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The Research of Touch-screen Calibration Algorithm and Its Application to the Embedded System

Shuangye Chen, Xiaoyu Qin
Electronic Information and Control Engineering
Beijing University of Technology
Beijing, China

Abstract—**An calibration algorithm of the touch-screen is researched which exploring an eliminating noise method after the analysis of linear principle. The block diagram of the touch-screen system is introduced, and the calibration program is designed based on the four-point linear calibration algorithm in this paper. An embedded system with touch-screen software is designed with the development tool ADS. The stability and precision of touch screen system with the improvement of algorithm calibration is proved by the testing and valid dating of the algorithm in practical system.**

Keywords-linear calibration algorithm; touch-screen; LPC2378; ADS7843

I. INTRODUCTION

Because of its specialization, real time, low power and high reliability, embedded system has been widely applied to aerospace technology and civil products such as machinery, medicine, etc. Because of its durability, fast responsible, easy to communication, abundant performance ability, flexible and easy access and space saving, the touch-screen has generally replaced the mouse and keyboard, and become the primary input device of embedded systems. The touch-screen is divided into three types: resistive, capacitive and inductance. The resistive touch-screen is adopted in the design and research due to its high speed, high sensitivity and good stability.

II. HARDWARE SYATEM

Hardware system is composed of micro-controller, touch-screen and touch-screen controller. Fig. 1 is the block diagram of the four-wire touch-screen input system, the micro-controller is LPC2378 produced by NXP [1], the touch-screen controller uses ADS7843 produced by Burr-Brown (BB) company [2].

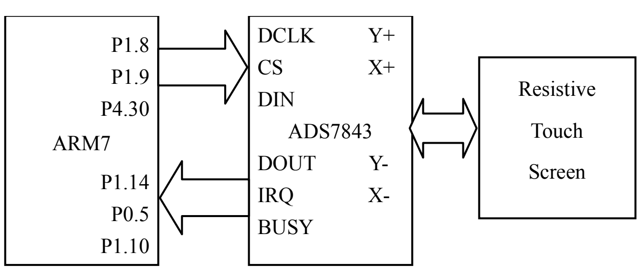

Figure 1. The four-wire touch-screen input system

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The software used in the interface circuit is to simulate the Serial Peripheral Interface Bus (SPI) time sequence. Five GPIO pins of LPC2378 are respectively connected to the DCLK, CS, DIN, BUSY, DOUT of ADS7843, the IRQ of ADS7843 is connected to the LPC2378 supporting external interruption signal. Four pins of the 4-wire resistive touch-screen are respectively connected with X+, Y+, X-, Y- of ADS7843. +5V is adopted as the operation voltage of ADS7843, which operates from a single supply of 2.7V to 5.25V.

Touching the panel generates noise and parasitism because of panel mechanical vibrations and transients, as well as a result of electrostatic discharge (ESD) and electromagnetic pulses (EMP) from users and the operating environments. Such noise is often picked up by the touch-screen device from its analog input circuitry, as shown in Fig. 1. This noise can drastically reduce the accuracy and reliability of the entire touch screen system [3]. Adding several 100nF high frequency filter capacitors, from DCLK, DIN, DOUT and IRQ to grand, is good way to reduce analog input noise.

III. SOFTWARE SYSTEM

A. Calibration Principle

Typically, the touch-screen controller and the liquid crystal display (LCD) do not have the same resolution, so calibration is needed to match their coordinates to each other [4], [5].

Three calibration methods are often applied in practical system, and described as: minimum and maximum values, two-point calibration and four-point linear calibration. There are errors in the minimum and maximum values, and because of moving and rotation errors (as shown in Fig. 2) of mechanical misalignment between the display and the touch-screen, transformed coordinates by two-point calibration has poor precision [5]. So we introduce the four-point linear calibration with high precision in this article.

When pressure is applied to the touch screen, calibration of the touch-screen translates the coordinates reported by ADS7843 into coordinates that accurately represent the point and image location on the liquid crystal display. Now, two technical terms are introduced in this paper, Physical Coordinates and Logical Coordinates [6]. Physical Coordinates: the X and Y coordinates of some points on the touch screen,

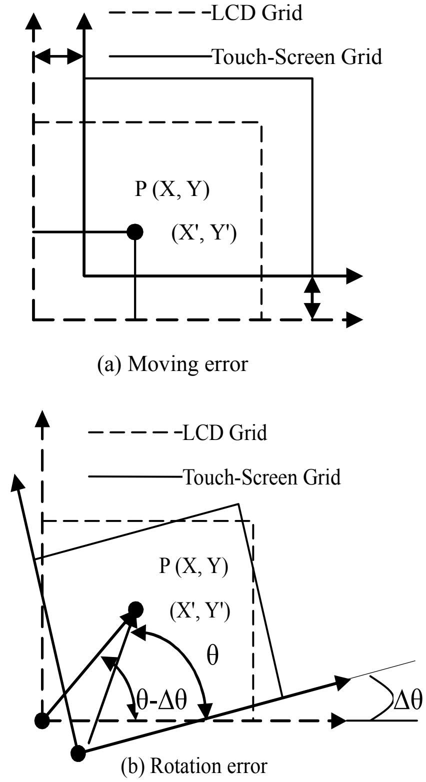


Figure 2. Mechanical misalignments

represented as (X, Y) on the LCD. Logical Coordinates: the X and Y coordinates of the corresponding point reported by the touch-screen controller ADS7843. When a point is touched on the touch-screen, consider the point P, as show in Fig. 2, the physical coordinates are (X, Y) on the LCD, and the logical coordinates are (X', Y') on the touch-screen. The touch-screen coordinate X below includes the scaling, the moving error in Fig. 2(a) and the rotation error in Fig. 2(b), and can be expressed as

$$\begin{aligned} X &= K_X \times R \times \cos(\theta - \Delta\theta) + \Delta X \\ &= K_X \times R \times \cos\theta \times \cos(\Delta\theta) + K_X \times R \times \sin\theta \times \sin(\Delta\theta) + \Delta X \\ &= K_X \times X' \times \cos(\Delta\theta) + K_X \times Y' \times \sin(\Delta\theta) + \Delta X \\ &= \alpha_X \times X' + \beta_X \times Y' + \Delta X, \end{aligned} \tag{1}$$

where $\begin{matrix} X' = R \times \cos\theta, \alpha_X = K_X \times \cos(\Delta\theta) \\ Y' = R \times \sin\theta, \beta_X = K_X \times \sin(\Delta\theta) \end{matrix}$. Similarly, the touch-screen coordinate Y can be expressed as

$$\begin{aligned} Y &= K_Y \times R \times \sin(\theta - \Delta\theta) + \Delta Y \\ &= K_Y \times R \times \sin\theta \times \cos(\Delta\theta) - K_Y \times R \times \cos\theta \times \sin(\Delta\theta) + \Delta Y \\ &= K_Y \times Y' \times \cos(\Delta\theta) - K_Y \times X' \times \sin(\Delta\theta) + \Delta Y \\ &= \alpha_Y \times X' + \beta_Y \times Y' + \Delta Y, \end{aligned} \tag{2}$$

where $\alpha_Y = -K_Y \times \sin(\Delta\theta), \beta_Y = K_Y \times \cos(\Delta\theta)$ [5].

Equation (1) and (2) show that a minimum of three independent points are required to get the coefficients α_X, β_X, α_Y, β_Y, ΔX and ΔY. The points are independent if not on one linear. In order to obtain the accurate physical coordinates, the points are dispersed enough, and the distances between the points and the touch screen margin are approximately 10% of the touch-screen length, because the touch screen margin is nonlinear [5].

B. *Calibration Algorithm*

In many applications, more than three points are used in the calibration routine to average or filter the noise reading from the touch-screen controller. Four calibration points on the touch-screen are chosen in the embedded system, and respectively touched twice, meanwhile two groups of the logical coordinates(X', Y') and (X'', Y'') are collected by the micro-controller. If the difference between two groups of the logical coordinates is below the reasonable value α, the logical coordinates (X'', Y'') are supposed to be reasonable, and stored in an array. Otherwise, they are discarded as isolated points. In order to obtain the accurate logical coordinates, the corresponding point on the touch-screen is sampled m times. Median filter technology is applied to process the data, which is applied to resolve (1) and (2). Test point is chosen on the LCD. When pressure is applied to the corresponding point on the touch-screen, calibration procedure compares the coordinates (X, Y) calculated from the calibration equation with the physical coordinates on the LCD. If the error is below the reasonable value β, calibration procedure is believed to be successful, else return to the calibration procedure, and repeat it again. Calibration procedure flow chart is shown in Fig. 3.

C. *Interrupt Handling*

When pressure is imposed on the touch-screen, the level of IRQ is pulled low. In order to save CPU resource, the interrupt mode uses the falling edge of IRQ. When the IRQ is pulled low in practice, jitter of the digital signal of IRQ will last for a moment [7]. If jitter is not properly filtered, interrupt service routine will be inaccurately called by the touch-screen driver. Therefore, the falling edge interrupt with inquiring IRQ low power method is adopted in interrupt service routine, the interrupt with inquiry method is described as follow: when there is a trigger signal controlled by IRQ pin of ADS7843, the trigger signal delays before a low power detection to eliminate false trigger in the interrupt service routine. The interrupt service routine is designed as following steps:

1) If a trigger signal generated by the touch screen controller is received, call the interrupt service routine, disable the interrupt function.

2) If the trigger signal is noise judged by the interrupt and inquiry method, step into 5), else step into 3).

3) If the micro-controller is busy, step into 5), else step into 4).

4) Set touch screen interrupt flag(TscIntFlag) to 0xff.

5) Enable the interrupt function, and exit the interrupt service routine.

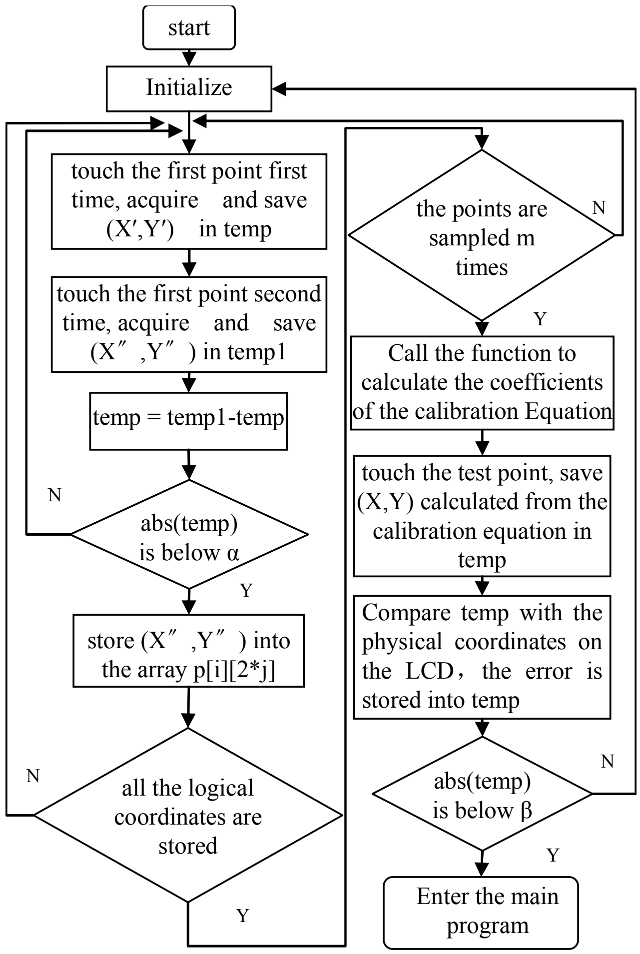


Figure 3. The flow of Calibration Procedure

D. *Test Program*

Test program is designed in embedded system to verify the effectiveness and applicability of the calibration procedure. When there is a trigger signal, the interrupt service routine is called, and the touch screen interrupt flag is queried periodically in test program. If the value of the touch screen interrupt flag is 0xff, AD conversion mode is initiated to get the logical coordinates, the function of (1) and (2) is called to calculate the touch-screen coordinates X and Y, which will be sent to the LCD. The test program flow chart is show in Fig. 4.

IV. TEST PROCESS AND RESULTS

Test program is verified in an embedded Sterilizer Controlling System, the display system of the embedded system is LCM3202401 with a resolution of 320(X coordinate) × 240(Y coordinate). Four calibration points are chosen: A(30,30), B(290,30), C(30,210) and D(290,210), as shown in Fig. 5(a). The logical coordinates of corresponding points are measured by the touch-screen controller with 12-bit resolution. The coefficients of (1) and (2) can be populated with the logical coordinates as follows:

$$\alpha_X = -0.3524165, \beta_X = 0.0025474, \Delta X = 340.9145,$$
$$\alpha_Y = -0.0004916, \beta_Y = -0.2622779, \Delta Y = 252.5471 \quad .$$

Thus the equation for X, from (1), is

$$X = -0.3524165X' + 0.0025474Y' + 340.9145, \tag{3}$$

and the equation for Y, from (2), is

$$Y = -0.0004916X' - 0.2622779Y' + 252.5471 \tag{4}$$

To test the accuracy and feasibly of the equations of X and Y, three test points are chosen on the LCD: E(40,40), F(280,40) and G(160,120), as shown in Fig. 5(b). These test points are respectively touched four times, and the data are showed in Table 1, the error absolute values are less than or equal to 5. The results show that the linear calibration algorithm is highly precise and feasible in the embedded system.

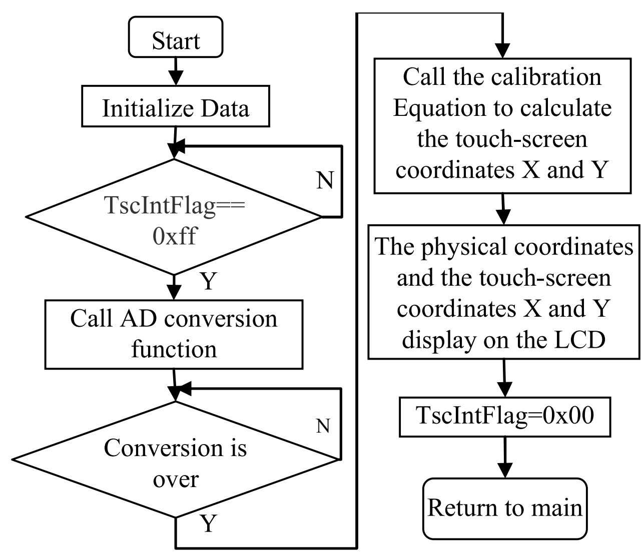
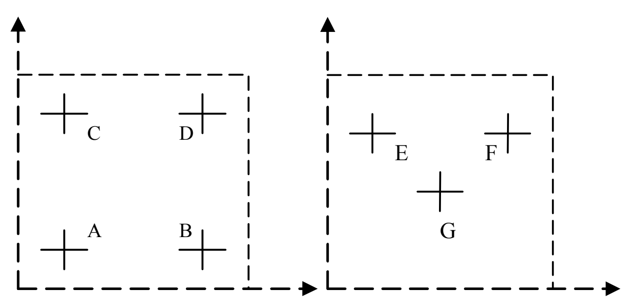


Figure 4. The flow of Test Program



(a)Calibration points (b) Test points

Figure 5. Calibration points and Test points

TABLE I. TEST RESULTS

Test points	The touch-screen coordinates (X , Y) calculated from (3) and (4)			
	first	*second*	*third*	*fourth*
E(40,40)	38,41	39,41	39,39	40,41
F(280,40)	276,43	276,42	275,41	277,41
G(160,120)	158,201	41,198	40,198	41,198

V. CONCLUSION

The Design and Commissioning of touch-screen software is completed, and applied to the embedded system. The results show that four-point linear calibration algorithm has high precision, sensitive and convenient in the human-computer interaction system.

The touch-screen input system with embedded chip LPC2378 has high speed and high performance price ratio. With software development tool of ADS, the software development efficiency and reliability is greatly improved. The algorithm testing in practical system show the stability and reliability of touch screen system and the practical value of four-point linear calibration algorithm.

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