[0052] FIG. **28** is an illustration of a touch screen with three-dimensional sensing functionality, in accordance with an embodiment of the present invention;

[0053] FIG. **29** is a graph illustrating different light intensities measured by a PD receiver corresponding to proximity of an object to a touch screen surface, in accordance with an embodiment of the present invention;

[0054] FIG. **30**A is a simplified illustration of a handset with a touch screen, in accordance with an embodiment of the present invention;

[0055] FIG. **30**B is a simplified illustration of a pattern of dots projected into the space above a touch screen, in accordance with an embodiment of the present invention;

[0056] FIG. **30**C is a simplified illustration showing how the density of a pattern projected by a projector in the space above a touch screen, and reflected by an object, is dependent upon the distance of the object from a projector, in accordance with an embodiment of the present invention;

[0057] FIGS. **30**D and **30**E are simplified illustrations of patterns of digits projected into the space above a touch screen, in accordance with an embodiment of the present invention;

[0058] FIG. **31** is an illustration of use of a touch screen for processing finger motions as input to a computer, in accordance with an embodiment of the present invention; and

[0059] FIG. **32** is a simplified illustration of a touch sensitive display case containing items of merchandise, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

[0060] Aspects of the present invention relate to light-based touch screens. According to embodiments of the present invention, a light-based touch screen includes a plurality of infra-red light-emitting diodes (LEDs) and a plurality of photodiodes (PDs) arranged along the perimeter surrounding the screen. The LEDs project light substantially parallel to the screen surface, and this light is detected by the PDs. An object, such as a finger, placed over a portion of the screen blocks some of the light beams, and correspondingly some of the PDs detect less light intensity. The geometry of the locations of the PDs, and the light intensities they detect, suffice to determine screen coordinates of the object. The LEDs and PDs are controlled for selective activation and de-activation by a controller. Generally, each LED and PD has I/O connectors, and signals are transmitted to specify which LEDs and which PDs are activated.

[0061] In one embodiment of the present invention, plural LEDs are arranged along two adjacent sides of a rectangular screen, and plural PDs are arranged along the other two adjacent sides. In this regard, reference is now made to FIG. **1**, which is a diagram of a touch screen **100** having 16 LEDs **130** and 16 PDs **140**, in accordance with an embodiment of the present invention. The LEDs **130** emit infra-red light beams across the top of the touch screen, which are detected by corresponding PD receivers that are directly opposite the LEDs. When an object touches touch screen **100**, it blocks light from reaching some of PD receivers **140**. By identifying, from the PD receiver outputs, which light beams have been blocked by the object, the object's position can be determined.

[0062] Reference is now made to FIGS. **2**A-**2**C, which are diagrams of a touch screen that detects two objects, **10** and **20**, that touch the screen simultaneously, in accordance with an embodiment of the present invention. Objects **10** and **20**, which are touching the screen, block light from reaching some of PD receivers **140**. In accordance with an embodiment of the present invention, the positions of objects **10** and **20** are determined from the crossed lines of the infra-red beams that the objects block. In distinction, prior art resistance-based and capacitance-based touch screens are unable to detect more than one object simultaneously touching the screen.

[0063] When two or more objects touch screen **100** simultaneously along a common horizontal or vertical axis, the positions of the objects are determined by the PD receivers **140** that are blocked. Objects **10** and **20** in FIG. **2**A are aligned along a common vertical axis and block substantially the same PD receivers **140** along the bottom edge of touch screen **100**; namely the PD receivers marked a, b, c and d. Along the left edge of touch screen, two different sets of PD receivers **140** are blocked. Object **10** blocks the PD receivers marked e and f, and object **20** blocks the PD receivers marked g and h. The two objects are thus determined to be situated at two locations. Object **10** has screen coordinates located at the intersection of the light beams blocked from PD receivers a-d and PD receivers e and f; and object **20** has screen coordinates located at the intersection of the light beams blocked from PD receivers a-d and PD receivers g and h.

[0064] Objects **10** and **20** shown in FIGS. **2**B and **2**C are not aligned along a common horizontal or vertical axis, and they have different horizontal locations and different vertical locations. From the blocked PD receivers a-h, it is determined that objects **10** and **20** are diagonally opposite one another. They are either respectively touching the top right and bottom left of touch screen **100**, as illustrated in FIG. **2**B; or else respectively touching the bottom right and top left of touch screen **100**, as illustrated in FIG. **2**C.

[0065] Discriminating between FIG. **2**B and FIG. **2**C is resolved by either (i) associating the same meaning to both touch patterns, or else (ii) by associating meaning to only one of the two touch patterns. In case (i), the UI arranges its icons, or is otherwise configured, such that the effects of both touch patterns FIG. **2**B and FIG. **2**C are the same. For example, touching any two diagonally opposite corners of touch screen **100** operates to unlock the screen. In case (ii), the UI arranges its icons, or is otherwise configured, such that only one of the touch patterns FIG. **2**B and FIG. **2**C has a meaning associated therewith. For example, touching the upper right and lower left corners of touch screen **100** operates to unlock the screen, and touch the lower right and upper left of touch screen **100** has no meaning associated therewith. In this case, the UI discriminates that FIG. **2**B is the correct touch pattern.

[0066] Reference is now made to FIGS. **3**A and **3**B, which are diagrams of a touch screen that detects a two finger glide movement, in accordance with an embodiment of the present invention. The glide movement illustrated in FIGS. **3**A and **3**B is a diagonal glide that brings objects **10** and **20** closer together. The direction of the glide is determined from changes in which PD receivers **140** are blocked. As shown in FIGS. **3**A and **3**B, blocked PD receivers are changing from a and b to PD receivers **140** more to the right, and from c and d to PD receivers **140** more to the left. Similarly, blocked PD receivers are changing from e and f to PD receivers **140** more to the bottom, and from g and h to PD receivers **140** more to the top. For a glide in the opposite direction, that moves objects **10** and **20** farther apart, the blocked PD receivers change in the opposite directions.

[0067] When objects **10** and **20** are aligned in a common vertical or horizontal axis, there is no ambiguity in identifying