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DEVELOPMENT OF CAPACITIVE TOUCH CONTROL FABRIC KEYBOARD

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ABSTRACT

Flexible fabric keyboard is a field of smart textile. It can overcome traditional horniness keyboard can't be foldable and washing. To overcome the problems such as low resolution and complicated structure that are associated with the existing fabric keyboard device， based on the capacitive touch principle a flexible touch control fabric keyboard device is developed using a double-layer conductive fabric as its touchpad. When a working area in the touch pad is set as 126 mm ×72 mm， with 72 mm side length of L−shape electrode， the test results show that the linearity of the touch control device in X and Y directions is ±4. 40% and ±4. 39%, respectively, and that the resolution reaches as high as 251 dpi ×243 dpi． For further discussion on the controlling accuracy of the device， the deviation rate is defined. The test results show that the control positions， of which the deviation rates are greater than 6%， are located near the edges of the working area． In addition， increasing the side length of the L−shape electrodes has positive but limited effects on the improvement of the linearity． Therefore， it would be preferable to use point electrodes for flexibility and wearablity．

KEY WORDS: touch control device; capacitive; fabric keyboard; linearity; deviation rate; electrode.

I. INTRODUCTION:

Intelligence is undoubtedly one of the important trends in the development of textiles in the future. Smart fabric, also known as "electronic fabrics" and "smart clothing", is one of the most popular cutting-edge technology fields currently sought after by the academic community. The emergence of smart fabrics marks the further integration of the traditional textile industry with emerging technologies such as electronics, manufacturing, sensor, and Internet of Things technologies. Unlike traditional wearable devices such as smart watches and bracelets, smart fabrics are lighter, more flexible, more suitable for the human body, and more versatile.

Fabric keyboard is a relatively common smart fabric on the market. For example, this kind of Three-layer Fabric Shaped Once(TFSO) which adopted three dimensional weaving method [1]. When pressed in the key position, the top and down layer of the orifice part can contact with each other. Then the circuit can connect. When the applied force was released, the top and down layer can return to primary position due to the action of the support part.

However, the fabric keyboard still has some shortcomings. With the use of fabric keys, the elasticity of the spacer formed by the upper and lower layers of the double-layered organization will be affected, and eventually the elasticity will be lost, and the isolation of the upper and lower layers cannot be guaranteed, resulting in failure of the keyboard keys. In addition, the fabric keyboard requires the operator to accurately operate the key position, which requires higher accuracy. And as the number of uses increases, the keys may shift from the original area.

In this paper, the gesture touch recognition technology based on the capacitive screen principle is used to perform interactive control to improve these problems of the fabric keyboard [2], and simplify the fabric structure for easy operation. Based on this, the typical performance of the developed touch fabric keyboard is evaluated, such as the linearity in the X and Y directions; the offset rate is defined to describe the touch accuracy of each position in the working area.

II. MATERIALS AND METHODS:

The functional layer structure of the touch area of the fabric keyboard adopts the principle of a self-capacitive touch screen. The capacitive unit is composed of two layers of conductive fabric with a special shape structure. The upper and lower layers of the capacitive unit cross perpendicularly, corresponding to the X and Y axes of plane coordinates, respectively [3]. As shown in Fig. 1 .

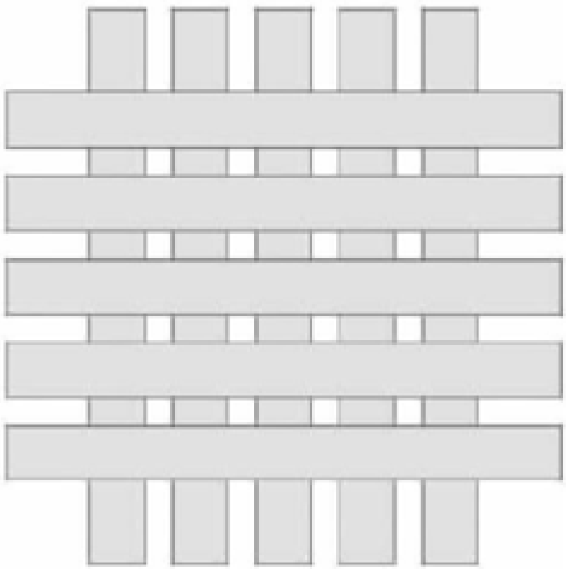


Fig. 1: (a) The fabric structure of the touch area

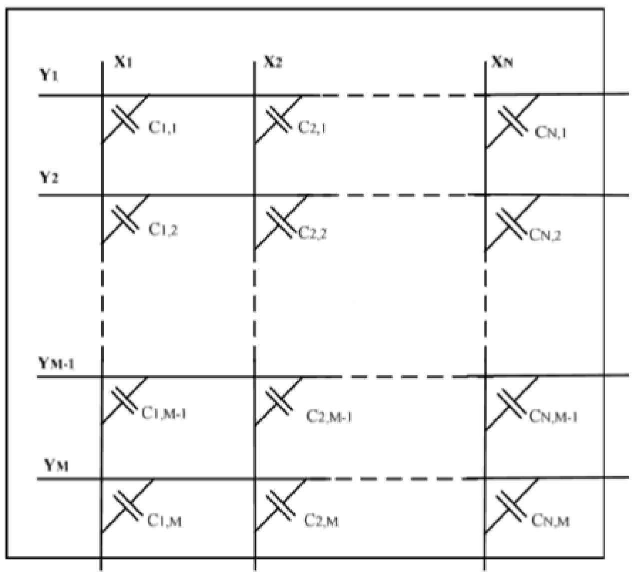


Fig. 1: (b) Capacitive unit consisting of fabric structure in the touch area

Four electrodes are drawn from the four corners of the lower capacitor unit. When the human body touches, due to the human body's electric field, a coupling capacitor is formed on the surface of the fabric keyboard. For high-frequency current, the capacitor is a direct conductor, so the human body draws a small current from the contact point. This current flows from the electrodes on the four corners of the lower capacitor unit, and the current flowing through the four electrodes is proportional to the distance from the touch point to the four corners. The controller calculates the position of the touch point through accurate calculation of the four current ratios.

The touch device of the entire fabric keyboard is composed of a touch area, a controller lead and a capacitance controller, as shown in Fig. 2. The touch area consists of a conductive fabric in the working layer and a normal fabric that protects the working layer. The size of the touch area is 150mm * 150mm * 0.05mm, and the sheet resistance is (168.0 ±3.2) Ω / sq. The conductive fabric under the working area leads out four wires to the capacitor controller, and then connects to the computer through the USB protocol port.

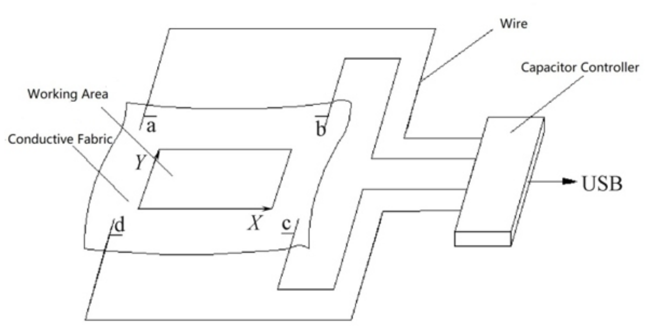


Fig. 2: Schematic diagram of touch control device

Fig.2 show that a, b, c and d correspond to the four electrodes on the four corners of the fabric keyboard, respectively. The currents on the leads of the connection electrodes a, b, c, and d are L_a, L_b, L_c, and L_d, respectively. After a series of calculations in the controller, the current signal is sent to the computer with two identifiable X and Y axis output voltages as signals V_X and V_Y, and then connected to the computer via USB, with the computer screen as the display terminal. V_X and V_Y satisfy the following relations as[4]

$$V_X = \frac{I_a + I_b}{I_a + I_b + I_c + I_d}$$
$$V_Y = \frac{I_b + I_c}{I_a + I_b + I_c + I_d} \tag{1}$$

The coordinate of the electrode d is (0, 0), the direction of the line connecting the electrode d to the electrode c is the X axis, and the direction of the line connecting to the electrode a is the Y axis. The coordinates (X_p, Y_p) of the touch point satisfy the following relationship as[5]

$$X_p = L_X \frac{I_a + I_b}{I_a + I_b + I_c + I_d}$$
$$Y_p = L_Y \frac{I_b + I_c}{I_a + I_b + I_c + I_d} \tag{2}$$

In the formula, L_X and L_Y are the distances from electrode c and electrode a to electrode d, respectively. From equations (1) and (2), we get:

$$V_X = \frac{X_p}{L_X}$$
$$V_Y = \frac{Y_p}{L_Y} \tag{3}$$

V_X, V_Y determine the position of the touch point. Then, V_X and V_Y are parsed by the correction program into pixel coordinates reflecting the position of the touch point on the computer screen in the form of a cursor.

III. RESULTS AND DISCUSSION:

According to the touch screen test method and sensor test parameters[6-8], the linearity test is performed on the touch device using the shape of British "Union Jack". Based on this, an offset rate index is proposed to further characterize the output offset of the touch device.

A. Linearity and Resolution:

The linearity of the sensor is defined as the maximum deviation of the average output characteristic curve of the sensor from the calibration straight line, expressed as a percentage of the sensor's full-scale output. The smaller this value, the better the linearity. The linearity in the X and Y directions can be calculated by equations (4) and (5):

$$P_X = \pm \frac{\Delta X_{max}}{X_{max} + X_{min}} \times 100\% \tag{4}$$

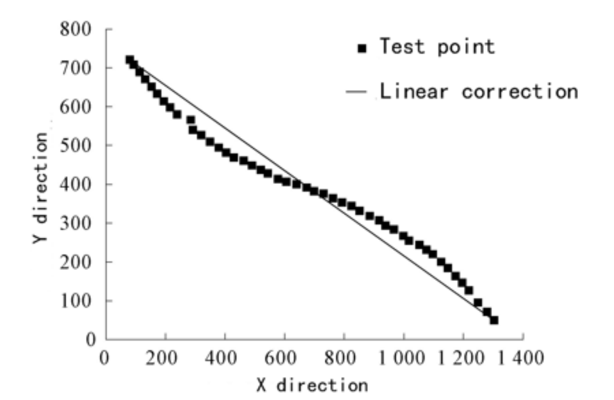
$$P_Y = \pm \frac{\Delta Y_{max}}{Y_{max} + Y_{min}} \times 100\% \tag{5}$$

In the formula, P_X and P_Y are the linearity in the X and Y directions, respectively. $\triangle X_{max}$ and $\triangle Y_{max}$ are the maximum deviations in the X and Y directions, respectively. X_{max} and Y_{max} are the maximum coordinate values of the working area in the X and Y directions, respectively. X_{min} and Y_{min} are the minimum coordinate values in the X and Y directions of the work area, respectively.

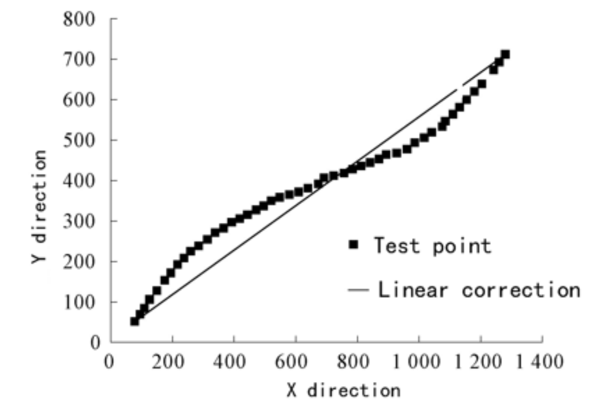
In order to make the working area correspond to the screen aspect ratio, the position of the touch area should be in one-to-one correspondence with the pixel coordinates on the screen. To do this, first define a rectangular area and screen to complete the four-point correction procedure within the electrode range on the touch area. The four endpoints of the rectangular area are the correction points. The working area used in this paper is 126mm × 72mm.

The shape of British "Union Jack" test method is to test the linearity along the main diagonal, sub diagonal, horizontal centerline and vertical centerline of the work area. During the test, take points every 3mm along these 4 straight lines and touch them with your fingers. Using the top left corner of the screen as the pixel zero, the X and Y coordinates of the corresponding display point on the screen are extracted by the pixel analysis software. Touch each point 5 times to find the average pixel coordinates of the displayed point. In the above four directions, the point farthest from the calibration straight line is the point of maximum deviation. According to the coordinates of the point and the theoretical equation of the correction straight line, the linearity is calculated from the equations (4) and (5).

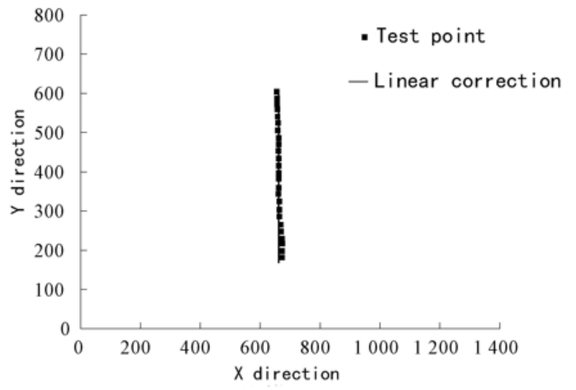
In a touch device with a right-angle electrode length of 72mm, the relationship between the test points in each direction and the calibration straight line is shown in Fig. 3. In this figure, the abscissa is the pixel coordinate in the X direction, and the ordinate is the pixel coordinate in the Y direction.



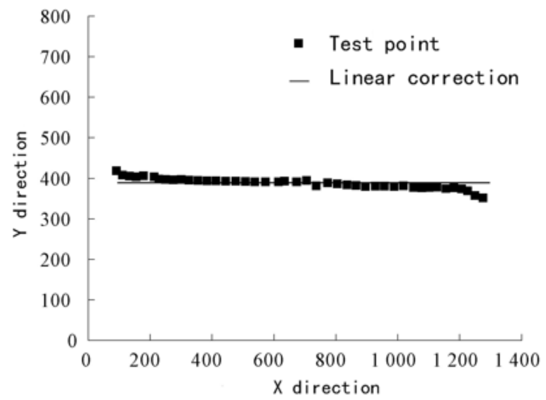
(a) Leading diagonal



(b) Sub-diagonal



(c) Vertical centerline



(d) Horizontal centerline

Fig. 3: Test results and reference lines.
(a) Leading diagonal; **(b)** Sub-diagonal; **(c)** Vertical centerline; **(d)** Horizontal centerline

It can be seen from the figure that the maximum offset point appears in the sub-diagonal direction. After calculation, the linearity in the X direction is $P_X = \pm 4.40\%$, and the linearity in the Y direction is $P_Y = \pm 4.39\%$. Test results show that the linearity of the flexible touch device is good, close to the nominal linearity of the commercial touch screen ± 1.5%.

Resolution is an index of the positioning accuracy of the input device, and it refers to the maximum number of information that can be accurately positioned for each 2.54 cm of movement of the touch device. The resolution of the X and Y directions in the 126mm × 72mm working area is 251dpi × 243dpi, which is close to the calibration resolution of 300dpi on the market.

B. Offset rate:

Because linearity is an index that characterizes the offset on the test straight line and cannot effectively characterize the output offset of each position of the fabric keyboard, an offset rate is proposed as an evaluation index. Offset rate defined as the percentage of the touch point offset opposite the output screen, is calculated by the formula (6).

$$C = \sqrt{\left(\frac{X_2 - X_1}{X_{fs}}\right)^2 + \left(\frac{Y_2 - Y_1}{Y_{fs}}\right)^2} \tag{6}$$

In the formula: X_2 and Y_2 are the actual pixel coordinates of the display point, X_1 and Y_1 are the analytical coordinates of the display point, and X_{fs} and Y_{fs} are the maximum pixels of the screen in the X and Y directions.

Assume that the screen resolution of a computer with a screen aspect ratio of 16: 9 is 1366 pixels x 768 pixels. The four vertex coordinates of the rectangular working area set in this paper are (9, 36), (9, 108), (135, 108), (135, 36). Therefore, the coordinates X_p, Y_p of the ideal touch point and the display point analysis coordinates X_1, Y_1 after the 4-point positioning should satisfy the following relationships:

$$X_1 = \frac{X_p - 72}{126} \times 1246 + 683$$

$$Y_1 = 384 - \frac{Y_p - 72}{72} \times 688 \tag{7}$$

In the offset rate test, the working area can be divided into several test units (a rectangular unit of 3mm × 3mm in the experiment). Taking the vertex of each unit as the touch point, the coordinates of the touch point and the pixel coordinates of the display point are recorded, and the offset rate *C* of each position on the fabric keyboard is calculated. Use MatLab to generate a grid diagram of the offset rate of the touch points on the fabric keyboard, as shown in Fig. 4.

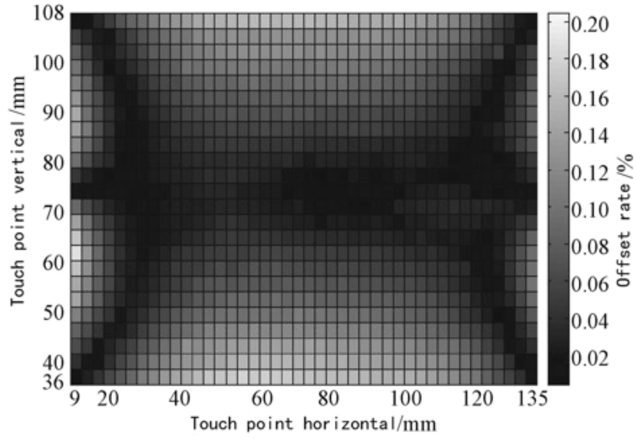


Fig. 4: Grid map of deviation rate of fabric keyboard

As can be seen from Fig. 4, the output offset of the middle area of the fabric keyboard is small, and the output offset of the edge area is relatively large. The actual display area is closer to the center than the theoretical display area. Regions with an offset rate greater than 6% exist at the edges, and the closer the sensing points are to the edge regions, the greater the offset rate.

IV. CONCLUSION:

A fabric keyboard was developed using the capacitive touch principle. The linearity, resolution, and offset of the fabric keyboard were tested.

(1) The linearity of the signal between the touch point and the display point in the 126mm × 72mm working area of the fabric keyboard with an electrode length of 72mm: the X direction is ± 4.40% and the Y direction is ± 4.39%; the resolution is 251dpi × 243dpi.

(2) The output offset of the middle area of the fabric keyboard is small, and the output offset of the edge area is relatively large. The actual display area is closer to the center than the theoretical display area. Regions with an offset rate greater than 6% exist at the edges, and the closer the sensing points are to the edge regions, the greater the offset rate.

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