Computerized Mechanical Movement Control System for Two Dimensional Ultrasound Breast Scanning

Lai Khin Wee, Lee Siew Wen, Eko Supriyanto

***Abstract*—** Ultrasound scanning system is a non-ionizing technique for breast mammography. Unfortunately, ultrasound has not approved by FDA as a screening tool yet due to the lack of spatial resolution and high operator dependent. Therefore, the quality of imaging depends on the operator technique and experience. The purpose of this project is to develop an automated 2D motion system for ultrasound scanning designed for breast cancer patient. The scanning was performed by automated movement of a transducer during image acquisition. Therefore, the automated motion system needs a very high precision of position control system which integrated with a microcontroller and two appropriate distance sensors on each axis. Besides, graphical user interface has been designed to interface between the microcontroller and personal computer. The control method for the automated motion system can achieve a resolution of 2mm. This is used to replace the conventional handholding ultrasound probe and to increase the spatial resolution of ultrasound.

***Keywords*—** Ultrasound, breast, mammography, sonography, control, position, microcontroller.

I. Introduction

Nowdays, Nowadays, breast cancer is the most common cancer disease among women all over the world. In the diagnosis of breast cancer diseases, breast ultrasound examination is only used as a supplement to mammography. The breast screening tool, mammography has been introduced at many countries. Mammography is widely used as an examination tool for detecting breast cancer at the early stage. However, the breast density sometimes decreases the detection performance. Thus, the estimation of breast density will be required to increase the detection rate at the early stage because most of normal mammary gland may obscure mass regions.

Breast ultrasound scanning is used to evaluate breast abnormalities that are found with screening or diagnostic mammography or during a physician performed clinical breast exam. Although breast ultrasound has excellent contrast resolution, it lacks the detail of mammography. Therefore, ultrasound is not approved by the U.S. Food and Drug Administration (FDA) as a screening tool for breast cancer. It was because ultrasound is lacks spatial resolution and it cannot detect most calcium deposits on breast tumours which is less of calcifications. Besides, its effectiveness depends largely on the operator. It is highly dependent on the operator and equipment factors. Therefore, the quality of imaging depends on the operator technique and experience.

Basically, conventional handholding probes are employed in the ultrasound scanning. The scanning method is operator dependent and has some substantial issues for image acquisition, the position marking of the disease [6-8], the angle or pressure used by operator while scanning [1-5], and the reproducibility of whole scanning process. Some of the researchers and medical device companies are proposing automated scanning mechanism to depict whole breast regions without handholding procedures. This can be a solution of operator dependent for the breast ultrasound scanning.

In current studies, we have developed an automated 2D motion system for breast ultrasound scanning with high precision position control system. The probe will be moving under the breast while the probe will be controlled by automated movement with a proper control system. The control system is designed to have high accuracy and decision of position control. This is used to increase the spatial resolution of the ultrasound scanning due to image recording. Microcontroller will be used in this project to integrate within the mechanical mechanism and the appropriate control system. Finally, we have performed the optimization of the scanning mechanism by testing on tissue sample.

This position control system is designed to have high decision which is able to measure to an accuracy of 2mm. This system will be integrated on the mechanical mechanism which consists of two linear movement axes. The position control of the automated motion system is control by microcontroller by connected with two sensors on each axis. The overall control system consists of computerized GUI interfacing with the hardware through RS232 serial port communication.

II. Background

The incident rate of breast cancer is the highest among all

Manuscript received May 23, 2011: Revised version received July 25, 2011. This work was supported in part by the University Technology Malaysia, Skudai, Johor, Malaysia.

Lai Khin Wee is with Department of Clinical Science and Engineering, University Technology Malaysia, and Biomedical Engineering Department, BMTI, Technische Universität Ilmenau, Germany. (e-mail: kwlai2@live.utm.my).

Lee Siew Wen is with Department of Clinical Science and Engineering, University Technology Malaysia (e-mail: christine_swl86@yahoo.com).

Eko Supriyanto is Head Department of Clinical Science and Engineering, University Technology Malaysia (e-mail: eko@utm.my).

women's cancers in worldwide. The detection and treatment of breast cancer at an early stage gives good treatment results; therefore, the early detection of the cancer is an important task for radiologists and surgeons.

Currently there are two imaging modalities which are mammography and ultrasonography, are effective and established methods for the detection of breast masses in breast cancer screening. It has been reported that the use of mammography for breast cancer screening is useful for women aged 40 and above. However, it is known that mammography is rather limited in dense breasts because small masses might be obscure in dense breast tissues. In addition, younger women tend to have dense breasts and Asian women tend to have denser ones. However, ultrasonography is capable of detecting masses even in dense breasts, as in the case of young women.

It has also been reported that breast cancer screening becomes effective when mammography and ultrasonography are used concurrently. The importance of breast ultrasonography has been increasing yearly. Conventional hand-held probes are generally used in ultrasound screening. However, there is a disadvantage in that such ultrasound screening is operator dependent. Therefore, the obtained images are poorly reproducible, screening examination takes a long time to scan an entire breast, and some areas of the breast may not be scanned.

In order to overcome these problems, several mechanical whole breast ultrasound scanners have been developed. For example, ALOKA Co., Ltd., Japan has developed the ASU-1004 whole breast US scanner. This scanner has an automated water path system and scans the entire breast in three overlapping runs. U-systems, Inc. have developed the SomoVu automated breast US system. This system sweeps the breast using a wide aperture linear transducer.

The advantages of ultrasonography using automated scanners are that the reproducible whole breast images can be easily acquired in a short duration and non-scanning areas are not generated. Due to these advantages, such scanners are effective and can potentially be used as devices for a large-volume screening in the detection of masses. However, the screening will generate a large volume of US images and radiologists might tire while interpreting them. Therefore, it is possible that masses may remain undetected. The screening accuracy might be improved if a computer-aided detection CAD system could assist radiologists by indicating the location of mass candidate regions, e.g., mammography with CAD.

Several research groups have reported the development of breast ultrasonography CAD schemes for the detection of masses and their classification as either benign or malignant. Drukker et al. [9] have reported an automatic lesion detection technique using a radial gradient index filtering. They have also evaluated the performance of their detection and diagnosis method with breast US images obtained using US equipment from two different manufacturers. Horsch et al. [10] have attempted to classify masses using a Bayesian neural network or a linear discriminate analysis based on computer extracted lesion features. Chang et al. [11] have proposed a method that uses the watershed segmentation algorithm to find suspicious frames in whole breast US images, which physicians acquired by using a conventional two dimensional 2D hand-held probe. They have also reported a mass detection method in whole breast US images and a classification technique that makes use of textural and morphological features. Fukuoka et al. [12-13] have developed a CAD scheme based on active contour model and active balloon model in 2D and three-dimensional 3D spaces.

Some systems also require a radiologist to manually indicate the locations of masses in images, while others that use segmentation based on the pixel value and density gradient magnitude may encounter difficulties in detecting masses with obscure boundaries, i.e., with posterior echo attenuation. Therefore, CAD system for a large-volume breast cancer screening by ultrasonography is required to improve the screening performance and efficiency.

III. Materials and Methods

In this project, microcontroller will be used to obtain the output from the distance sensors. The block diagram of whole automated scanning system is shown in Fig. 1; it is a closed-loop with real time control system.

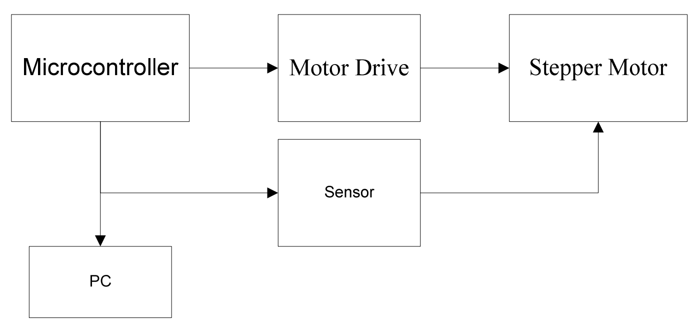

Fig. 1 Block diagram of automated scanning system

The position control system will be applied on the automated scanning system. The actual position will be measured by sensor and feedback to microcontroller.

The mechanical scanning mechanism will be drive by stepper motor while the sensor will detect the actual position from the movement of the scanning mechanism. Fig. 2 shows the picture of the components used in this project, and its corresponding system block diagram in Fig. 3.

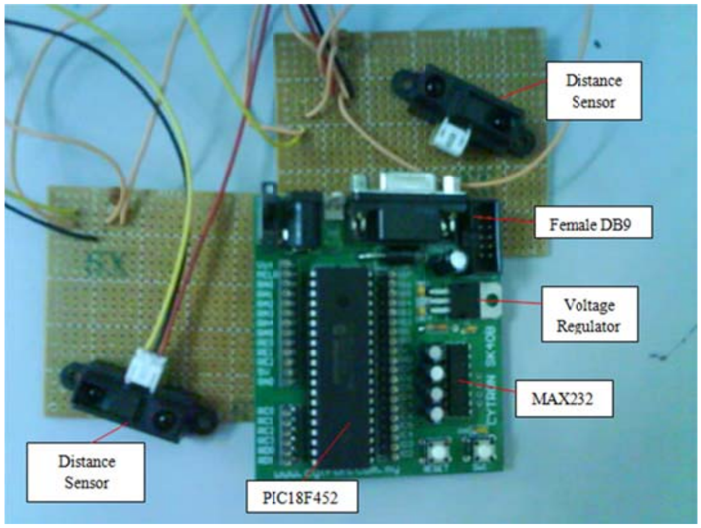

Fig. 2 Picture of the components used in the project

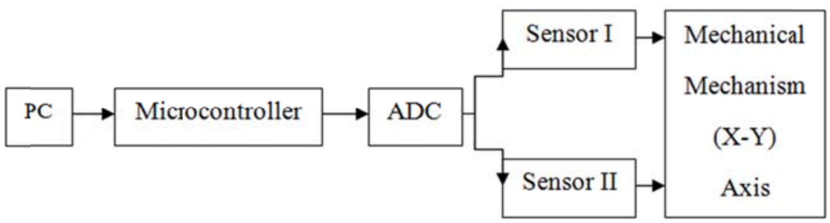

Fig. 3Block diagram of position control system

A. Distance Sensor

Fig. 4 shows the sensor being used which is a distance sensor. This sensor composed of an integrated combination of position sensitive detector (PSD), infrared emitting diode (IRED) and signal processing circuit. Because of adopting the triangulation method, these sensors are hardly influenced by the variety of the reflectivity of the object, the environmental temperature and the operating duration. This device outputs the voltage corresponding to the detection distance. So this sensor can also be used as a proximity sensor. The specification of this sensor is shown in Table 1.

Fig. 4 Distance Sensor

Table 1 Specification of the sensor

Manufacture	Sharp
Model	GP2Y0A21YK
Voltage supply	4.5V – 5.5V
Distance measuring range	10cm – 80cm
Output type	Analog voltage

Consumption current	30mA
Typical difference of output Voltage from 10 to 80cm	2V

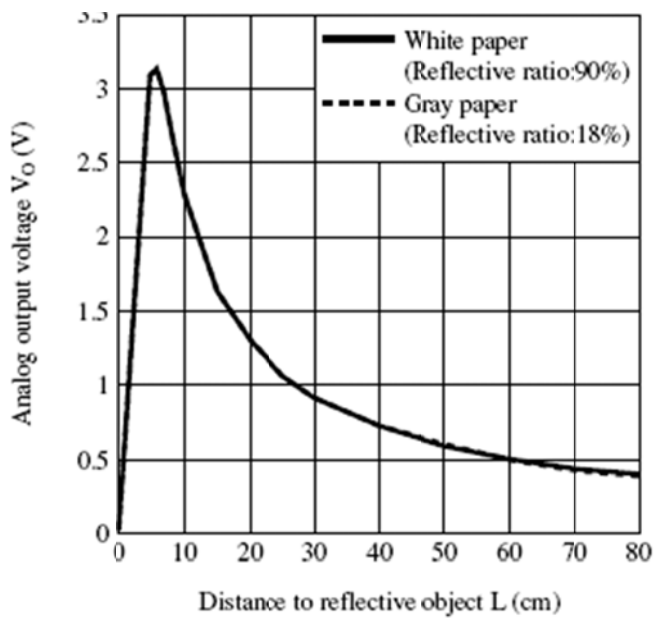

Fig. 5 Graph of analog output voltage versus distance

Fig. 5 shows the relation between the analog output voltage and distance. From the figure, it showed that from 0 to 10 cm, the output voltage is unstable while for the distance from 10cm to 80cm, the relation between output voltage and distance is in logarithmic form. Because of the infinite resolution of the sensor, the resolution of sensor is depends on the number bits of the analog to digital converter (ADC). The calculation of the sensor's resolution in 10bit ADC is shows below. The output Voltage for a 10bit ADC is calculated by,

$$V = \frac{V_{ref}}{2^n} \quad (1)$$

Where n = number of bits

$$V = \frac{5}{2^{10}} = 4.8\text{mV/ bit}$$

Since the difference voltage for 700mm is 2V, thus the output voltage for 2mm is calculated by,

$$V = \frac{\text{Travel distance} * \text{difference voltage of } 700\text{mm}}{\text{Total distance}} \quad (2)$$

$$= \frac{2mm*2V}{700mm}$$

$$= 5.7\text{mV}$$

From the calculation above, it shows that the resolution of sensor is 2mm by using a 10 bit analog to digital converter. It is because 10 bit ADC can measure 4.8mV per bit while the output voltage for 2mm is 5.7mV. Thus, it is enough to detect the output voltage of sensor by a resolution of 2mm.

B. Power Supply +5V

Microcontroller needs a +5 volt voltage supply. Thus, to regulate the power supply to a positive 5 volt source, a voltage regulator needed in the circuit. A voltage regulator IC (Integrated Circuit) which is LM7805 was applied in the circuit.

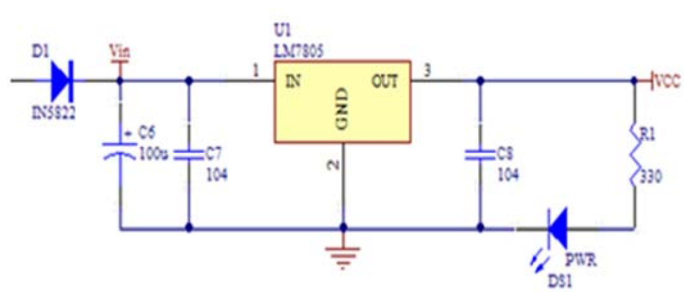

Fig. 6 Schematic circuit of voltage regulator

C. PIC18F452

There are many types of microcontroller. In this project, PIC18F452 which manufactured by Microchip had been chosen. It is because its portability and low current consumption. Besides, PIC18F452 had 16 bit core with 75 standard instructions and 8 extended instruction in order to program the chip. This chip had 256 bit of EEPROM data registers and 8 bit of data memory or registers. Besides, this chip had 16bit of FLASH program memory. The most useful peripheral of this chip is its 8 channel of 10 bit ADC. A 10 bit ADC can obtain a resolution of 2mm for the distance sensors.

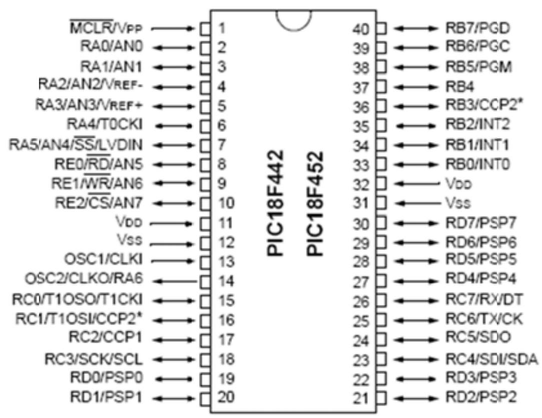

Fig. 7 Pin Diagram for PIC18F452

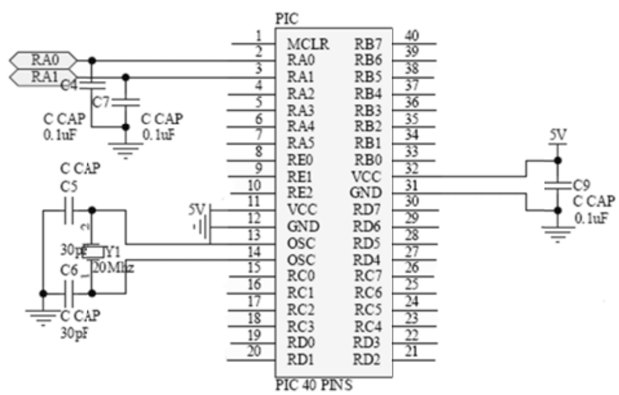

Fig. 8 Schematic circuit of PIC18F452

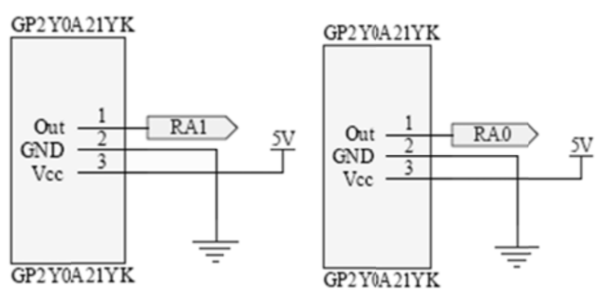

Fig. 9 Schematic circuit of sensor

Fig. 8 and Fig. 9 show the schematic circuit for the microcontroller and the sensor. The two distance sensors were connected at the RA0 and RA1 which is the input channel for ADC of the PIC18F452. Besides, a capacitor cap which is 0.1µFarad had been connected between the output voltage of sensor and grounding. This is because to make sure the stability of the output voltage of sensor.

D. RS232 Serial Communication

The Universal Synchronous Asynchronous Receiver

Transmitter (USART) is also known as a Serial Communications Interface or SCI. In this project, the USART configured as a full duplex asynchronous system that used to communicate with personal computers. In order to make the hardware communication, a standard NRZ (Non Return to Zero) format which also known as 8 (9)-N-1, or 8 or 9 data bits, without parity bit and with one stop bit was used. Apart from that, the transmission speed is fixed to 9600 baud while T is 104µs. Besides, the signal level needs to be adjusted in order to connect the microcontroller to a serial port on a computer. This is because the signal level on a PC is -10V for logic zero, and +10V for logic one while the signal level on the microcontroller is +5V for logic one and 0V for logic zero. Thus, an intermediary stage needed to convert the level which is MAX232. It is a chip that receives signals from -10 to +10V and converts them into 0 and 5V.

E. Algorithm and Programming in CCS C Compiler

The two distance sensors at x and y axes will send output voltage to microcontroller. Then, the microcontroller will calculated the distance traveled and display the actual position of the scanning mechanism to PC by interface with RS232 serial port. An algorithm has to be developed to make the microcontroller to read the input from sensor. Therefore, the algorithm is established and represented by a flowchart in Fig. 10. These flowcharts are then translated into C language and compiled using CCS C Compiler.

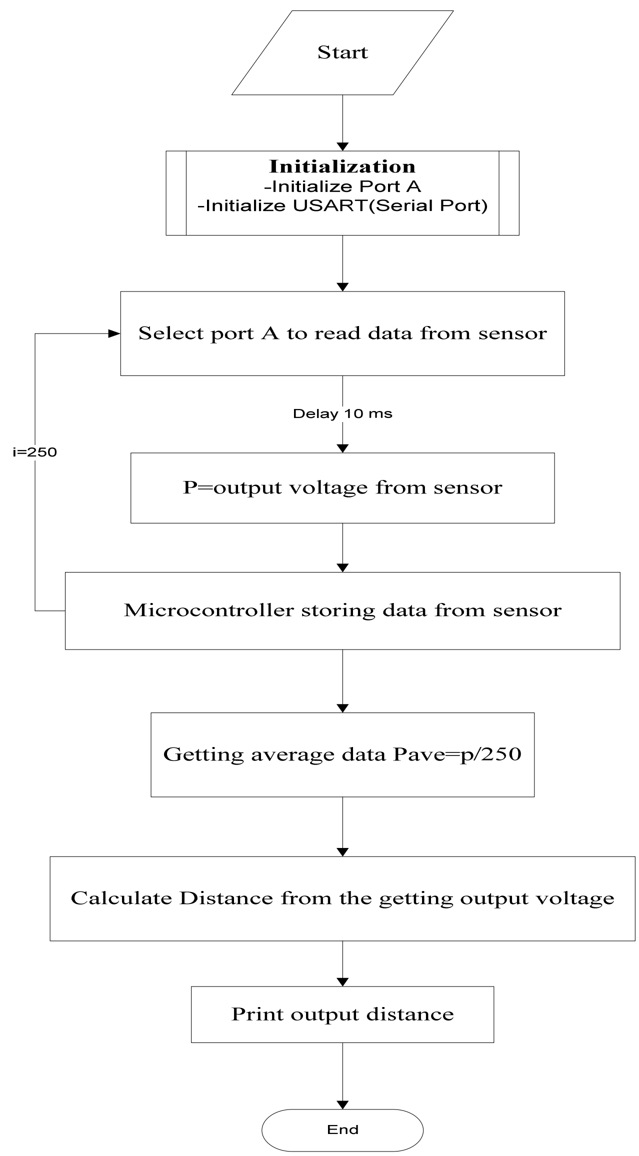

Fig. 10 Flow chart of microcontroller's main program

There are two main parts of main program in microcontroller which is the initialization of ports and setup for serial port.

a) Initialization of the mode of ports A

In this project, pin RA0 of port A used as analog input where it receives analog signal from sensor I which mounted at X – Axis. The pin RA1 also used as analog input where it receives analog signal from sensor II which mounted at Y – Axis. Fig. 11 shows the whole mechanical scanning mechanism.

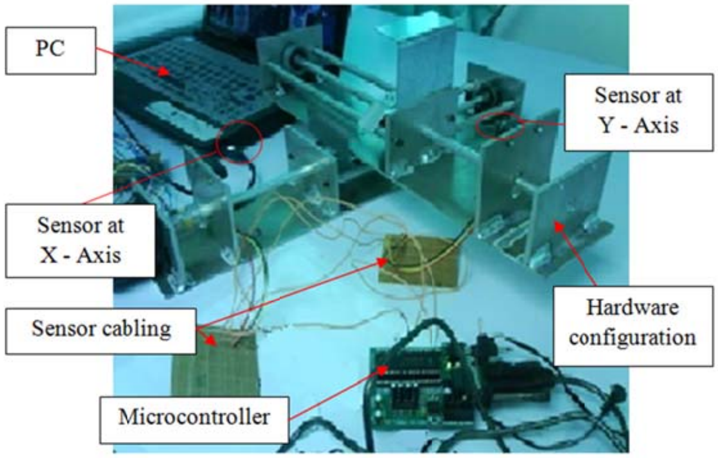

Fig. 11 Mechanical Scanning Mechanisms

Each sensor will take the reading from a same location for about 250 times. This is to ensure the accuracy of the reading. After taking the output voltage from sensor, microcontroller will calculate the travel distance by using the equation from the sensor linearization. This is to compute the output voltage of sensor to an approximate distance range value.

b) Setup for serial port

The Universal Synchronous Asynchronous Receiver Transmitter (USART) is also known as a Serial Communications Interface or SCI. In this project, the USART configured as a full duplex asynchronous system that used to communicate with personal computers. The USART is configuring in asynchronous mode. In this mode, the USART uses standard non-return-to zero (NRZ) format (one START bit, eight or nine data bits, and one STOP bit). The most common data format is 8-bits and it is used in this project. An on-chip, dedicated, 8-bit baud rate generator can be used to derive standard baud rate frequencies from the oscillator.

The transmitter and receiver are functionally independent, but use the same data format and baud rate. Fig. 12 shows the developed main program to receive data (actual position) to microcontroller and interface with personal computer.

To do the graphical user interface (GUI) which interface with microcontroller in Visual Basic 6.0, we need to use a standard object of Visual Basic called MSCOMM control to do the interface. As the form execute, the setting of the PortOpen property set to true to open the port. The MSCOMM control will closed the serial port and clear the receives and transfer buffer as the setting of PortOpen property set to false. The input buffer for the MSCOMM control had set to be six. Thus, there are only three numbers will be allowed to store in the buffer and display in the text box each time the button of START being pressed. The RESET button is used to clear all input buffer and empty all the values in the text box in the form.

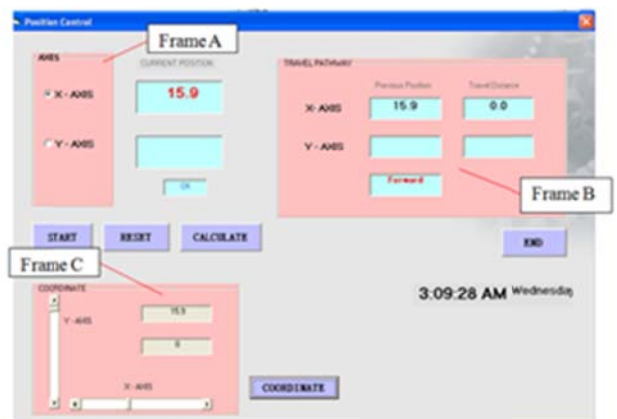

Fig. 12 Main Program Form

As the form execute, the form will display the updated timing on time. The Frame A is used to select which axes to get input data from microcontroller. If X – AXIS being selected, the output distance at x-axis of the scanning mechanism will be display at text box and the same if we select Y – AXIS. In Frame B, it is used to calculate the travel distance for each axis if the CALCULATE button being pressed.

Besides, the textbox will showed the movement whether in backward or forward after it calculated the travel distance for the selected axis. In Frame C, the vertical scroll bar represents the location of the movement for the Y – axis while the horizontal scroll bar represents the location of the movement for X – axis. The updated coordinate will always show in the text box in Frame C if the COORDINATE button being press. The default value for the horizontal and vertical scroll bar is fixed to be zero. The length of each scroll bar was fixed to the length of each x and y axes.

IV. RESULTS

First and foremost, an experiment is conducted to do the calibration and the linearization of the distance sensor. Then, data collection is done by taking experimental data at each 2mm to observe performance of the position control system. Last but not least, the position control system had been tested on the mechanical scanning mechanism and interface with PC by GUI.

A. *Experiment: Sensor calibration and linearization*

An experiment is conducted to do the calibration and linearization of the distance sensor. This is because the output of the sensor is non-linear response. The procedures and the result will be discussed in following sections.

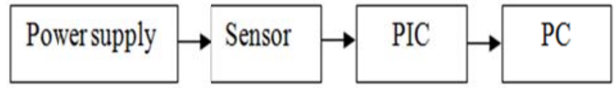

Fig. 13 Sensor Calibrations and Linearization

1) The circuit was connected as Fig. 13.
2) 5V DC supply was supplied to the sensor.
3) Output voltage of sensor was recorded in Table 2. The distance range set from 0cm to 80cm.
4) Plot the graph of output voltage versus distance. This used to analysis the sensor's output response.
5) From the graph, taken appropriate data to do the linear regression by Matlab.

From the experiment, the data was recorded in Table 2. A graph of voltage versus distance is shown in Fig. 14.

Table 2 Experimental Data

Distance (cm)	Output Voltage (V)	1 / Distance
2	1.41	0.500
3	2.15	0.333
4	2.74	0.250
5	3.05	0.200
6	3.11	0.167
7	3.08	0.142
8	2.85	0.125
9	2.52	0.111
10	2.31	0.100
15	1.64	0.070
20	1.27	0.050
25	1.03	0.040
30	0.89	0.033
35	0.79	0.028
40	0.69	0.025
45	0.64	0.022
50	0.58	0.020
55	0.54	0.018
60	0.50	0.017
65	0.48	0.015
70	0.46	0.014
75	0.44	0.013
80	0.42	0.0125

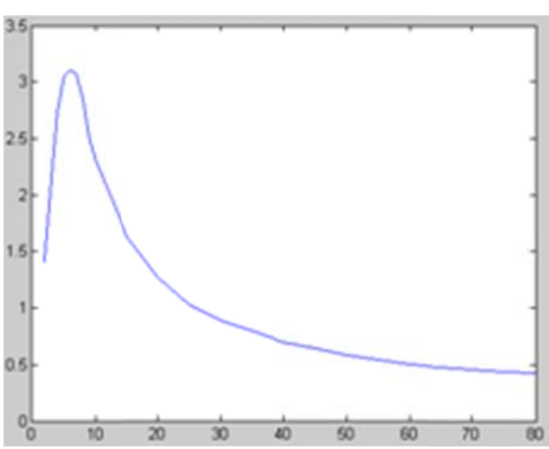

Fig. 14 Graph of output voltage versus distance

Figure 14 shows the sensor's output response is nonlinear. Besides, the output voltages which range from 0 to 10cm are unstable. The response of output voltage range from 10 to 80 cm is stable and in logarithmic form.

Fig. 15 shows the relation between the output voltage and the inverse distance. From the figure, it showed that the response similar to straight line for the output voltage which range from 10 to 80cm. Thus, these values will be taken to do the linear regression by Matlab.

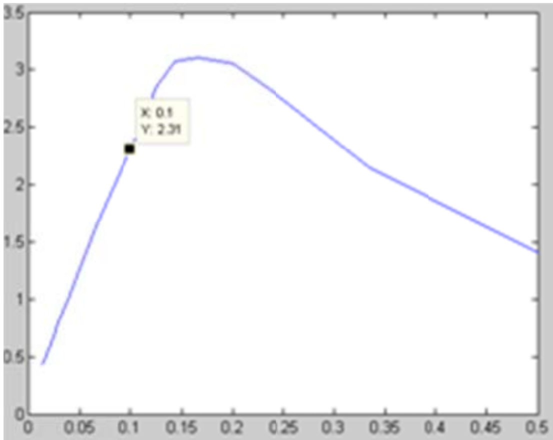

Fig. 15 Graph of output voltage versus inverse distance

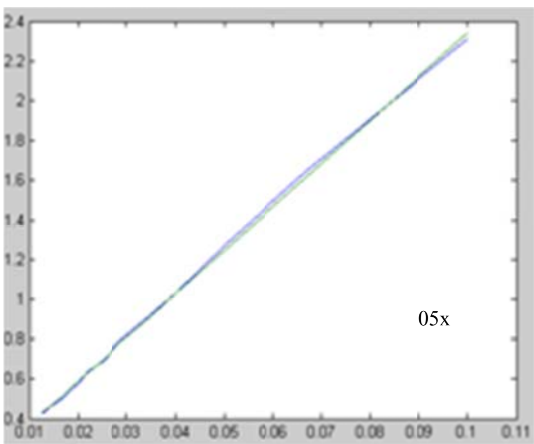

Fig. 16 Graph after linearization by Matlab

Fig. 16 shows the linear relation between the output voltage of sensor and distance. From the figure, the green line is the straight line fit which done after the linear regression method. The blue line indicated the relation before the linearization. These two lines seem do not much difference. Thus, to obtain the distance from the sensor, we can use the equation which obtained from the linearization.

$$x = \frac{y - 0.1494}{21.9205} \quad (3)$$

$$Q = 1 / x \quad (4)$$

Where Q = Distance detected by sensor.

The sum of squares of the residual error, S_r obtained is 0.0032 which was a quite small value. The residual error used to reflect the error in the line fit. Thus, this shows that the graph had a good linear line fit and a minimum error.

B. Testing the Resolution of Distance Sensor

An experiment had been conducted to test the resolution of the distance sensor. By using 10bit ADC, we can get a resolution of 2mm for the distance sensor. This experiment had been done to test on the accuracy of the sensor.

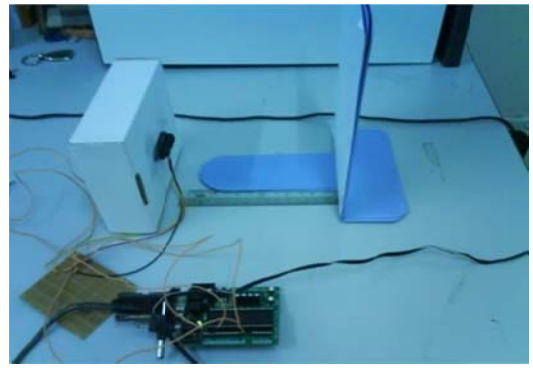

Fig. 17 Experimental picture

1) The circuit was connected as Fig. 17.
2) 5V DC supply was supplied to the sensor.
3) A manual movement of 2mm of the reflective object. The output voltage of sensor was recorded in Table 3. 15 sample data was taken.
4) Plot the graph of output voltage versus distance. This used to analysis the sensor's output response.

From the experiment, the data was recorded in Table 3. The response of the distance sensor is shown in Fig. 18.

Table 3 Experimental Data

Number of movement	Output Voltage (V)
1	17.9
2	18.1
3	18.2
4	18.4
5	18.6
6	18.8
7	18.9
8	19.1
9	19.2
10	19.4
11	19.6
12	19.8
13	20.0
14	20.2
15	20.4

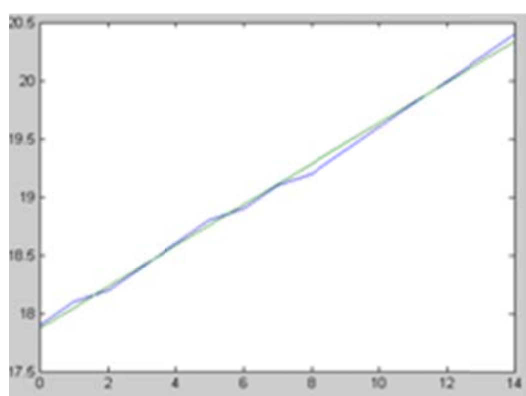

Fig. 18 Response of Distance Sensor

From the figure, the green line is the straight line fit which done after the linear regression method. The blue line indicated the output voltage which taken every 2mm of manual movement. These two lines seem do not much difference. Thus, the resolution of sensor can be said equal to 2mm. The sum of squares of the residual error, S_r obtained is 0.0242. The residual error used to reflect the error in the line fit. Thus, this shows that the graph had a good linear line fit and a minimum error.

V. Conclusion

In this project, the position control system in a 2D automated movement ultrasound breast scanning system has been developed. Besides, this system has been integrated with the mechanical mechanism and able to measure a 2D position by a resolution of 2mm.

The system consist of two linear movement axis which is x and y axes. The movement of these two axes and driven by microcontroller. Two infrared distance sensor are mounted on both axes to get the actual position on time. These sensors are manufactured by Sharp. Because of adopting the triangulation method, these sensors are hardly influenced by the variety of the reflectivity of the object, the environmental temperature and the operating duration. A graphical user interface had been designed to interface the system with personal computer.

In conclusion, the resolution of the developed position control system is 2mm. This position control system can be used for automated scanning mechanism.

References

[1] Lai Khin Wee Hum Yan Chai, Eko Supriyanto, Surface rendering of three dimensional ultrasound images using VTK, *Journal of Scientific & Industrial Research*, Vol. 70, 2011, pp. 421-426

[2] Wee L.K., Eko S., Automatic Detection of Fetal Nasal Bone in 2 Dimensional Ultrasound Image Using Map Matching, *12th WSEAS International Conference on Automatic Control, Modeling & Simulation*, 2010, pp. 305-309

[3] Eko S., Wee L.K., Min T.Y., Ultrasonic Marker Pattern Recognition and Measurement Using Artificial Neural Network, *9th WSEAS International Conference on Signal Processing*, 2010, pp. 35-40

[4] Wee L.K., Arroj A., Eko S., Computerized Automatic Nasal Bone Detection based on Ultrasound Fetal Images Using Cross Correlation Techniques, *WSEAS Transactions on Information Science and Applications*, Vol. 7, No. 8, 2010, pp. 1068-1077

[5] Wee L.K., et al., Nuchal Translucency Marker Detection Based on Artificial Neural Network and Measurement via Bidirectional Iteration Forward Propagation, *WSEAS Transactions on Information Science and Applications*, Vol.7, No.8, pp. 1025-1036

[6] Hum Y.C., Lai K. Wee, Tan T. Swee , Sh-Hussain Salleh , A. K. Ariff and Kamarulafizam, Gray-Level Co-occurrence Matrix Bone Fracture Detection, *American Journal of Applied Sciences*, Vol. 8, No. 1, 2011, pp. 26-32

[7] Hum Y.C., Lai K. Wee, Tan Tian Swee , Sheikh Hussain, GLCM based Adaptive Crossed Reconstructed (ACR) k-mean Clustering Hand Bone Segmentation, *10th WSEAS International Conference on Signal Processing, Robotics and Automation*, 2011, pp. 192-197

[8] Hum Y.C., Lai K. Wee, et al., Adaptive Crossed Reconstructed (ACR) K-mean Clustering Segmentation for Computer aided Bone Age Assessment System, *International Journal Of Mathematical Models and Methods In Applied Sciences*, Vol.5, No. 3, pp. 628-635

[9] Karen Drukker et al., Computerized detection and classification of cancer on breast ultrasound, *Academic Radiology*, Vol. 11, No. 5, 2004, pp. 526-535

[10] K. Horsch, M. L. Giger, L. A. Venta, and C. J. Vyborny, "Computerized diagnosis of breast lesions on ultrasound," *Med. Phys*. 29, 2002, pp. 157–164

[11] R. F. Chang, K. C. Chang-Chien, H. J. Chen, D. R. Chen, E. Takada, and W. K. Moon, Whole breast computer-aided screening using free-hand ultrasound, *in CARS2005: Computer Assisted Radiology and Surgery*, 2005, pp. 1075–1080.

[12] D. Fukuoka, T. Hara, H. Fujita, T. Endo, and Y. Kato, Automated detection and classification of masses on breast ultrasonograms and its 3D imaging technique, *in IWDM2000: 5th International Workshop on Digital Mammography*, 2001, pp. 182–188.

[13] D. Fukuoka, T. Hara, and H. Fujita, "Detection, characterization, and visualization of breast cancer using 3D ultrasound images," *in Recent Advances in Breast Imaging, Mammography, and Computer-Aided Diagnosis of Breast Cancer*, 2006, pp. 557–567.