

# Multi-touch Detection Technology Using a Divergence IR Beam Profile for Large LCD Touch Solutions

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## Abstract

This paper proposes a multi-touch detection technology that can be applied to large LCDs. To achieve this goal, a set of IR LEDs and sensors was used to construct an IR matrix, and a new algorithm based on Hough transform was applied. This approach reduced the “Ghost” response of the multi-touch detection technology to make it better than other IR touch recognition technologies, and showed robust performance in terms of multi-touch recognition.

**Keywords:** Multi-touch recognition, IR touch, Divergence beam, Hough transform

## 1. Introduction

Touch technology, as a convenience input interface, has been used widely in various applications, from public equipment such as ATMs, POSs, and KIOSKs to personal devices such as NBPCs, PDAs, mobile phones, MP3 players, and cameras. Conventional touch technology was focused on selecting a certain object, and therefore, was limited to single-touch performance. After Apple released iPhone [1] in the market, however, various multi-touch and gesture applications were developed, and now, multi-touch technology is required broadly in the touch market.

The leading touch technologies in the market are currently the resistive, capacitive, and IR types [2]. Among these types, the capacitive type supports a clear multi-touch feature, and is being developed most actively as an alternative touch technology to the resistive type, which used to be the most common type. With the release of Windows 7, personal computer devices started adopting touch screen technology with the multi-touch feature, and its applications have been expanded to large screens such as monitors or public displays [3]. The capacitive-type touch technology has limited size expansion capacity, however, so it is difficult to apply to large screens [4].

On the other hand, the IR-type touch technology can be more easily added on to large panels than earlier introduced types. There are two main areas for improvement with respect to the conventional IR type, however--its “Ghost” response, and its limited number of possible simultaneous touch points [5].

This paper presents an IR-type touch system with a multi-touch algorithm based on Hough Transform [6], to reduce the “Ghost” response and to allow an unlimited number of simultaneous touch points.

## 2. Algorithm

The algorithm that was applied to the suggested structure is the main factor that embodies the differentiated performance of the IR-type touch technology. Unlike commonly used mechanisms, the IR LEDs that are installed all around the two edges of an LCD panel are radiated one by one, and all the sensors in the range of each LED simultaneously collect data and construct a Matrix Map of the IR LEDs and sensors. If light from a LED does not reach the sensor of any object, the light is designated as ‘0: Closed beam’; otherwise, it is designated as ‘1: Open beam’ (Fig. 1).

Once all the open or closed beam data from each sensor are collected, geometric transform is applied to the data of the LED-sensor pairs of the closed beam.

One closed beam that passes through a certain point on a panel is presented as a dot in a geometric space after the transformation (Fig. 2a). If all the closed beams pass through a certain point (the touched point), the number of dots will be located in a geometric space, and all the dots

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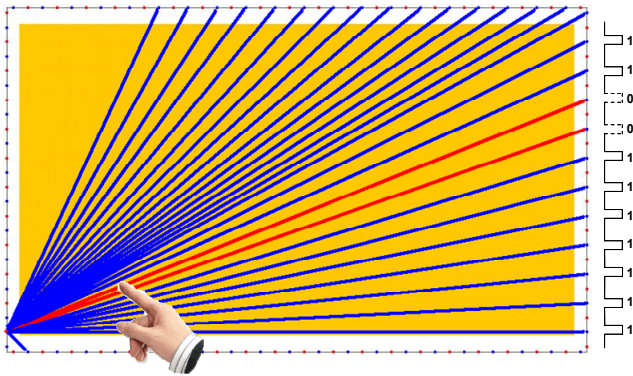
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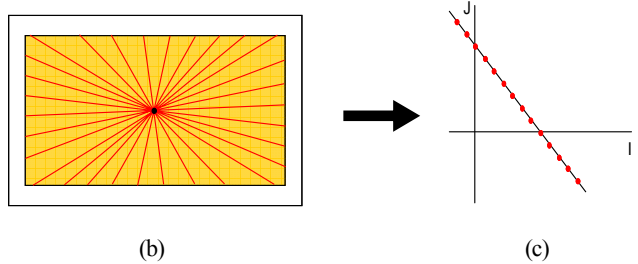
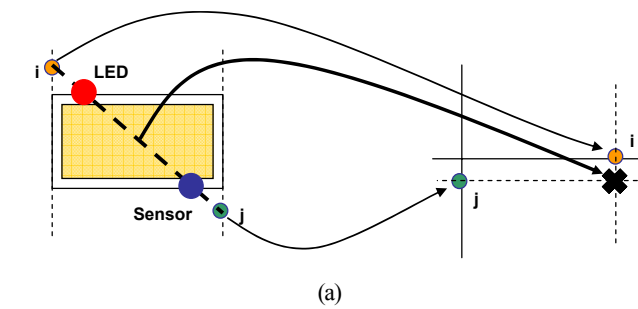
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**Fig. 1.** Divergence beam between the IR LED (red dot) and the IR sensor (blue dot). ‘0’: Closed beam (red line) and ‘1’: Open beam (blue line).



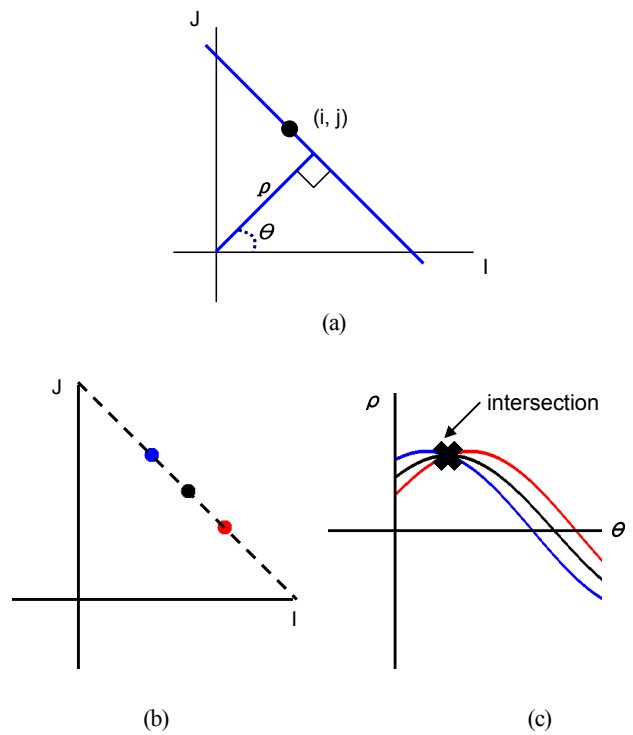
**Fig. 2.** (a) Geometric transform (1 point by 1 line). (b) Multi-closed beam on the LCD. (c) Geometrically transformed points.

will be on one straight line (Fig. 2b and 2c). That is, if the information on the straight line is figured out, the touched point can be calculated inversely.

To identify the coordinates of the touched points, Hough transform (Fig. 3a), which calculates a straight line in a geometric space, was used (Eq. 1).

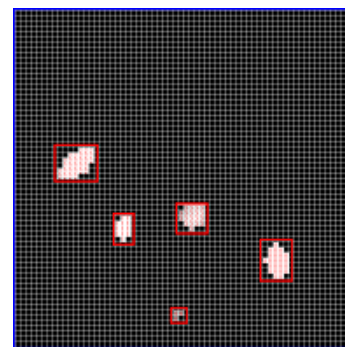
$$\rho = i \cdot \cos\theta + j \cdot \sin\theta \quad (1)$$

The straight line on the points (Fig. 3b) in a geometric space is calculated at the intersection of the lines of the dots via Hough transform (Fig. 3c). Moreover, if the multi-points are touched, the closed beam of each point is ex-



**Fig. 3.** (a) Straight line that represents the beam after the Hough transform. (b) Points in the geometric space. (c) Detection of the intersection after the Hough transform.

pressed as a different line in the geometric space, so there would be no “Ghost” response, which usually happens at the multi-touch point. Finally, multi-touch can be recognized by classifying consecutive fields, including the local maxima, in the quantized Hough space, as shown in Fig. 4. The dots in the mathematical space can be denoted as points in the fields after the Hough transform. The least squares method is then applied to each group of points in a field, to calculate the straight line in a mathematical space. Finally, the center coordinates of the touched points are



**Fig. 4.** Grouping parameters in the Hough space: Touch area (red line).

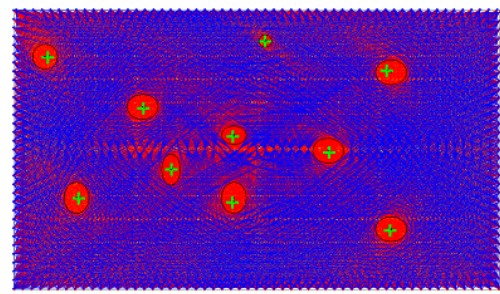
calculated via the inverse transform of any two points on the straight line.

### 3. Hardware

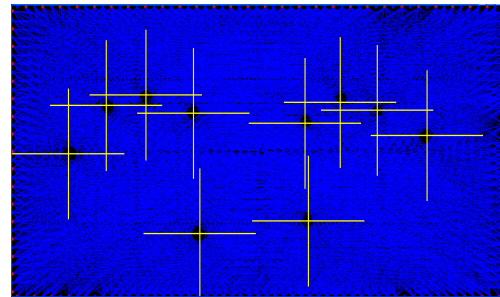
The hardware system that is needed to realize the multi-touch detection technology is shown in Fig. 5. First, through the processor and the IR LED driver, the IR LEDs are controlled and produce divergence beams. These beams are sorted into either closed beams, which are blocked by a touched object, or open beams, which are free from the object, and are collected by the IR sensor. The collected beams are then transmitted back to the processor as binary data through the IR receiver. The ALU (Arithmetic Logic Unit) part in the processor calculates the number of touched points and the coordinates with the collected data by applying the algorithm. Finally, the information on the calculated touched points is transmitted to the system through its interface and a USB as an HID (Human Interface Device) standard.

### 4. Results and Discussion

At first, the suggested novel methodology of the use of the algorithm was simulated under the virtual environment of large LCDs in which the IR LED and the sensors are arranged around the edges at certain intervals. The 10-point simultaneous touch was simulated to test the multi-touch recognition performance. The red dots and green crosses in Fig. 6 (a) denote the fields of the closed beam and the center coordinates of the touched points, respectively, which were calculated using the algorithm. Consequently, as shown in Fig 6 (a), this algorithm enables recognition of correct touch points without a “Ghost” response from the



(a)



(b)

Fig. 6. The test results from the simulation (a) and the 23-inch prototype TSP (b) of the 10-point touch.

multi-touch technology when more than one point is touched.

Based on the results of the touch test simulation, a 23-inch prototype TSP (Touch Screen Panel) with 90 LEDs and 90 sensors was built to produce thin stylus pens that are recognizable, and the response time was less than 12.5 ms. Each LED was located next to each sensor to reduce the touch failure of the edges of the TSP. The touch recognition test results of the prototype are shown in Fig. 6 (b). The number of recognized touched points was 10, which was the same as in the simulation, and all the 10 calculated

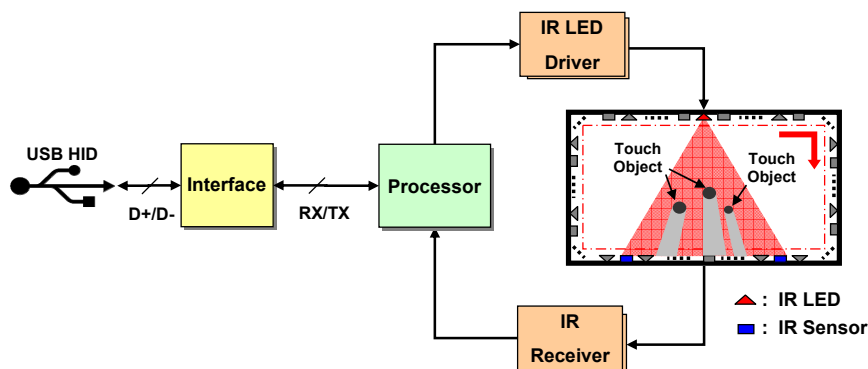


Fig. 5. Hardware design for multi-touch detection.

touched points (yellow crossed lines) were correctly matched with the real touched area. To optimize the design, a study that will focus on a uniform beam distribution and precise center recognition of the touched points is required.

### 5. Summary

The proposed algorithm and structure that make precise multi-touch recognition feasible, which other IR-type touch screen technologies cannot do, are presented in this paper. The performance of this multi-touch recognition technology was verified with a 10-point simultaneous touch without a “Ghost” response by the 23-inch prototype TSP.

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