A MULTI-TOUCH THREE DIMENSIONAL TOUCH-SENSITIVE TABLET

Extended Summary[1]

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1. OVERVIEW

The transducer that we have developed is a touch-sensitive tablet; that is, a flat surface that can sense where it is being touched by the operator's finger. This in itself is not new. Several such devices are commercially available from a number of manufacturers. What is unique about our tablet is that it combines two additional features. First, it can sense the degree of contact in a continuous manner. Second, it can sense the amount and location of a number of simultaneous points of contact. These two features, when combined with touch sensing, are very important in respect to the types of interaction that we can support. Some of these are discussed below, but see Buxton, Hill, and Rowley (1985) and Brown, Buxton and Murtagh (1985) for more detail. The tablet which we present is a continuation of work done in our lab by Sasaki et al (1981) and Metha (1982).

In the presentation which follows, we focus mainly on issues relating to the transducer's implementation. Two important contributions discussed are our method of scanning the tablet surface, and our method of maintaining high resolution despite the surface being partitioned into a discrete grid. Additional technical details can be found in Lee (1984).

2. TOUCH and MULTI-TOUCH

Touch sensing has a number of important characteristics (Buxton, Hill, Rowley, 1985). There is no physical stylus or puck to get lost, broken, or vibrate out of position. Touch tablets can be molded so as to make them easy to clean (therefore making them useful in clean environments like hospitals, or dirty environments like factories). Since there is no mechanical intermediary between hand and tablet, there is nothing to prevent multi-touch sensing. Templates can be placed over the tablet to define special regions (Brown, Buxton, Murtagh, 1985), and since the hand is being used directly, these regions can be manually sensed, thereby allowing the trained user to effectively "touch type" on the tablet.

Without pressure sensing, however, the utility of touch tablets is quite limited. One can move a tracking symbol around the screen, for example, but when the finger is over a light button, there is nothing equivalent to the button on a mouse to push in order to make a selection. Yes, we could lift the finger off the tablet, but that would be more like pulling (rather than pushing) the button. And what if we wanted to drag an item being pointed at, or to indicate that we wanted to start inking? Lifting our finger would leave our finger off the tablet, just when we want it in contact with it the most. There are ways around this problem, but they are indirect. If, however, the tablet has pressure sensing, we can push a virtual button by giving an extra bit of pressure to signal a change in state.

Pressure has other advantages. One example is to control line thickness in a paint program. But why do we want multiple point sensing? A simple example would be if we had a template placed over the tablet which delimited three regions of 9 cm by 2 cm. Where we touch each region could control the setting of a parameter associated with each region. If we wanted to simultaneously adjust all three parameters, then we would have to be able to sense all three regions. An even easier example is using the tablet to emulate a piano keyboard that can play polyphonic music.

3. TWO DESIGN PROBLEMS

The tablet is based on a 32 by 64 matrix of discrete sensors. This differs from most touch tablets which are based upon a single continuous analogue sensor. However, the discrete matrix is required in our case in order to support the multi-touch feature. Two major design considerations were, therefore:

- how to rapidly scan the matrix
- how to get adequate spatial resolution despite the relatively low 32 by 64 resolution of the sensor matrix.

4. HARDWARE DESCRIPTION

The design of the sensor matrix is based on the technique of capacitance measurement between a finger tip and a metal plate. To minimize hardware, the sensors are accessed by row and column selection. Row selection registers select one or more rows by setting the corresponding bits to a high state in order to charge up the sensors while the column selection registers select one or more columns by turning on corresponding analog switches to discharge the sensors through timing resistors. The intersecting region of the selected rows and the selected columns represents the selected sensors as a group. A/D converting circuits measure the discharging time interval of the selected sensors. A University of Toronto 6809 board is used as a controlling CPU. The touch surface of the sensor board consists of number of small metal-coated rectangular-shaped areas serving as sensor plate capacitors. The design of the metal plate area of a unit sensor depends on the measurable capacitance change that results when the area is covered by a finger tip, and on the resolution that can be implemented. In order to select a sensor by row and column access, two diodes are used with each sensor.

1. The following is an extended summary of a paper that will appear in full in *Proceedings of CHI'85*, Conference on Human Factors in Computing Systems, San Francisco, April 1985.

5. SCANNING ALGORITHM

One idea of some significance that can be introduced is to avoid scanning of all the pixels in the tablet which contain no information. If the number of points to be searched is comparably small, then an improved algorithm, here called recursive area subdivision, can be used.

Consider a tablet with resolution 8 by 8 to be searched for a touch point as shown in Figure 1.

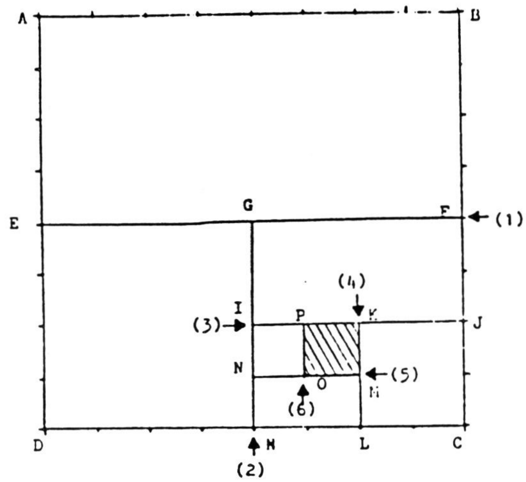

Figure 1. Recursive subdivision operation for 8 by 8 tablet.

First, check the tablet for touch as a whole region as shown by the area ABCD in the figure. If touch is detected, divide the tablet into two equal regions shown by the line EF and check each of the two regions ABEF and EFCD for touchedness. Select the touched region, region EFCD in this case, and divide this into two equal regions as shown by the division line GH. Continue this process on the touched region until no further division is possible, that is, until a unit sensor, designated as the region PKMO in Figure 2, is reached. The figure also shows the sequence of subdivision in the recursive subdivision scheme.

6. INTERPOLATION

It may seem that the resolution of the hardware is too low for use in graphics applications. However touch intensity and multi-touch sensitivity can be used to enhance resolution. This is possible because the center of a touch can be most accurately estimated by an interpolation utilizing the values of the adjacent sensor intensities.

Direct interpolation schemes for a few cases has been implemented. One of interest is to interpolate an array of 3 by 3 sensors using a touched point in the center. Another is to interpolate all points on the tablet. The later one obviously provides the highest resolution but as a result it simply emulates a single touch tablet with very high resolution.

7. CONCLUSIONS

A prototype of a fast-scanning multiple-touch-sensitive input tablet having both the adaptability and flexibility for a broad range of applications has been designed and implemented. Capacitance measurement of individual sensor(s) which can be uniquely addressed using two diodes per sensor, makes it possible to sense both the positions and intensities of one or more simultaneous touches without ambiguity. The sensor matrix is controlled by University of Toronto 6809 board whose serial port is connected to one of the I/O ports of a host computer. Software that utilizes the recursive subdivision algorithm for fast scanning an array of 64 by 32 sensors on the tablet, and that communicates with the host computer, has been implemented and tested.

8. ACKNOWLEDGEMENTS

The research described in this paper has been funded by the Natural Sciences and Engineering Research Council of Canada. This support is gratefully acknowledged.

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