window.

In the context of the present invention, the term "pulse of radiation" shall be understood as an emission/discharge/burst of electromagnetic energy within a predetermined period of time i.e. a rise and fall of electromagnetic energy within said period of time.

The first/second detector may be provided on or at the first and/or second surface of the transmissive element. Alternatively, or as a supplement, the first/second detector may be arranged on or at one of the edges of the transmissive element. The first/second detector may be arranged to detect radiation propagating in the transmissive element as a result of reflection/scattering by the reflecting/scattering object.

The first/second detector may be arranged with respect to neighbouring/adjacent edges, such that reflections of radiation by said edges may be detected by the detector. As an example, the detector may be provided at a corner of the radiation-transmissive element.

The first/second detector is adapted to output a signal such as an electrical signal relating to the detected radiation. The first/second detector may be electrically connected to the determining means, and the latter may be adapted to receive the outputted signal.

In the context of the present invention, the term "detector" shall be understood as an electronic device that responds in a predictable way whereby an electrical property of the detector is changed as a function of the detected radiation.

In one embodiment, the first radiation emitter and the first detector are provided adjacent to each other e.g. on one edge of the radiation-transmissive element. One advantage of providing the emitter and the detector adjacent to each other is, that the detector is not dazzled by the radiation emitted by the emitter, as the emitter emits the radiation away from the emitter and the detector.

In another embodiment, the first emitter and the first detector are provided on or at opposite edges of the radiation-transmissive element. In a further embodiment the first emitter and the first detector are provided at neighbouring edges of the radiation-transmissive element.

Moreover, the system may comprise a second radiation emitter and a second detector which may be provided adjacent to each other or on opposite or neighbouring edges of the transmissive element as mentioned in relation to the first emitter and the first detector.

Additionally, the system may comprise one or more further radiation emitters and/or one or more further detectors, such as one further emitter and two further detectors. It will be appreciated that the system may comprise any number of emitters and any number of detectors and that the number of emitters may be different form the number of detectors. Furthermore it will readily be realised, that the larger the number of detectors and emitters are the more precise the determination of the point-of-touch may be, as the number of ellipses which may be detected increases whereby the point-of-touch may be determined as the position wherein the majority of ellipses overlap.

As mentioned above, the first radiation emitter and the second radiation emitter may be adapted to be operated out of phase such that they are adapted not to be operated simultaneously. Accordingly, when the first emitter is operated, the second emitter may intentionally not be operated and vice versa. The advantage is that radiation from the two emitters may be distinguished from each other.

In order to improve the prediction of the point-of-touch, at least one of the radiation emitters may be adapted to emit radiation in a predetermined direction transverse to the first and/or second surface of the radiation-transmissive element. Thus, when radiation is emitted into the transmissive element the bouncing angle is known, whereby simple trigonometry may be used to determine the length of the radiation path as the distance between subsequent reflections by the two surfaces equals $d/\cos(a)$, where d is the distance between the first and second surface and a is the angle of the radiation relative to the normal of the first and/or second surface.

In the context of the present invention, the term "predetermined direction" shall not only cover a specific direction which defines one single angle relative to a reference (e.g. the normal of the first surface) and in a predetermined plane, but also any direction within an angular segment defined between two predetermined directions relative to a reference and in the predetermined plane.

The radiation may be emitted at an angle below the critical TIR-angle. In one embodiment the first/second emitter emits radiation through one of the edges of the radiation-transmissive element.

Moreover, at least one of the detectors may be adapted to detect radiation propagating in a predetermined direction transverse to the first and/or the second surface of the radiation-transmissive element. By adapting a detector to detect radiation in a predetermined direction, the bouncing angle of the detected radiation is known. Accordingly, the length of the radiation path of the radiation propagating from the object may be determined precisely, as shown above.

In one embodiment, the emitter is adapted to emit radiation in a predetermined transverse direction and the detector is adapted to detect radiation propagating in the same predetermined transverse direction. Accordingly, the length from the emitter to the touching object may be determined precisely and the distance from the object to the detector may also be determined precisely.

Additionally, at least one of the emitters may be adapted to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface (i.e. in the xy-direction) and to emit radiation in said predetermined directions in a predetermined sequence. The emitter may be adapted to emit radiation in a number of predetermined angular segments in said plane, such as two segments, such as five segments, such as ten segments, such as fifty segments, such as one hundred segments. In one embodiment, each segment defines a predetermined angle such as one degree, such as two degrees, such as five degrees, such as 10 degrees, such as 15 degrees, such as 30 degrees, such as 45 degrees, such as 60 or 90 degrees. In one example, the sum of the angular segments of an emitter is 90 degrees while in another example the sum is 180 degrees. When radiation is emitted in predetermined angular segments, it is possible to eliminate false points-of-touch, i.e. outside said angular segments.

In order to distinguish between the predetermined angular segments, radiation may be emitted in a predetermined sequence in said segments. In one example, emission into the segments may be synchronised such that radiation is only emitted into one segment at the time, while in other embodiments the system is adapted to emit radiation into two or more segments at the same time. In the latter example, the system may be adapted to avoid emission of radiation into two neighbouring segments simultaneously. In one embodiment, the emitter is adapted to emit radiation into angular segments which are separated by at least one other angular segment. The system may track points of touch and only emit radiation towards foreseen points-of-touch.

Additionally, at least one of the detectors may be adapted to determine an angle of incidence of the detected radiation in a plane parallel with the first surface, i.e. in the xy-direction. Again, the angle of incidence of the detected radiation may be used to eliminate points-of-touch which would have a different angle of incidence, whereby the point-of-touch may be determined more precisely.

The radiation-transmissive element may comprise a plurality of corners, such as three, such as four, such as five, such as six. The first radiation emitter and the first detector may be located in or at a first corner, while the second radiation emitter and the second detector are located in or at a second corner. The first and second corners may be neighbouring corners or opposite corners.

In one embodiment, the determining means may furthermore be adapted to determine the position of the reflecting/scattering object on the basis of information relating to the relative and/or absolute positions of the radiation emitters and the detectors.

In the second aspect, the present invention relates to a system for determining the position of an object adapted to reflect/scatter radiation, the system comprising:

- a radiation-transmissive element having a first surface being adapted to be engaged by the object so as to reflect/scatter radiation into the element and a second surface opposite the first surface, the radiation-transmissive element being adapted to guide radiation by internal reflection;
- a radiation emitter being arranged to emit a pulse of radiation into the element and towards the first/second surface;
- a detector arranged to detect radiation emitted into the radiation-transmissive element and reflected/scattered by the reflecting/scattering object, the first detector being adapted to output a signal relating to the detected radiation;

wherein

  - the radiation emitter is adapted to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface, and/or
  - the detector is adapted to determine an angle of incidence of the detected radiation in the plane,

the system further comprising:

- a determining means being adapted to determine the position of the reflecting/scattering object on the first surface on the basis of:
  - point(s) in time of emission of a pulse of radiation by the radiation emitter, and

- point(s) in time of outputting of said signal, and
- the direction of the emitted radiation and/or the angle of incidence of the detected radiation.

Since the radiation emitter is adapted to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface, it is possible to focus the radiation towards specific zones on the radiation-transmissive element. Moreover, the determining means may be adapted to control the radiation emitter such that radiation is not emitted in all directions simultaneously, thus, making it possible to eliminate point-of-touch in non-irradiated (non-illuminated) zones. Accordingly, the determining means may be adapted to determine the position of the reflecting/scattering object on the basis of which directions/zones were irradiated at the time of detecting of a point-of-touch, i.e. at the time of detection of a reflection by an object engaging the first surface, said reflection being a reflection of radiation emitted by the radiation emitter.

Alternatively, or as a supplement, the detector may be adapted to determine an angle of incidence of the detected radiation in the plane. Thus, if the radiation emitter emits radiation in a plurality of or all directions in the plane, the determining means may be adapted to eliminate areas on the transmissive element from which radiation has not been detected. This simplifies the detection procedure. Moreover, by determining the reflections/scatterings as a function of time and angle of incidence, it may be possible to eliminate reflections by the edges of the radiation-transmissive element as they will be detected subsequent to detection of radiation propagating in the direct radiation path from the reflecting/scattering object and to the detector.

In the second aspect, the determining means together with the configuration of the emitter and the detector defines a range-finder, Based on the distance to the point-of-touch given by the range-finder together with the angle/direction data, the system may be capable of determining the position of the point-of-touch for the object on the radiation-transmissive element.

In one embodiment, the emitter may be adapted to emit radiation in said predetermined directions in a predetermined sequence. In one embodiment, the radiation emitter is adapted to emit radiation in one direction/zone at the time while in other embodiments the emitter emits radiation in two or more zones at the time. The emitter may be adapted to emit radiation in two or more adjacent directions/zones simultaneously. Alternatively, the emitter may be adapted to emit radiation in directions/zones separated by at least one other zone/direction such as one zone, such as two zones, such as three zones. In one embodiment, every second emission by the emitter may be directed towards an expected or predicted point-of-touch, while the remaining emissions are directed in all directions. The expected point-of-touch may be determined on the basis of one or more previous detections of the point-of-touch.

The radiation-transmissive element may comprise two or more edges such as two edges, such as three edges, such as four edges. The radiation emitter and the radiation detector may be provided on or at different edges, such as at neighbouring edges or at opposite edges. In one embodiment the emitter and the detector are provided adjacent to each other at the same edge.

In order to improve the prediction of the point-of-touch, the radiation emitter may be adapted to emit radiation in a plurality of predetermined directions transverse to (at an angle to) the first and/or second surface of the radiation-transmissive element. When radiation is emitted into the transmissive element the bouncing angle is known, whereby simple trigonometry may be used to determine the radiation path and thus the distance to the point-of-touch.

Moreover, the detector may be adapted to detect radiation propagating in predetermined direction transverse to the first and/or the second surface of the radiation-transmissive element. By adapting a detector to detect radiation in a predetermined transverse direction, the bouncing angle is known. Accordingly, the length of the radiation path of the radiation propagating from the object may be determined precisely.

In one embodiment the emitter is adapted to emit radiation in a predetermined transverse direction and the detector is adapted to detect radiation propagating in a predetermined transverse direction. Accordingly, the length from the emitter to the touching object may be determined precisely and the distance from the object to the detector may also be determined precisely.

The determining means may be adapted to determine the position of the reflecting/scattering object on the basis of information about relative or absolute positions of the radiation emitter and detector.

It is to be understood that the invention according to the first aspect of the invention may comprise any feature or element of the invention of a second aspect of the invention, and vice versa. As an example, the description of the radiation-transmissive element of the first aspect of the invention also applies to the radiation-transmissive element of the second aspect of the invention. In fact, the first and second aspects may be combined to provide further improved position determination.

Still other objectives, features, aspects and advantages of the present invention will appear from the following detailed description, from the attached dependent claims as well as from the drawings.

Brief Description of the Drawings

Embodiments of the invention will now be described in further detail with reference to the accompanying schematic drawings in which:

Fig. 1 is a top plan view of a radiation-transmissive element comprising two emitters and two detectors,

Fig. 2 is a side view of a radiation-transmissive element to illustrate smearing of radiation emitted by an emitter,

Fig. 3 is a top plan view of a radiation-transmissive element to illustrate an object irradiated directly and by single and double reflections, and

Figs 4A-4C are top plan views of a radiation-transmissive element to illustrate different embodiments of the first aspect of the invention.

Detailed Description of Embodiments of the Invention

Fig. 1 illustrates a radiation-transmissive element 100 having a first surface 102 (facing upwards in the drawing) and an opposite second surface (not visible in the drawing). The radiation-transmissive element comprises a first, second, third and fourth corner 104,106,108,110. A first radiation emitter 112 and a first detector 114 are provided at/on the first corner 104 and a second radiation emitter 116 and a second detector 118 are provided at/on the second corner 106. Accordingly, the first emitter/detector 112,114 and the second emitter/detector 116,118 are located at adjacent corners 104,106.

In this example, the emitters 112,116 are adapted to emit radiation into the radiation-transmissive element 10 so as to cover an angular segment defining a 90 degree angle, i.e. each emitter emits radiation covering the full extent of the radiation-transmissive element 100. Due to the bounce angle of the emitted radiation, concentric circles 120,122 on the first surface are irradiated. The first emitter 112 irradiates a first set of concentric circles 120, while the second emitter 116 irradiates a second set of concentric circles 122. In Fig. 1, the concentric circles 120,122 are illustrated as straight lines, however, it will be appreciated that the concentric circles in a real situation may be essentially circular. The concentric circles 120,122 define an illuminating grid.

Additionally, the detectors 114,118 are adapted to detect radiation propagating with a predetermined angle with respect to the z-axis (i.e. the axis perpendicular to the first surface), whereby radiation must be reflected from predetermined (concentric) zones of the first surface in order to be detected. These predetermined zones define a sensing grid.

Alignment of the emitters 112,116 relative to the radiation-transmissive element 100 may be important in order to avoid that radiation is directed towards the two element sides adjacent to each emitter 112,116 as this may result in total reflection of the radiation and thus a secondary radiation pattern on the radiation-transmissive element 100 which creates undesired noise in the detected radiation.

Radiation reflected/scattered by the reflecting/scattering object 124 may be spread in all directions and bounce towards the edges 126 of the radiation-transmissive element as illustrated in Fig. 3. In some embodiments this reflected/scattered radiation will be reflected by the edges 126 and some this radiation will be detectable by the sensors. The occurrence of reflection depends on the location of the point-of-touch. The closer the point-of-touch is to the edges the more TIR-reflection may occur and the further away the point-of-touch is the more Snell-reflection may occur.

Undesired reflections may be reduced or eliminated by providing an absorptive material on one or more of the edges of the radiation-transmissive element. In one embodiment use of materials having lower refractive indices than the waveguide are avoided as such materials result in TIR in high angles.

The determining means (shown in Figs 4A-4C) may be adapted to determine the distance from each detector to the point-of-touch. Thus, when two detectors are provided the actual point-of-touch may be determined by triangulation.

Optical noise created by reflections from surface imperfections and surface contaminants such as grease, water, dirt etc. will to some extent create background noise. A part of this noise will be static, and the determining means may be adapted to subtract said static noise from the received signal. The non-static part may be statistical as it smears out the radiation. The effect is that bouncing angle of the reflected/scattered radiation may change whereby the optical pathway is changed. Furthermore, surface imperfections and surface contamination may also deflect the reflected/scattered radiation. The deflected radiation will normally be statistical as it propagates in its initial x,y,z direction with a smear spread.

Fig. 2 illustrates smearing of radiation 130 emitted by the emitter 112. The bouncing angle of smeared radiation 132 differs from the bouncing angle of the emitted radiation and, thus, the optical pathway is not the same. Furthermore, as radiation is smeared out over an angular segment the irradiated areas 134,134′ on the first (and second) surface increases with the distance to the emitter.

It will be appreciated the distance between the concentric circles 120,122 depends on the angle at which the emitters emit radiation. The smaller the angle is (with respect to the normal of the first surface), the smaller is the distance between the circles 120,122. However, the larger the angle is, the further into the radiation-transmissive element the radiation may be emitted, as each reflection weakens the radiation. However, large angles increases the distance between the circles 120,122 whereby the size of non-irradiated zones are increased.

In one embodiment, the illuminating grid (defined by the concentric circles 120,122 in Fig. 1) and the sensing grid are identical. This may be achieved by providing a beam-splitter whereby the emitted radiation and the detectable radiation is co-axial. In other embodiments, the field of view of the emitter and the detector are not exactly co-axial. However, in such embodiments only points-of-touch in overlapping grids are detectable.

In one embodiment, a laser emitter is adapted to irradiate the radiation-transmissive element by scanning a beam of radiation, either across the entire surface of the element or within a limited angular segment thereof. The latter approach may, e.g., be used if the location of the point-of-touch is known to some extent, e.g. as determined by prediction or by a preceding low-resolution determination step. The system may thus be adapted to restrict the scanning angle/segment to a limited angle/segment corresponding to the direction of the point-of-touch, the size of the point-of-touch, the distance between emitter and point-of-touch and the scanning speed. This may serve to improve the position resolution and/or reduce the power consumption of the system.

In one embodiment the system is adapted to increase the scanning speed, so as to obtain a low photon budget, when the point-of-touch is close to the detector, and to reduce the scanning speed, so as to obtain a high photon budget, when the point-of-touch is farther away.

Furthermore, the system may be adapted to run at slow scanning speed interrupted by intervals with no scanning, which may be sufficient to handle slow moving points-of-touch especially when the point-of-touch is made with a finger, which does not require very high resolution.

Scanning also allows for the use of reflective edges as mirrors to create virtual viewpoints towards the touching object. If the edges where perfect mirrors, then radiation directed towards the mirrors would be reflected while preserving the z-axis bounce-angle, thus making it possible to illuminate a point-of-touch indirectly.

Fig. 3 illustrates an emitter arranged at a corner 104 of the radiation-transmissive element 100. The emitter 112 irradiates a point-of-touch 124 directly, indirectly by single-reflections 136,136′ and indirectly by double-reflection 138,138′. The direct reflection irradiation will have the highest intensity and the lowest time delay, as its optical pathway is the shortest. The single-reflections and the double-reflection will have longer pathways and their signals will be weaker. Analogously, the reflected/scattered radiation will propagate both directly and by reflection to the detector. Since the time delay will be the shortest for radiation propagating directly, the system may be adapted to distinguish between the direct and the reflected radiation on the basis of the time of receipt of the radiation.

Moreover, the provision of scanning emitters provides the possibility of determining the size and shape of the touching object, as a bright centre and two borders of a point-of-touch may, thus, be determined. As an example, a finger moving across the first surface will often change shape due to the shear forces. Additionally, the shape of a finger is dependent on the pressure it applies to the first surface and its angle of incidence. This may be used to determine a moving finger or a finger pushing a virtual button on a display below the radiation-transmissive element.

In one embodiment, the emitter is adapted to scan in three dimensions. By scanning in three dimensions it is possible to irradiate the entire radiation-transmissive element whereby non-irradiated zones may be avoided, accordingly the possible scanning areas do not depend on the thickness of the radiation-transmissive element. Moreover, objects close to the detector may be scanned by radiation at angles which is not trapped by TIR as the Snell reflections for such close points-of-touch are strong enough to provide adequate return signal strength.

The emitter and detector may be provided on or at edges or surfaces of the radiation-transmissive element, provided that they are sufficiently index matched to the waveguide to avoid undesired critical angles which limit the optical pathways necessary to scan the waveguide as desired. Usually simple index match between the unit and the waveguide will be preferred. If this cannot be achieved, the angle shift occurring when the radiation changes from one refractive index material to another must be compensated either by measurement and mathematical compensation or by system calibration based on fix points measurements.

The system of the present invention may be used in connection with existing windows such as shop-windows. As existing windows are normally optimised for visible radiation transmission, they may be poor at guiding radiation outside the visible range. In such embodiments, it may thus be advantageous to emit radiation in the visible spectrum. In some embodiments, this provides up to five times longer half-length for visible radiation than for IR radiation. However, visible radiation may leak out of the surface due to surface imperfections and surface contamination whereby the radiation may be visible. Thus, when using visible radiation, it may be advantageous to limit the amount of radiation injected into the existing window, e.g., by restricting the scanning angle and/or by reducing the scanning speed, as explained above. Alternatively, or as a supplement, radiation may be emitted into the window at angles above the TIR angles.

In one embodiment, one or more scanning emitters are adapted to emit at least a part of the radiation above the first surface. Additionally, a detector may be arranged to detect radiation propagating above the first surface. Thus, an object above the surface may be illuminated and detected. Additionally, the determining means may be adapted to determine the position of a object hovering above the first surface on the basis of radiation reflected into the radiation-transmissive element by the hovering object. The radiation may be detected through the element by means of a photo sensitive sensor, such as at least one large avalanche photo diode (APD) attached to the edges or surfaces of the radiation-transmissive element. The position of the object may be determined by means of conventional range-finder equations.

The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope and spirit of the invention, which is defined and limited only by the appended patent claims.

CLAIMS

1. A system for determining the position of an object adapted to reflect/scatter radiation, the system comprising:

- a radiation-transmissive element having a first surface adapted to be engaged by the object so as to reflect/scatter radiation into the element and a second surface opposite the first surface, the radiation-transmissive element being adapted to guide radiation by internal reflection;
- a first radiation emitter being arranged to emit a pulse of radiation into the element and towards the first/second surface;
- a first detector arranged to detect radiation emitted into the radiation-transmissive element and reflected/scattered by the reflecting/scattering object, the first detector being adapted to output a signal relating to the detected radiation;
- at least one of:
  - a second radiation emitter being arranged to emit a pulse of radiation into the element and towards the first/second surface, and
  - a second detector arranged to detect radiation emitted into the radiation-transmissive element and reflected/scattered by the reflecting/scattering object, the second detector being adapted to output a signal relating to the detected radiation; and
- a determining means being adapted to determine the position of the reflecting/scattering object on the first surface on the basis of:
  - point(s) in time of emission of a pulse of radiation by the radiation emitter(s), and
  - point(s) in time of outputting of a signal(s).

2. A system according to claim 1, wherein the first radiation emitter and the first detector are provided adjacent to each other.

3. A system according to claim 1 or 2, wherein the system comprises the second radiation emitter and the second detector and wherein the second radiation emitter and the second detector are provided adjacent to each other.

4. A system according to any of the preceding claims, wherein the system comprises at least one further radiation emitter and one further detector.

5. A system according to any of the preceding claims, wherein the first radiation emitter and the second radiation emitter are adapted to be operated at non-overlapping time intervals.

6. A system according to any of the preceding claims, wherein at least one of the radiation emitters is adapted to emit radiation in a predetermined direction transverse to the first and/or second surface of the radiation-transmissive element.

7. A system according to any of the preceding claims, wherein at least one of the detectors are adapted to detect radiation propagating in a predetermined direction transverse to the first and/or the second surface of the radiation-transmissive element.

8. A system according to any of the preceding claims, wherein at least one of the emitters is adapted to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface and to emit radiation in said predetermined directions in a predetermined sequence.

9. A system according to any of the preceding claims, wherein at least one of the detectors is adapted to determine an angle of incidence of the detected radiation in a plane parallel with the first surface.

10. A system according to any of the preceding claims, wherein the radiation-transmissive element comprises a plurality of corners and wherein the first radiation emitter and the first detector are located in or at a first corner and the second radiation emitter and the second detector are located in or at a second corner and wherein the first and second corners are neighbouring corners.

11. A system according to any of the preceding claims, wherein the determining means furthermore is adapted to determine the position of the reflecting/scattering object on the basis of information relating to relative positions of the radiation emitters and the detectors.

12. A system for determining the position of an object adapted to reflect/scatter radiation, the system comprising:

- a radiation-transmissive element having a first surface being adapted to be engaged by the object so as to reflect/scatter radiation into the element and a second surface opposite the first surface, the radiation-transmissive element being adapted to guide radiation by internal reflection;
- a radiation emitter being arranged to emit a pulse of radiation into the element and towards the first surface;
- a detector arranged to detect radiation emitted into the radiation-transmissive element and reflected/scattered by the reflecting/scattering object, the first detector being adapted to output a signal relating to the detected radiation;

wherein

- the radiation emitter is adapted to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface, and/or
- the detector is adapted to determine an angle of incidence of the detected radiation in the plane,

the system further comprising:

- a determining means being adapted to determine the position of the reflecting/scattering object on the first surface on the basis of:
  - point(s) in time of emission of a pulse of radiation by the radiation emitter, and
  - point(s) in time of outputting of a signal, and
  - the direction of the emitted radiation and/or the angle of incidence of the detected radiation.

13. A system according to claim 12, wherein the radiation emitter is adapted to emit radiation in said predetermined directions in a predetermined sequence.

14. A system according to claim 12 or 13, wherein the radiation-transmissive element comprises two or more edges, and wherein the radiation emitter and the radiation detector are provided on or at different edges.

15. A system according to any of the claims 12-14, wherein the radiation emitter is adapted to emit radiation in a predetermined direction transverse to the first and/or second surface of the radiation-transmissive element.

16. A system according to any of the claims 12-15, wherein the detector is adapted to detect radiation propagating in predetermined direction transverse to the first and/or the second surface of the radiation-transmissive element.

17. A system according to any of the preceding claims, wherein the determining means is adapted to determine the position of the reflecting/scattering object on the basis of information about relative positions of the radiation emitter and detector.

18. An optical interface system, comprising:

- an optical waveguide having a first surface adapted to be engaged by an object so as to reflect/scatter radiation into the waveguide,

- at least one emitter adapted to inject radiation into the waveguide,
- at least one detector adapted to detect radiation injected into the waveguide and reflected/scattered by the object,

wherein said at least one emitter and said at least one detector form part of at least one range-finder for determining a distance to the object on the basis of point(s) in time of emission of a pulse of radiation by said at least one emitter, and point(s) in time for detecting radiation by said at least one detector, and

further comprising:

- -a calculator adapted to determine the position of the object based at least on the distance(s) determined by said at least one range-finder.

19. An optical interface system according to claim 18, wherein said range-finder is adapted to determine the distance on the basis of information on the relative positions of said at least one emitter and said at least one detector.

20. An optical interface system according to claim 18 or 19, including at least two range-finders.

21. An optical interface system according to any of the claims 18-20, wherein said at least one emitter is adapted to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface, and/or said at least one detector is adapted to determine an angle of incidence or the detected radiation in the plane, and wherein said calculator is further adapted to determine said position based on information representing at least one of a direction of the emitted radiation and an angle of incidence of the detected radiation.

22. A method of determining the position of an object that engages a first surface of an optical waveguide so as to reflect/scatter radiation into the waveguide, comprising:

- operating at least one emitter to inject radiation into the waveguide,
- operating at least one detector to detect radiation injected into the waveguide and reflected/scattered by the object,
- determining a distance to the object on the basis of point(s) in time of emission of a pulse of radiation by said at least one emitter, and point(s) in time for detecting radiation by said at least one detector, and
- calculating the position of the object on the waveguide based at least on the distance(s) determined by said at least one range-finder.

23. A method according to claim 22, further comprising: operating said at least one emitter to emit radiation in a plurality of different predetermined directions in a plane parallel with the first surface, and/or operating said at least one detector to determine an angle of incidence or the detected radiation in the plane, wherein said calculating further comprises: calculating said position based on information representing at least one of a direction of the emitted radiation and an angle of incidence of the detected radiation.

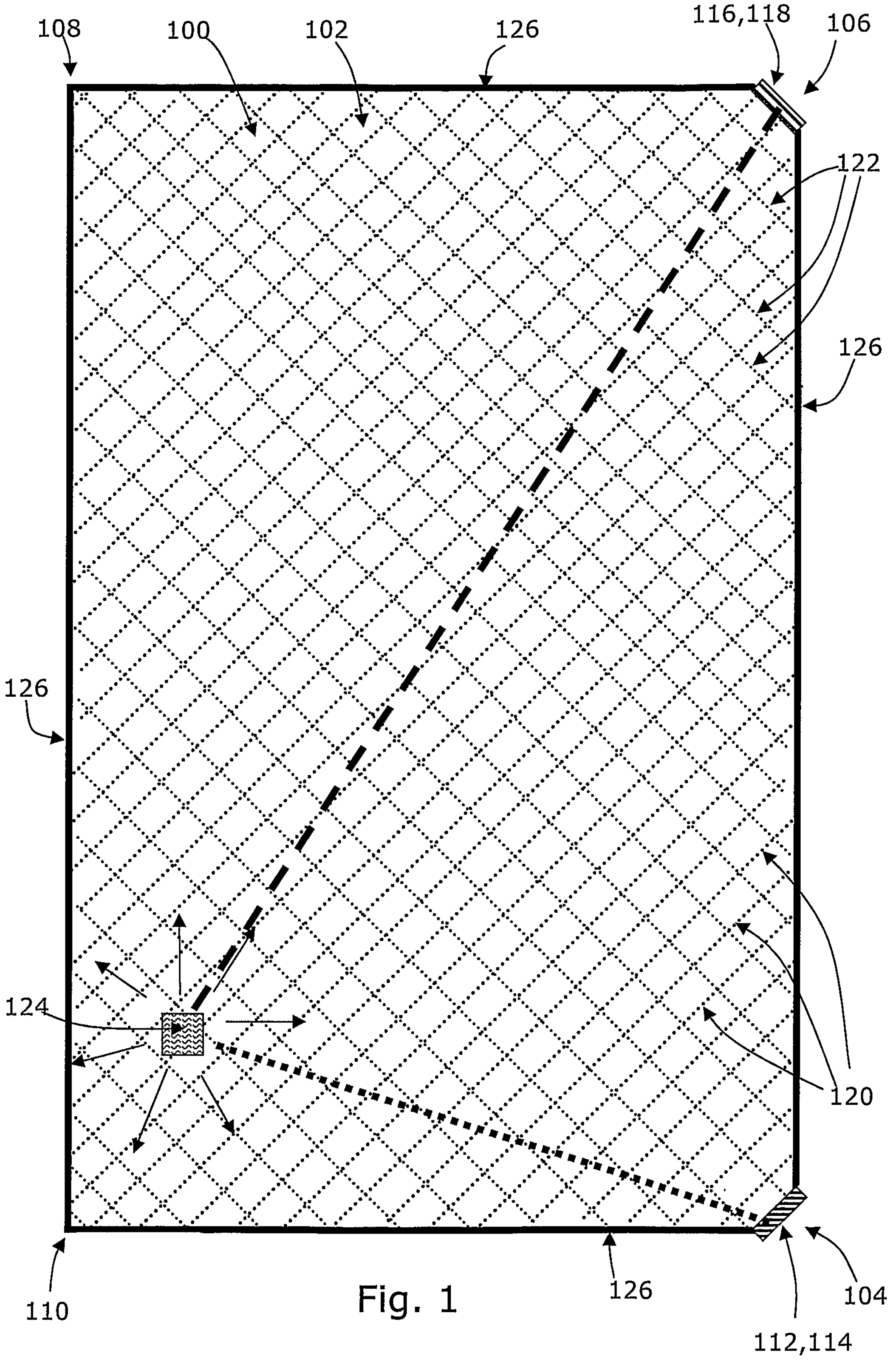
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Fig. 1

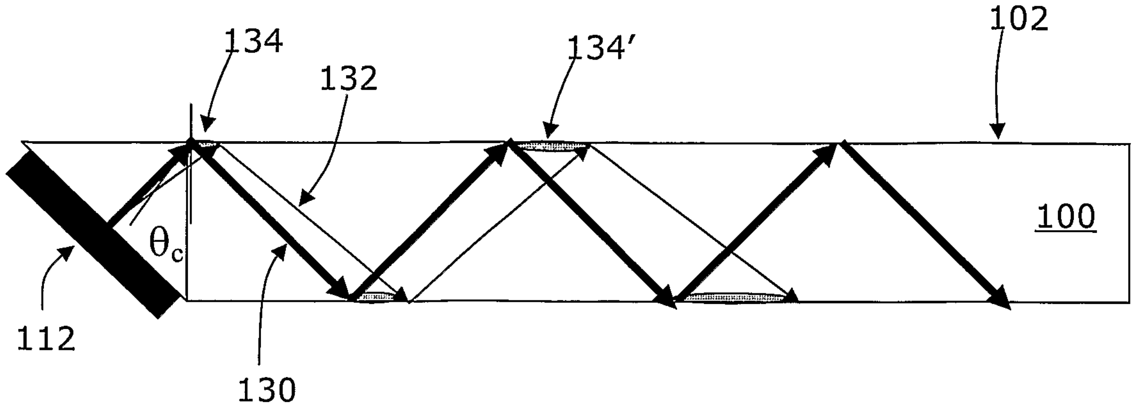
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Fig. 2

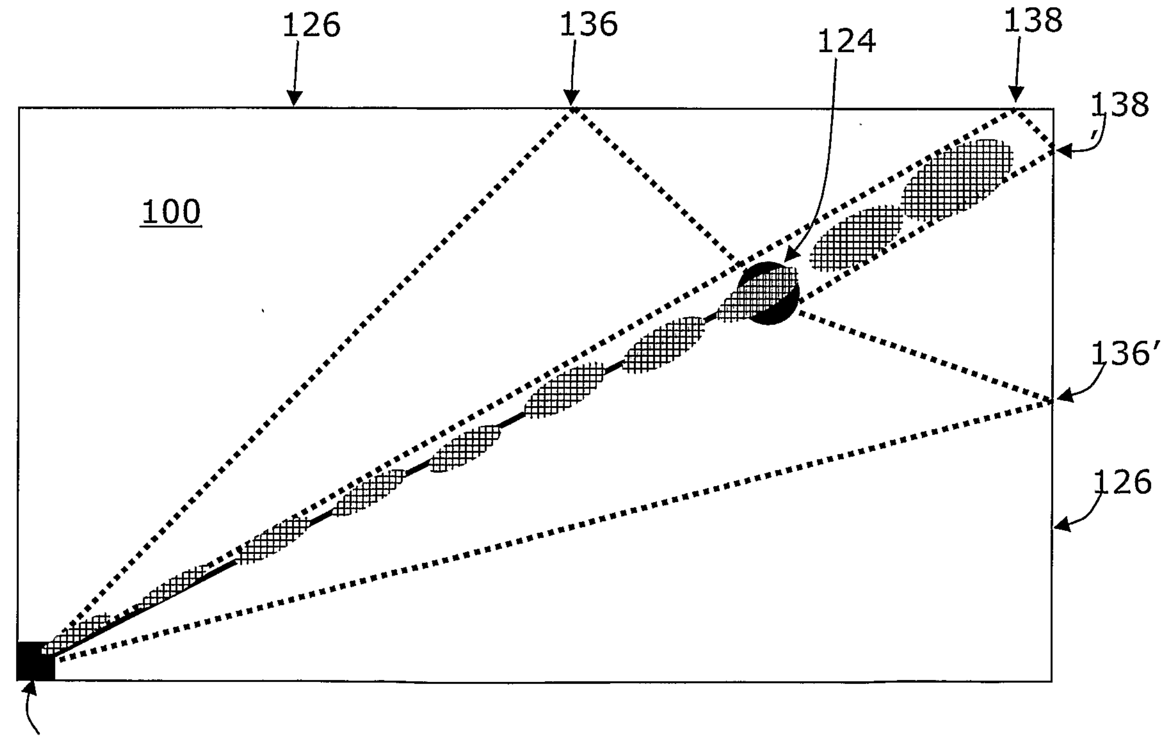
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Fig. 3

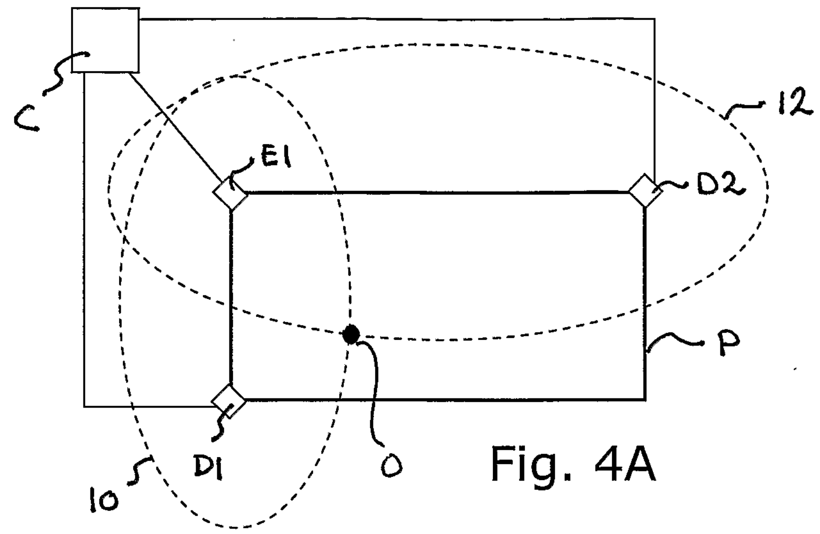

Fig. 4A

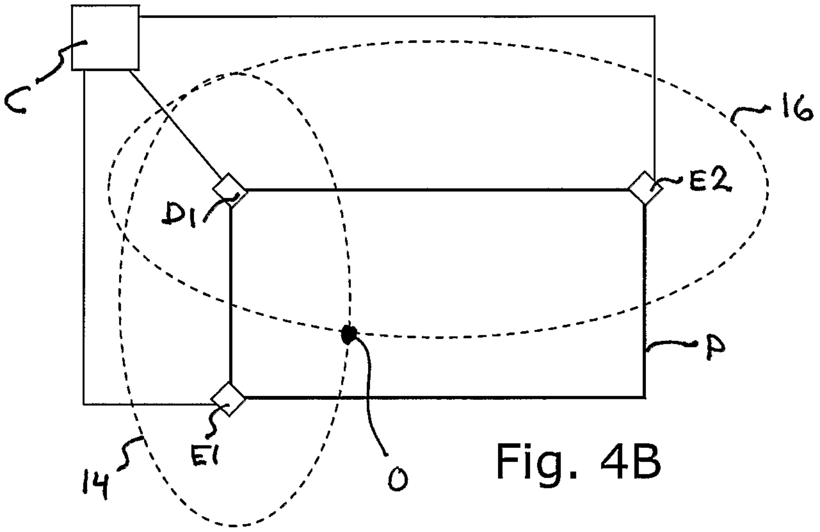

Fig. 4B

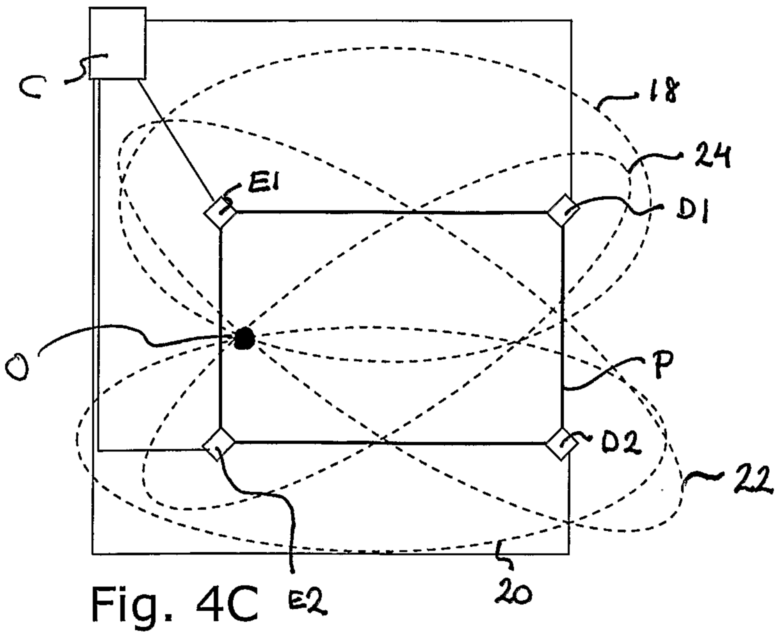

Fig. 4C