Performance Analysis of Free-Style Writing and Drawing using Ultrasonic Position System

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Abstract—In future domestic context aware applications the location of mobile devices is often required. Ultrasonic technology enables high resolution indoor position measurements. A disadvantage of state-of-art ultrasonic systems is that several base stations are required to estimate 3D position. This study aims to evaluate the efficiency and effectiveness of using UPS as a 3D free-hand writing or drawing tool. The processes include the design and testing of UPS as an efficient 3D free-hand writing or drawing tool in the air. The paper will further explain the system architecture of the UPS and how to use GPS as 3D free-hand writing or drawing tool. The efficiency and effectiveness of the system was confirmed by a computer software simulation. The software will further display the result of drawing or writing from the user by graphics. As a result, it is possible to implement UPS as a 3D free-hand writing or drawing tool in the air.

Index Terms— Ultrasonic Positioning System (UPS), GPS, 3D free-hand writing, indoor location

I. INTRODUCTION

The measurement of position is one of the fundamental requirements of location aware computing. The introduction of UPS has been a significant factor in the development of outdoor location aware computer applications. Shortcomings of ultrasonic system arise from loss of direct signal and interference. Freehand 3D ultrasound allows intra-operative imaging of volumes of interest in a fast and flexible way. However ultrasound device must be calibrated before it can be registered with other imaging modalities. A requirement for 3D free style ultrasound imaging is a motion tracking system that monitors the position and orientation of a tracked transducer. Other investigators have created 3D free style ultrasonic with tracking system that utilize electromagnetic sensors, optical sensors, acoustic speak gaps, or a combination of these types. To obtain indoor location information, several positioning systems have been proposed. Even though, ultrasonic positioning system requires additional hardware to send and receive ultrasonic pulses, it can determine 3D positions of indoor objects with an accuracy of a few mm to a few cm. However, such systems usually require manual pre-configurations of the locations of reference beacons or sensor. The setup and management costs would be unacceptably high if we apply them to large scale environment such office room. With 4 transceivers and 1 GPS receiver mounted on the robot, the robot absolute position can be further determined in 3D coordinate. With four satellites and one GPS receiver attached to an object , the object absolute position can be further determined in three-dimensional coordinate.[1] However, the disadvantages of the GPS system are weak reception signal in the indoor and poor result showing whenever there are less than 4 transceiver.

In this work, we attached the 4 transmitter on the ceiling whereby the coordinates of each transmitter are known. Besides, the GPS receiver is mounted on another specific object. The receiver on the specific object receives wave signals from the 4 transmitter and perform calculation to obtain the position in real time with respect to the (x,y,z) coordinates. [1]

The objective of this paper is to evaluate the efficiency and effectiveness of using UPS as a 3D free-hand writing or drawing tool. User could use an object with ultrasonic receiver attached to it, writing down important points in the air during class in E-classroom. In each E-classroom, there is a need to attached 4 transmitters at each of the corner. We aim to provide a situation in where the lecturer can direct write in air instead of writing on an electronic board. [3]

II. THE IDEAS BEHIND UPS [1], [3]

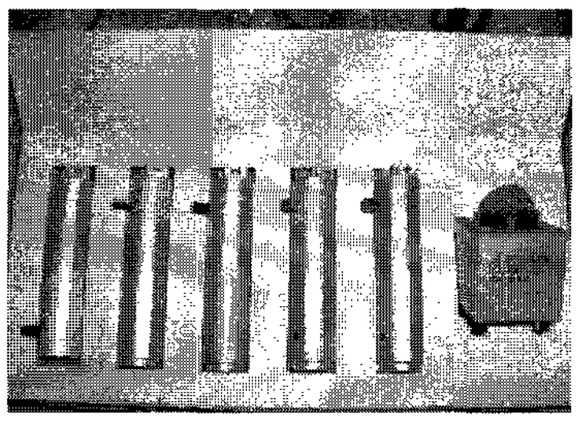

Fig. 1 Ultrasonic Positioning System (U-SAT)

As shown in Figure 1, the box packet consists of 4 transmitters and 1 receiver. Ultrasonic transmitters

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function as ultrasonic satellites and locate on the fixed places whose coordinates are known. As shown in Figure 3, the transceiver are placed on the four corners of the ceiling with height, h1, h2, h3 and h4 from the ground in fixed position, and a receiver is placed inside the satellites' network formed by four satellites. Each satellite is connected to each other by using different cables in specific x, y, and z coordinates. For instance, as shown in Figure 3, transceiver 1 (0, 0, 0) is connected to transceiver 2 (9, 0, 0), transceiver 2 is connected to transceiver 3 (9, 6, 0), and transceiver 3 is connect to satellite 4 (0, 6, 0). A wave signal broadcasting flag with Dc 9V Adapter supplied is first connected to the transceiver 1. Accurate distance can be obtained by measuring the TOF (Time of Flight) value of the ultrasonic sensor.

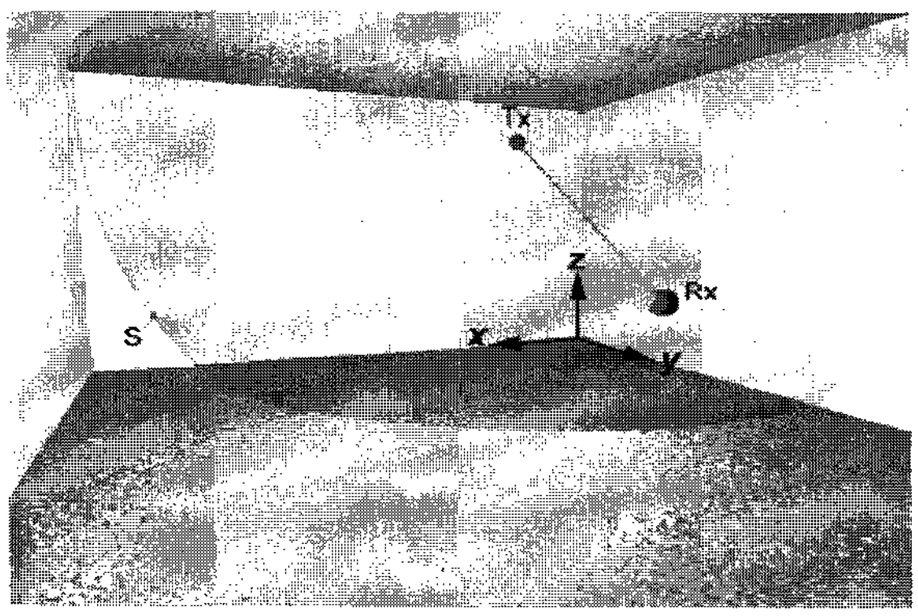


Fig.2 3D views of a room with transmitter Tx and receive Rx

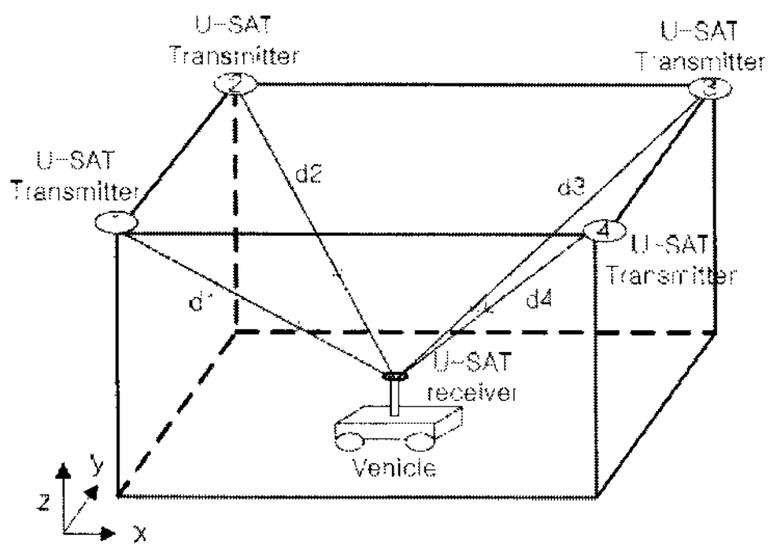


Fig.3 Hardware Configuration of U-SAT

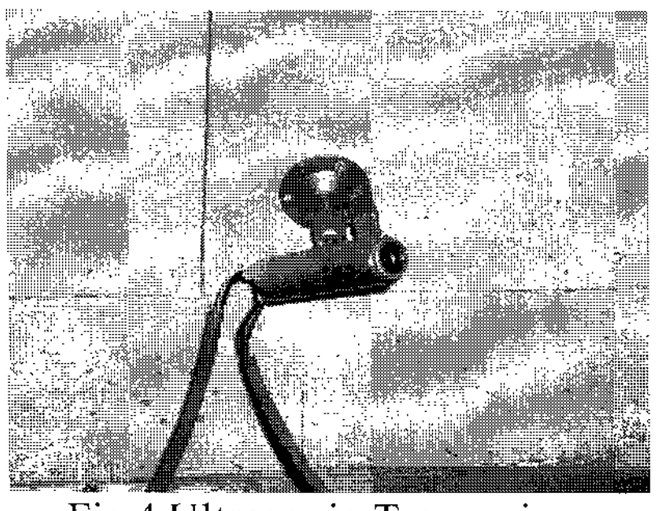


Fig.4 Ultrasonic Transceiver

The basic formulation of positioning using ultrasonic waves is to use formula (1) in conjunction with formula (2), to measure the Time of Flight (TOF), the gap between the time of transmission of ultrasonic waves and the time receives of the waves in Figure 5. It is necessary to measure the TOF precisely for exact positioning.

$$d = c \times TOF \quad (1)$$

$$c = 331.5 + 0.60714T \quad (2)$$

Where d is distance, c is sound velocity in the air temperature of Temp and T is the temperature.

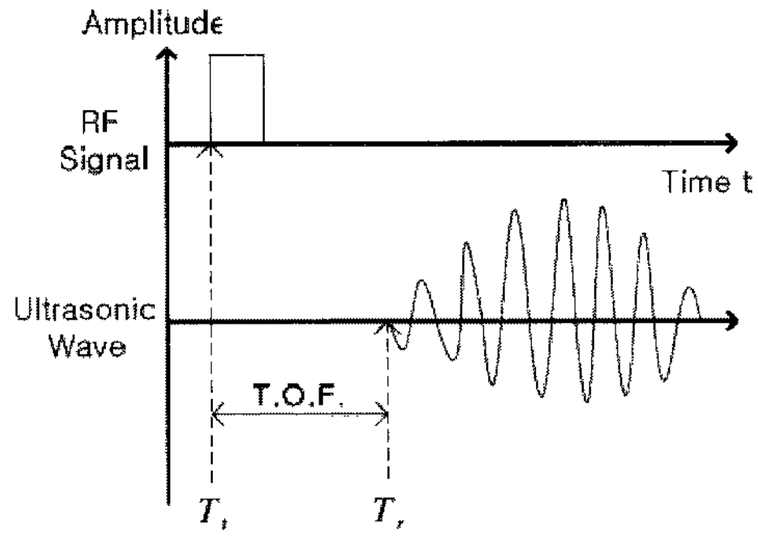


Fig.5 Definition of TOF

For this work, the accuracy to the ultrasonic detection is about 2mm. Based on this, the precise three-dimensional positions can be estimated through trilateration. In addition, ultrasonic waves are transmitted consecutively at the interval of 0.1 second in order to prevent interference of ultrasonic waves generated among each of the ultrasonic transmitter. At specific period of 83ms, Ultrasonic transceiver 1 transfers synchronized RF signals to other transceiver and receiver. The other transceiver and receiver will receive synchronized RF signals and find when ultrasonic waves are radiated. In order to avoid the interference of ultrasonic waves and the influence of the reflection of the other satellites and receiver, synchronized RF signals are transferred with the period of 83ms. This period can be flexibly regulated according to the environment. [1]

III. UPS AS A 3D FREE-HAND WRITING OR DRAWING TOOL [3]

In this experiment, the UPS is used as 3D free-hand writing or drawing tool and the experimental results regarding the efficiency and effectiveness. The experimental data is RS232 data format with baud rate 115200kbps. First and foremost, the four UPS transceiver are connected to each other by using different cables and a wave signal broadcasting flag with 9V adapter connected is connected to the Ultrasonic transceiver 1 as the way to provide RF same flag signal transmission between the other satellites. As shown in Figure 6, the ultrasonic receiver is connected to the local PC via a standard RS232 serial port. External voltage source is needed to for the ultrasonic receiver.

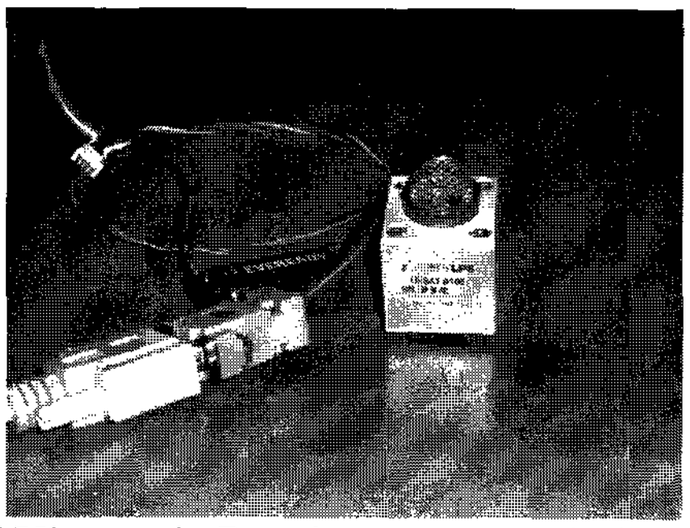


Fig. 6 Ultrasonic Receiver connected via RS232

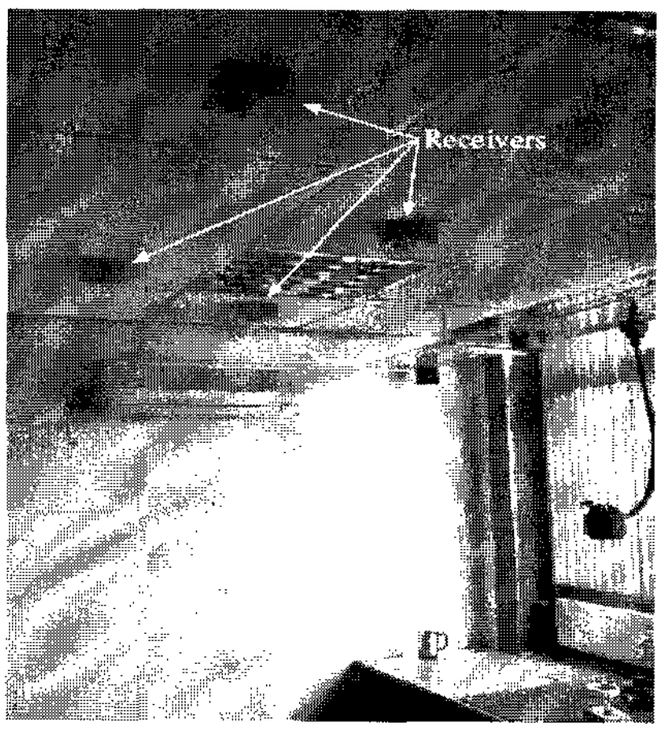


Fig. 7 Experimental indoor Room

The receiver is placed inside the UPS network formed by the four ultrasonic transceivers and the radio broadcasting flag, as shown in Figure 8

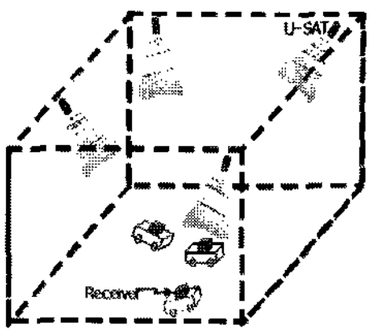
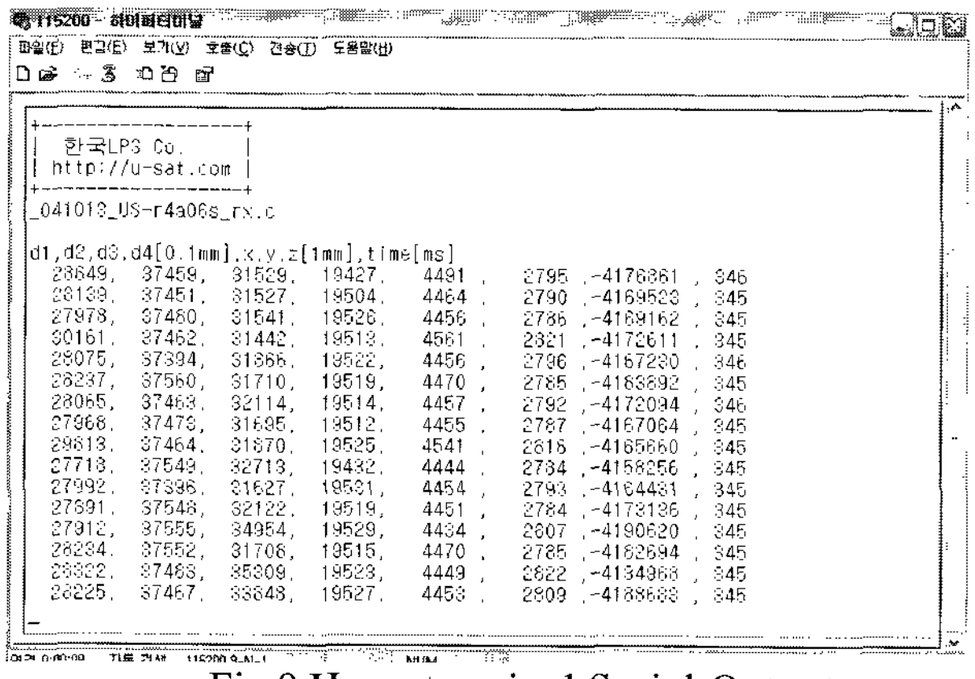


Fig. 8 Ultrasonic receiver is placed inside the UPS

We are using Hyperterminal as a data monitor tools to receive the data transfer from the RS232.



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+------------------+
|  한국LPS Co.     |
| http://u-sat.com |
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_041013_US-r4a06s_rx.c

d1,d2,d3,d4[0.1mm],x,y,z[1mm],time[ms]
  28649,  37459,  31529,  19427,   4491 ,   2795 ,-4176861 ,  346
  28139,  37451,  31527,  19504,   4464 ,   2790 ,-4169523 ,  345
  27978,  37460,  31541,  19526,   4456 ,   2786 ,-4169162 ,  345
  30161,  37462,  31442,  19513,   4561 ,   2821 ,-4172611 ,  345
  28075,  37394,  31866,  19522,   4456 ,   2796 ,-4167230 ,  346
  28237,  37560,  31710,  19519,   4470 ,   2785 ,-4168692 ,  345
  28065,  37463,  32114,  19514,   4457 ,   2792 ,-4172094 ,  346
  27968,  37473,  31695,  19512,   4455 ,   2787 ,-4167064 ,  345
  29813,  37464,  31870,  19525,   4541 ,   2818 ,-4165660 ,  345
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  27912,  37556,  34954,  19529,   4434 ,   2807 ,-4190620 ,  345
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  28382,  37468,  35309,  19523,   4449 ,   2822 ,-4134968 ,  345
  28225,  37467,  33648,  19527,   4458 ,   2809 ,-4188688 ,  345
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Fig.9 Hyperterminal Serial Output

In Figure 9, the Hyperterminal showing the result of the distance of four transceivers to the receiver, d1, d2, d3, and d4.The coordinate of receiver in x, y, z direction, and the time of transmission are also displayed in the Hypterminal.

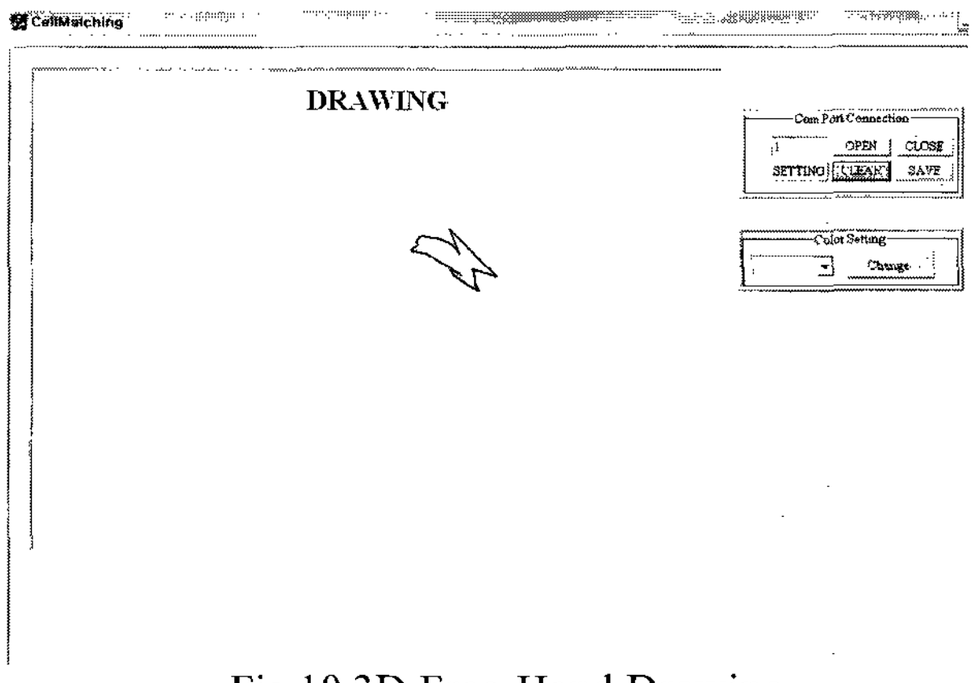

Fig.10 3D Free-Hand Drawing

Figure 10 is the experimental result which generated by using C++ MFC software. There is an "Open" button to enable the RS232 com port. By moving the ultrasonic receiver in any position in the air, for instant, drawing a "bird" in the air, you may see the picture in the software shown in Figure 10.

IV. LIMITATION OF UPS [3]

It can be expected that the above error effects become more frequent, if more objects and obstructions are present in the room. The more objects clutter a room, the less valid model of an empty room will become, which could degrade positioning accuracy. Tests are needed for the realistic case of a cluttered room. Likely, the method itself has to be improved to cope with these situations. Since the four UPS transmitter radiate ultrasonic signals accordingly, the receiver can only able to determine the position after finish receiving the signal. The transmission speed of the wave signal is playing important role in position determination. The best solution to solve this problem, sampling time of the system should be increased. In addition, more UPS receiver has to be used for faster reception. The errors also can be reduced. The prior position information makes it possible to estimate the position while UPS receiver is obtaining the distance value from four transmitters. The main disadvantage of using UPS in 3D-free-hand writing would be the noise. Due to the noise generated when the receiver is blocked by obstacles from receiving wave signal from the 4 transceiver, the estimated position might not be calculated correctly. The example noise generated drawing is shown in Figure 11.

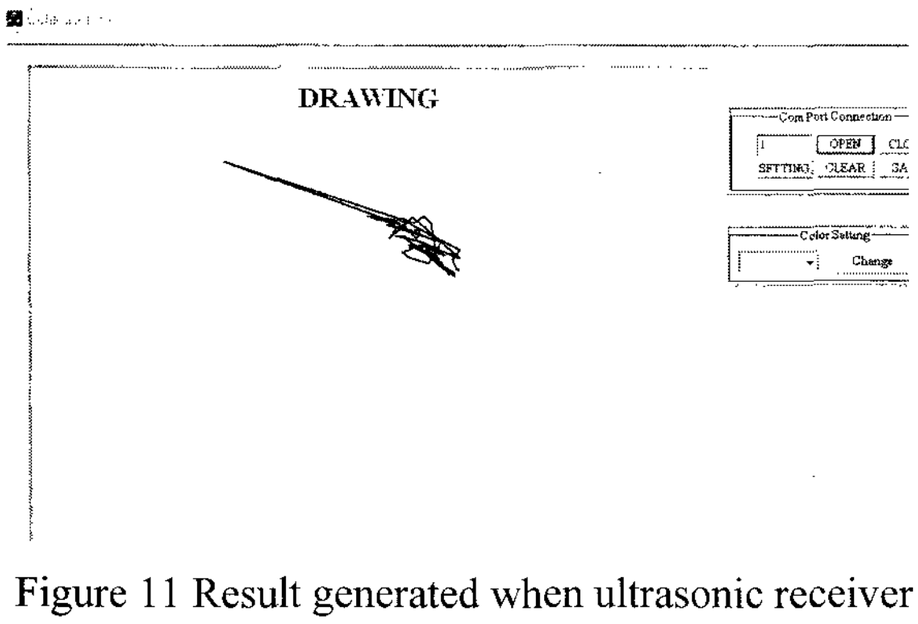

Figure 11 Result generated when ultrasonic receiver is blocked by an obstacle

IV. CONCLUSIONS

Based on the experimental work it can be concluded that measured ultrasonic signals contain more information than the transmitter-receiver line-of-sight distance. In existing ultrasonic location system, only the latter is used. In case of efficiency and effectiveness, the position information guarantees very stable performance. Although, there problem as mentioned above to solve such as influence of speed and environmental condition existed. We are still carrying out our research in the way to improve the accuracy of UPS. A first improvement is to implement a tracking system that integrates a set of position estimates over time for improved accuracy robustness. This paper aims to provide an idea of using UPS in any E-classroom system.

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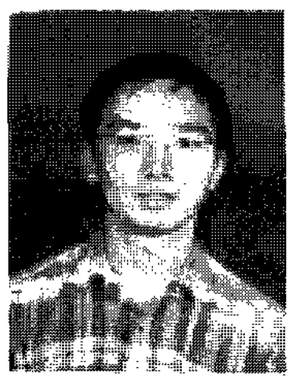

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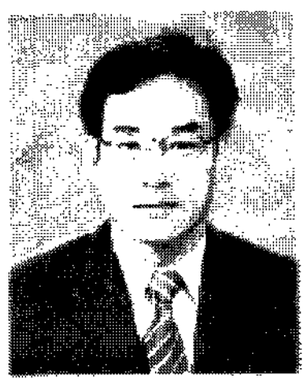

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