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Algorithm for Real Time Pen Coordinate Estimation of Electromagnetic Digitizer

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Abstract: An electromagnetic induction input device which measures an electromagnetic induction signal emitted from an electromagnetic input device and provides information on a pen position in real time. Such an electromagnetic induction input device provides a high resolution, hovering function indicating a position even when the electronic pen does not touch the screen, and excellent durability at the rear of the display. In order to measure the position of the electronic pen, an algorithm that calculates the position of the maximum value after curve fitting by using multiple AD-converted sensor values. Such a conventional method requires a large amount of computation and has a limitation in speeding up. This research, suggests an algorithm that measures the pen coordinates in real time with three sensor signal values that detect signals generated by the pen. In order to show the proposed algorithm, a simple sensor was realized and a control board was designed. According to the diagonals of the sensor center, the experimental results show that the pen has good performance.

Keywords: electromagnetic induction input device, the electronic pen, pen coordinates

1. Introduction

The input device used in smartphones, tablets, and external auxiliary monitors can be divided into the capacitive type and the electromagnetic induction type according to how the input signal of the sensor is sensed.[1] Although the response speed of capacitive type touch screen is relatively slow, most smart phones use capacitive type touch screen after the iPhone comes into the market, so most of the electronic pen input methods are capacity type. Capacitive input sensor is difficult to accurately input, but is used as a method instead of a simple hand touch.

Different from the capacitive type mentioned above, the electronic pen with electromagnetic induction type in the Galaxy note series of Samsung Electronics is composed of the following Fig. 1.

Fig. 1 Configuration of electromagnetic induction type electronic pen input device

The advantage of the electromagnetic induction input device is that there is a sensor in the form of the PCB on the rear of the display, which not only providing a high resolution, but also has the hovering function indicating a position even when the electronic pen does not touch the screen, and the force between the pen and the display without battery.

In this research, in order to measure the position of the electronic pen in the conventional electromagnetic induction type input device, an algorithm that obtains the position of the maximum value after curve fitting a number of AD-converted sensor values is used. [2,3,4] There is a limit to high speed because it requires a large amount of computation. This research, suggests an algorithm that measures pen coordinates in real time with three sensor signal values that detect signals generated by the pen. In order to show the proposed algorithm, a simple sensor was realized, the control board was designed, and the pen position was measured along the diagonal line of the center of the sensor. From a series of experimental results, it was found the measurement performance is satisfactory as an algorithm for electromagnetic type input device.

II. Measurement principle of electromagnetic induction pen

The Fig. 2 shows the configuration of a general electromagnetic induction input device. When a sine wave (A) signal is input by wire from an electronic pen in which a number of coils are wound around a cylindrical ferrite core, the electromagnetic induction signal emitted from the coil of the electronic pen is induced from a multiple of loop coils. The fine coil voltage signal (B) is output through the mux. Signal (B) periodically selects each loop coil and outputs a signal of each coil. This fine signal is amplified like a signal (C) through a filter and an amplifier. The amplified signal shows the process of detecting the maximum value corresponding to each loop coil through a peak detector as shown in signal (D), and then passing through the AD converter as a digital data to the microprocessor.

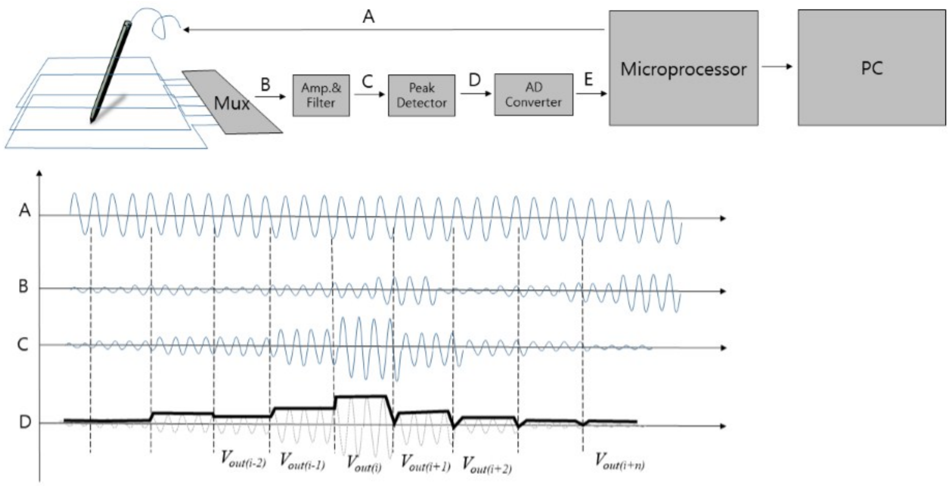

Fig. 2 Example of circuit configuration and sensor signal of electromagnetic input device

The signal measured in each coil loop described above is AD converted and transmitted to the microprocessor, so this data will be transmitted to the PC through wired communication. The signals will be arranged on the computer as shown in Fig. 3 (A). By curve fitting the signal data around the maximum value with a second order polynomial, the position with the maximum value of this function is calculated, and the pen position is obtained as shown in Fig. 3(B).

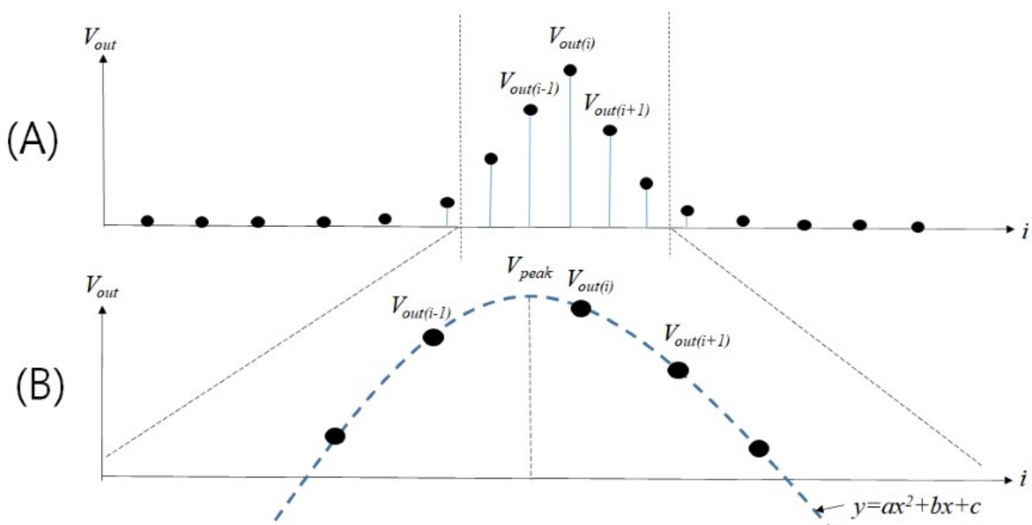

Fig. 3 Pen position estimation by curve fitting the signal data around the maximum value with a second order polynomial

In order to measure the position of the pen by curve fitting method, a large amount of computation is required so that the speed of measurement is limited. In order to overcome this problem, this research proposes an algorithm that calculates the pen position with a simple operation using only sensor values without curve fitting.

The Fig. 4 shows the process of measuring the pen position in two dimensions after detecting the signal of each coil by arranging multiple coils orthogonal to each other. [5]

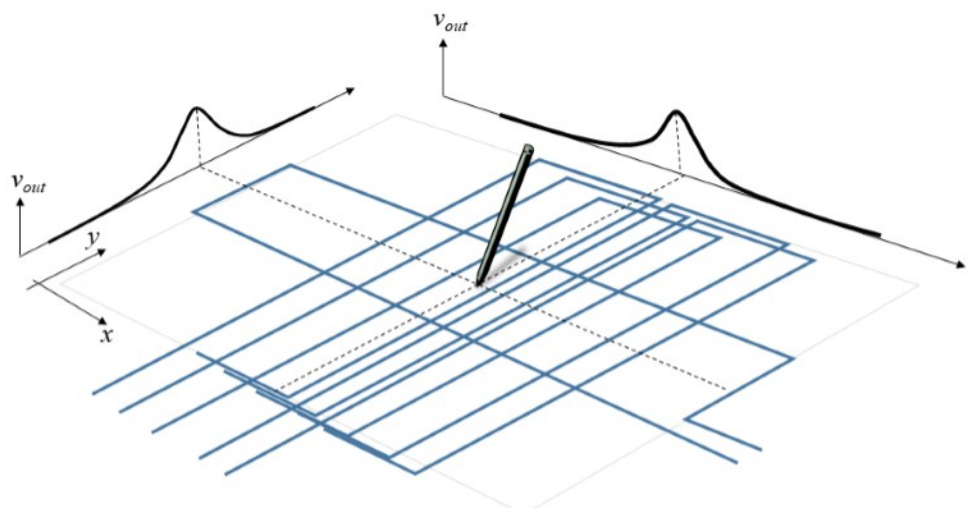

Fig. 4 The process of measuring the pen position in two dimensions

III. Pen position estimation algorithm

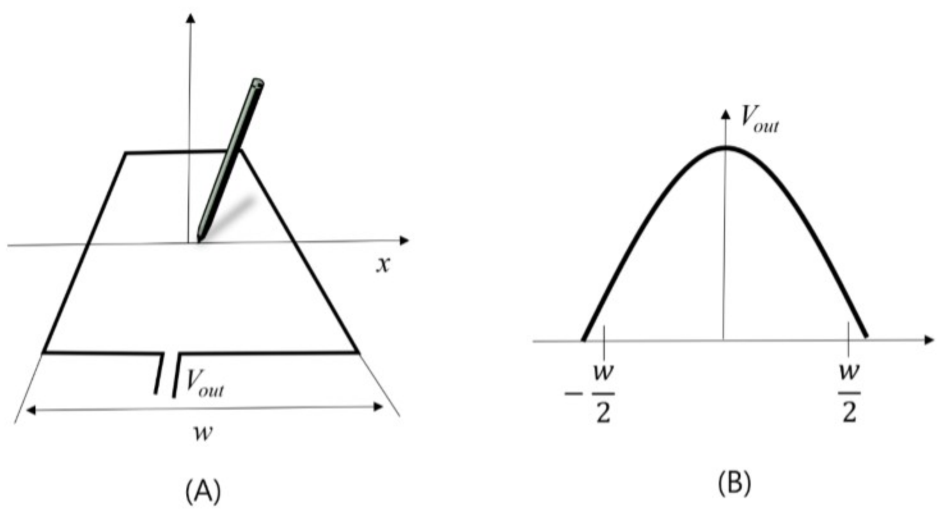

Fig. 5 Sensor output signal based on pen position in single loop coil

The Fig. 5 above is a picture that expresses the magnitude of the signal (V_{out}) measured while moving the pen from the center to the outer side in a single loop coil with width w. As shown in the figure, when moving in the x direction, the maximum value appears at the center and the value decreases toward the outer side of the coil, showing a tendency of a second-order polynomial.

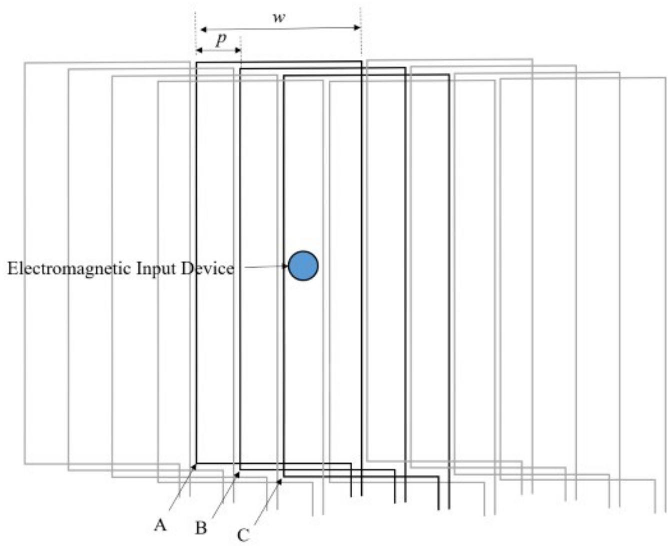

Fig. 6 Electromagnetic input device included in three loop coils

Fig. 7(a) shows three loop coils (A, B, C) that measure the signal of the pen simultaneously. The detection signal value from the pen in each coil can be expressed as V_A, V_A and V_C as shown in Fig. 7(b). These values can be described at the coil center position as shown in Fig. 7(c). For example, if the center distance of coil B is expressed as x_B, the center distance of coils A and C can be expressed as x_B-*p*, and +*p* respectively.

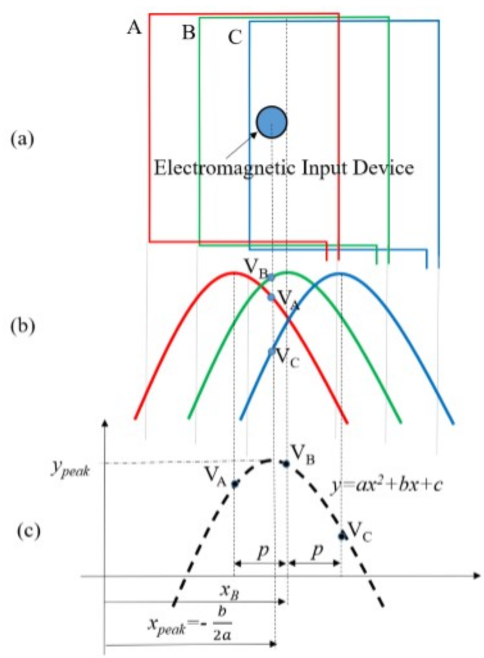

Fig.7 Sensor signal value from three loop coils overlapped with an interval of *p*

If the measured value in the single coil assumed as a second-order polynomial, the curve passing through the three points in Fig.7 (c) can also be expressed as a second-order polynomial as shown in Eq. (1).

$$y = ax^2 + bx + c \tag{1}$$

In this case, the maximum value is the position where the slope of Eq. (1) is 0. If Eq. (2) is a derivative of equation Eq. (1), the Eq. (2) is 0 at the position of maximum value in x axis. Then the position of the maximum value is x_{peak} is expresses as Eq. (3).

$$\frac{dy}{dx} = 2ax + b = 0 \tag{2}$$

$$x_{peak} = -\frac{b}{2a} \tag{3}$$

The equation above is a general second-order polynomial consisting of the parameters a, b, and c. If the parameters a and b of this second-order polynomial can be obtained in real time from the three sensor measurements (V_A, V_B, and V_C), the estimation time for obtaining the pen position will be reduced.

Therefore, substituting the measured values V_A, V_B, and V_C and the coil positions x_B-p, and +p into the second-order polynomial will be expressed as Eq. (4).

$$\begin{aligned} V_A &= a(x_B - p)^2 + b(x_B - p) + c \\ V_B &= a{x_B}^2 + bx_B + c \\ V_C &= a(x_B + p)^2 + b(x_B + p) + c \end{aligned} \tag{4}$$

From the Eq. (4), the parameters a and b are expressed by the following Eq. (5),

$$\begin{aligned} a &= \frac{V_A + V_C - 2V_B}{2p^2} \\ b &= \frac{V_C - V_A}{2p} - \frac{x(V_A + V_C - 2V_B)}{p^2} \end{aligned} \tag{5}$$

Substituting the parameters, a and b that shown in Eq. (5) into the Eq. (3) will be expressed as Eq. (6).

$$x_{peak} = -\frac{b}{2a} = x_B + \frac{p}{2}\left(\frac{V_C - V_A}{2V_B - V_A - V_C}\right) \tag{6}$$

Eq. (6) is the equation that estimate the position of the pen. From the equation we know that the position of the pen can be obtained in real time with overlap distance p, the coil center position x_B, and the three sensor values V_A, V_B and V_C without the complicated curve fitting computation.

IV. Experimental results

In this research, the schematic of sensor pattern is shown in the Fig. 8. The width and height of each coil were designed to be 21mm × 93mm, and the coil overlapping interval p was 6mm, and each x, y axis channel was realized as 13 channels.

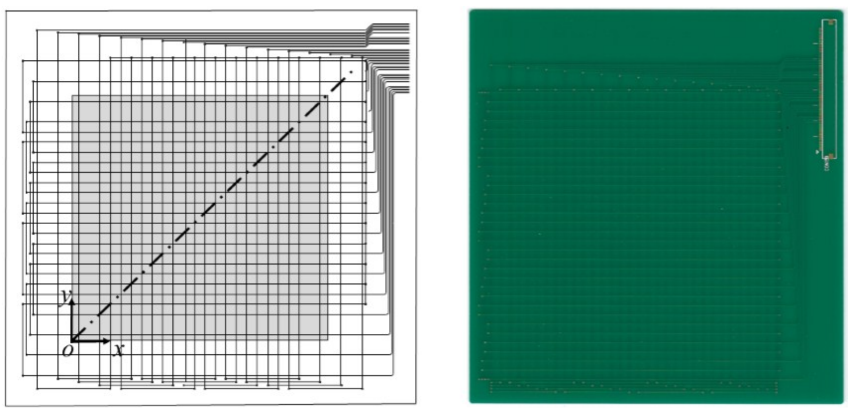

Fig. 8 Sensor board designed for this research

The proposed pen position estimation algorithm is derived from the assumption that it is expressed as a second-order function according to the pen movement from the center to the edge. Therefore, in this research, the result of fitting with a second-order function by measuring the distribution of sensing values at a width of 21 mm in the sensor pattern is shown in Fig. 9. As in the experimental results, it can be seen that the trend of the second-order function is shown.

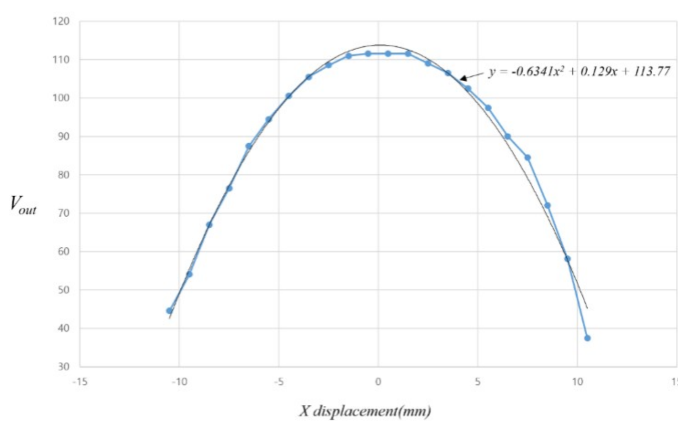

Fig. 9 Distribution of sensor output values for pen movement in a single coil loop in the realized sensor pattern

Since the x-axis and y-axis sensors have the same structure and configured to be orthogonal to each other, the precision of the sensor can be measured by pen position measurement along the diagonal line in the picture below. The following Fig. 10 below shows the relationship between the measured value and the measurement error along the central diagonal.[6]

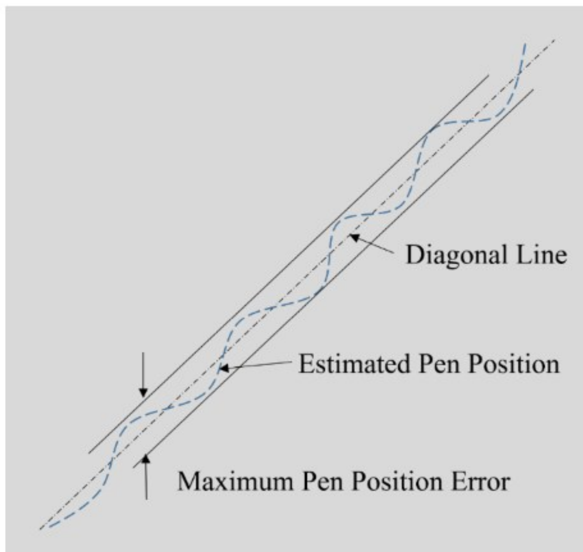

Fig. 10 Measurement value and error relationship when moving the pen along the diagonal

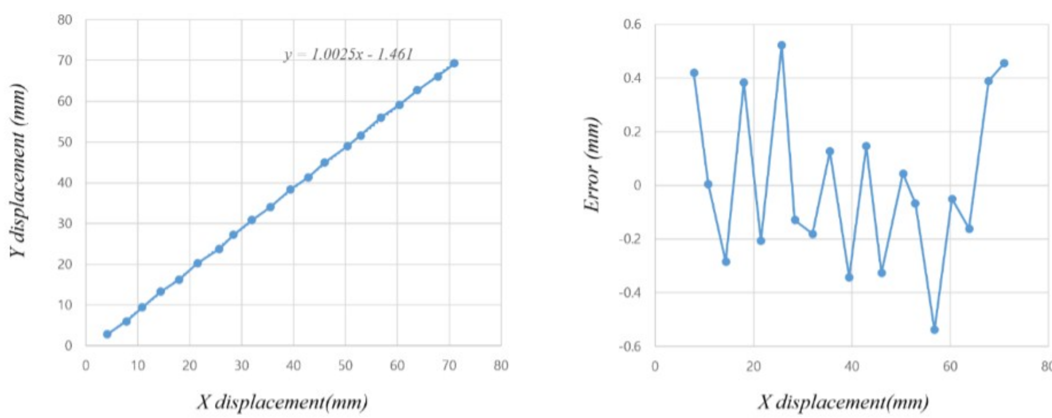

Fig. 11 Experimental results using the sensor board

The pen position and measurement error are displayed diagonal when the electronic pen is moved on the sensor board. Fig. 11(a) shows the result of measuring the pen position along the diagonal of the sensor board and Fig. 11(b) shows the error of measuring the pen position along the diagonal of the sensor board. As a result of the measurement, it was found that the result was about ±0.5mm.

V. Conclusions

The conventional method of measuring the position of an electromagnetic induction type electronic pen has a disadvantage that a large amount of computation is required by obtaining the position of the maximum value after curve fitting a several of AD-converted sensor values. In this research, to overcome for these shortcomings, a new simply measurement algorithm is proposed under the assumption that the measurement signal in a simple coil loop is expressed as a second-order polynomial.

In order to examine the performance of the proposed algorithm, the shape of the loop coil is 21mm × 93mm in each of the x and y axis and 13 channels are designed, and a control board for signal processing is realized. As a result of measuring the position of the pen with the experimental device, the following conclusions could be derived.

First, it was found through experiments that the sensor signal of a simple coil loop can be expressed as a second-order polynomial.

Second, by using the algorithm proposed in this research, the pen coordinates were measured in real time with three sensor signals that detect the pen signal. As a result of measure the pen position along the diagonal line at the center of the sensor, the measurement error was about ±0.5mm.

References

1. Young Kee Ryu, Kuk Won Koh1, and Hak Soo Kim," A Non-contact Two-Dimensional Position Sensing Device Using Electromagnetic Induction," J. of the KSPE, Vol. 29, No. 11, pp. 1159-1163, 2012
2. Yamanami, T., Funahashi, T., and Senda, T., "Position Detecting Apparatus," US Patent, No. 5028745, 1991.
3. Yamanami, T., Funahashi, T., and Senda, T., "Position Detecting Apparatus," US Patent, No. 4878553, 1989.
4. Weiner, A. J., Perski, H., and Morag, M., "Physical Object Location Apparatus and Method and a Graphic Display Device using the Same," US Patent, No. 6690156 B1, 2004.
5. Azuma, M., "Coordinate input apparatus," KR Patent, No. 10-0910348-00-01, 2009.
6. Hong, D.-G., Ryu, Y. K., and Oh, C.-S., "A Study on the Coordinate Estimate Algorithm of the Electromagnetic Induction Based Wired Tablet Device," Journal of the Institute of Webcasting, Internet and Telecommunication, Vol. 9, No. 4, pp. 153-159, 2009.