Calibration in Touch Screens System

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Abstract. The paper deals with calibration in touch screens systems. Explains general principle of basic sampled data filtration. Describes usual errors and the possibility of elimination. Its determination and calculation is given in the paper. Afterwards, shows calibration method and mathematical relations used while calibration. Derivation of equations in necessary to assemble the final algorithm. Finally, all methods and algorithm have been verified on the physical sample. The experimental verification is given at the end of the paper.

Keywords
touch screen, calibration methods, oversampling matrix operation, misalignment error, rotation error.

1. Introduction

Development of consumer electronics has brought to the market a lot device with LCD panels. Most of these devices are controlled by touch screen sensor, which lies on the top of LCD panel. In assembly process may occur some misalignment and therefore it is recommended to calibrate the system before use of touch screen sensor. Calibration is also necessary when display and touch screen sensor have different resolution. This article shows basic methods for oversampling and calibration for touch screen systems. Software implementation of algorithm is also mentioned [4], [5].

Resistive-type touch screens are normally used in cost-conscious designs. Their construction is simple, their operation is well understood, and the hardware and software required to support them is readily available from multiple manufacturers.

Despite the advantages of resistive-type touch screens, devices equipped with them almost always require a calibration algorithm to be the first task to run when the final product comes out of the box. Calibration is necessary because it is difficult to perfectly align a touch screen’s coordinates to the display (LCD or otherwise) behind it. If a button or other “live” feature on the display is to be properly activated, the coordinates of the area touched on the screen must be sufficiently close to the coordinates of the feature on the display. Otherwise, the software may not correctly act upon the soft button presses [3].

2. Touch screen system

Figure 1. shows typical scheme of touch screen system with LCD panel. In this case we used resistive touch panel connected by 4 wires to the controller. Touch screen controller (TSC) contain programmable A/D converter with different resolution, most of them are 12-bit. TSC communicate with host processor by serial interface SPI or I2C.

2.1 Methods for improving electrical noise

Nowadays, there are several methods for improving electrical noise in touch screen systems. Most of them are dependent on electrical layout. As an example, several methods:
- Correct design of PCB layout
- Adding of decoupling capacitors
- Implementation of filter algorithm
- Using TSC with pressure measurement
2.2 Sample averaging

Simply algorithm was implemented for averaging samples measured immediately after each. For example, X numbers of samples (in our case 3 samples) were received. Only 2 samples which values are close to each other, were used for averaging.

Generally, filtering or averaging can be formulated like

\[ X(k) = \sum_{n=0}^{N-1} b_n \times x(k-n) \] (1)

Samples average X(k) represents value of filtered data value (result value of coordinates without conversion to real value). Vector x(k) are raw data from TSC A/D converter. Coefficient b_n is weight of filter in our case if \( b_n = \frac{1}{N} \) for \( N = 3 \), where N represent numbers of samples.

\[ X(k) = \sum_{n=0}^{2} x(k-n) = \frac{[x(k) + x(k-1) + x(k-2)]}{3} \] (2)

Average value from several values may be considered as \( b_n = \frac{1}{N} \) for 2 nearest values of x(k), 0 for value of x(k) far from other samples [6].

2.3 Oversampling algorithm principle

For Eq. 3a-c it is necessary to obtain 3 samples, collected one by one for every single coordinate. So, 9 samples of coordinates must be received and average of values which are more closely spaced must be calculated.

\[ X_1 = \frac{[x(1) + x(2) + x(3)]}{3} \] (3a)

Average of the first three samples,

\[ X_2 = \frac{[x(4) + x(5) + x(6)]}{3} \] (3b)

and similar for other samples 4 to 9.

\[ X_3 = \frac{[x(7) + x(8) + x(9)]}{3} \] (3c)

It is necessary to calculate value of difference

\[ d_1 = |X_1 - X_2|, d_2 = |X_2 - X_3|, d_3 = |X_3 - X_1| \] (4)

Find two absolute averages which are closer to each other, for example d_1 and d_3 then result value for X coordinate is

\[ X' = \frac{d_1 + d_3}{2} \] (5)

In general, oversampling algorithm provides averaging samples and ensures that samples whose values are beyond the limit is not counted in the average [6].

3. Calibration of touch screen

Coordinates of point displayed on display and measured coordinates of this point from touch screen sensor may not be the same. In the case that a display has resolution 320 (X axis) x 240 (Y axis) and TSC for example 12 bit, has resolution 4095x4095, we it necessary to recalculate coordinates from TSC (identify scaling factor) and match it to display resolution. Scaling factors for X and Y coordinates

\[ k_x = \frac{S_x}{S_X} = \frac{320}{4095} = 7.81 \times 10^{-2} \] (6)

\[ k_y = \frac{S_y}{S_Y} = \frac{240}{4095} = 5.86 \times 10^{-2} \] (7)

Resolution of display in X and Y axis is represented by coefficients S_x and S_y.

Thus, a touchscreen controller’s X coordinate, X’, should be understood by the LCD (the host) as \( X = k_x \times X' \), same for Y-axis. In the preceding example, k_x and k_y, are simple linear scaling factors, which depend on resolution of LCD and TSC.

![Fig.2 Scaling factors on Y axes of LCD and touch screen](image-url)

Mechanical misalignment between display and touch screen panel includes moving and rotation errors. Figure 3a shows relative position shift of ΔX and ΔY in the Y direction, and Fig. 3b shows the relative rotation, Δθ, between the LCD and the touch screen. Consider a point P, read as (X’, Y’) on the touch screen. Misalignment error would be reflected like that shown in Fig. 3a as (X’ + ΔX, Y’ + ΔY). For a rotation error in Fig. 3b, the point on the touch screen is (R ×cos(θ), R ×sin(θ)), or on the display is [R ×cos(θ-Δθ), R ×sin(θ-Δθ)], where R is the distance from origin C, or(0, 0), to the point P. After calibration, the touch screen translates the coordinates that accurately represent the point and image location on the display. The result of calibration is a set of scaling factors. These allow...
correction of the moving and rotation errors that are due to mechanical misalignments.

Fig. 3 Mechanical misalignments

Point P is represented by coordinates on display as (X, Y) and (X', Y') on touch panel. Counting the scaling factor from Fig. 2 and the moving and rotation errors in Fig. 3, for X axis can be expressed as

\[
X = k_X \times R \times \cos(\theta - \Delta \theta) + \Delta X
\]

where \( \alpha_X = k_X \times \cos(\Delta \theta) \), and \( \beta_X = k_X \times \sin(\Delta \theta) \).

Similarly for Y coordinate

\[
Y = k_Y \times R \times \cos(\theta - \Delta \theta) + \Delta Y
\]

where \( \alpha_Y = k_Y \times \cos(\Delta \theta) \), and \( \beta_Y = k_Y \times \sin(\Delta \theta) \).

From Eq. 7-8 follows that for calculating coefficients \( \alpha_X, \alpha_Y, \beta_X, \beta_Y, \Delta X \) and \( \Delta Y \), at least 3 independent calibration points are needed. The points are independent if they are not on one linear line (see Fig. 4).

Equation 9 can be rewritten in matrix form

\[
\begin{pmatrix}
X_1 \\
X_2 \\
X_3
\end{pmatrix} = A \begin{pmatrix}
\alpha_X \\
\beta_X \\
\Delta_X
\end{pmatrix}
\]

where

\[
A = \begin{pmatrix}
X'_1 & Y'_1 & 1 \\
X'_2 & Y'_2 & 1 \\
X'_3 & Y'_3 & 1
\end{pmatrix}
\]

4. Calibration algorithm

Before use, the touch screen panel has to be recalibrated. In Fig. 3.b are shown three independent calibration points. Calibration coefficient necessary for correction of offset and misalignment error between LCD and touch screen can be calculated from Eq. 10. Multiplying both sides of Eq. 10 with inverse matrix A, we get

\[
\begin{pmatrix}
\alpha_X \\
\beta_X \\
\Delta_X
\end{pmatrix} = A^{-1} \times \begin{pmatrix}
X_1 \\
X_2 \\
X_3
\end{pmatrix}
\]
\[
\begin{pmatrix}
\frac{\alpha}{\gamma} \\
\frac{\beta}{\gamma} \\
\frac{\gamma}{\gamma}
\end{pmatrix} = A^{-1} \times
\begin{pmatrix}
X_1 \\
Y_1 \\
Y_2
\end{pmatrix}
\] (13)

Where \( A^{-1} \) is inverse matrix of Eq.1. Points \((X_1, Y_1), (X_2, Y_2)\) and \((X_3, Y_3)\) are selected calibration points on LCD. Elements of matrix \( A \) are values obtained during calibration of the touch screen controller.

For the calculation of the calibration coefficients of the matrix \( A \) it will be needed to calculate inverse matrix \( A^{-1} \).

\[
A^{-1} = \begin{pmatrix}
a & b & c \\
d & e & f \\
g & h & k
\end{pmatrix}^{-1} = \frac{1}{\det(A)} \begin{pmatrix}
A & B & C \\
D & E & F \\
G & H & K
\end{pmatrix}^T
\]

Where \( \det(A) \) is determinant of matrix \( A \), in this case, it can be calculated like

\[
\det(A) = a(ek - fh) + b(fg - kd) + c(dh - eg)
\] (15)

If the determinant is non-zero and the inverse matrix can be calculated according to Eq. 14 the matrix elements are

\[
A = (ek - fh), D = (hc - bk), G = (bf - ec)
\]
\[
B = (fg - dk), E = (ak - gc), H = (cd - af)
\]
\[
C = (dh - eg), F = (gb - ah), K = (ae - bd)
\] (16)

Substituting into Eq. 14, the values of the calibration coefficients will be obtained [1], [4].

5. Final algorithm verification

Algorithm was verified on development board with TFT LCD panel which contain resistive touch screen panel with controller ADS 9843. The calibration process began with plotting of calibration points (red circle Fig.5). User must click into every point sequentially and press confirm button. Confirming coordinates by pressing button improves calibration precision and avoids errors caused by accidental touch.

If touch screen controller contains function measurement of pressure, hardware button can be replaced by this function.

6. Conclusion

In the paper we discussed about touch screen system’s theory and application. General methods use only two calibration points, however, these maintained methods are limited by linearity of these points and therefore it is not possible to eliminate rotation error. Proposed method works with three or more calibration points which are non-linear. So, rotation error can be removed. Applied method and theoretical assumptions are confirmed by experimental verification on development of board with touch screen.

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References


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