A Study on a 3D Free-Hand using Ultrasonic Position System

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ABSTRACT

Ultrasonic Positioning System (UPS) is an absolute positioning system using ultrasonic waves and has better performance in low price than the other absolute positioning systems. UPS can be further used as pseudo-satellites in the place where GPS is not available. This study aims to evaluate the efficiency and effectiveness of using UPS as a 3D free-hand writing or drawing tool. The process includes 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.

I .Introduction

As we known, GPS (Global Positioning System) is widely used as an absolute position system [1]. With four satellites and one GPS receiver attached to an object [2], the object absolute position can be further determined in three-dimensional coordinate. However, the GPS system doesn't operate well in the place where no GPS satellite signal reaches or visible satellites are less than four. In other words, there will be poor result measurement of the absolute position of the object in the place where GPS satellite signal is blocked. Due the problem above, pseudolites or pseudo-satellites for indoor places have been widely developed.

UPS (Ultrasonic Positioning System) is an absolute positioning system using ultrasonic sensors. It used direct ultrasonic waves method to measure the distance between the transmitters and receiver. In this method, four ultrasonic transmitters are attached on the ceiling in the fixed positions whose coordinates are known and the ultrasonic receiver is attached on a specific object. Ultrasonic receiver receives ultrasonic waves signal from four ultrasonic transmitters and calculates its position real time with respect to the (x,y,z) coordinates.

The objective of this paper is to evaluate the efficiency and effectiveness of using UPS as a 3D free-hand writing or drawing tool. Our final goal is to implement the UPS inside an existing E-classroom system, in which a lecturer could uses an electronic pen with an ultrasonic receiver attached to it, to write down the important notes or explanations direct in the air during every class. In other words, inside a specific classroom, four ultrasonic transmitters are attached on the four-corner of the classroom's ceiling on the fixed positions whose coordinates are known and one ultrasonic receiver is attached to an electronic pen. When the lecturer write a mathematic equation, F=ma, in a 3D free-hand style by using the electronic pen, the result of the movement of the electronic pen will be further determined and displayed on the computer screen of every student inside the class. In the existing E-classroom system, a lecturer has to write down the notes or explanations on an electronic board and the result will be further display on the computer screen of every student inside the class. We aim to provide a situation in where the lecturer can direct write in air

instead of writing on an electronic board.

II. The idea behind UPS

Generally, UPS consists of four ultrasonic satellites and one receiver. Ultrasonic transmitters function as ultrasonic satellites and locate on the fixed places whose coordinates are known. Ultrasonic receivers receive ultrasonic waves transferred from those 4 satellites and the measurement of distance between the receiver and satellites will de further determined. The idea of UPS is exactly same as GPS. Although ultrasonic receiver exists between four ultrasonic satellites, the position of ultrasonic receiver is calculated respectively. As shown in Fig. 1, the four satellites are placed on the four corners of the ceiling with specific 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 Fig. 2, satellite 1 (0, 0, 0) is connected to satellite 2 (9, 0, 0), satellite 2 is connected to satellite 3 (9, 6, 0), and satellite 3 is connect to satellite 4 (0, 6, 0). A radio broadcasting flag with Dc 9V Adapter supplied is first connected to the satellite 1 by using a cable. The measurement of the distance using the ultrasonic waves is calculate with sound velocity and

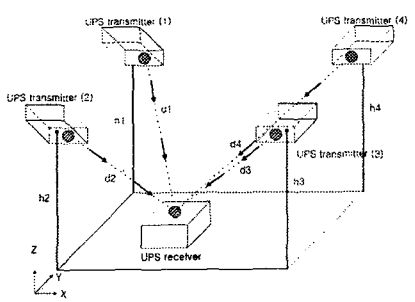

Fig.1 System Description

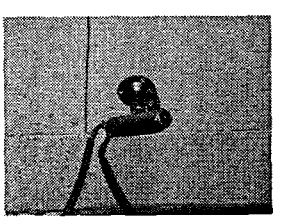

Fig. 2 Ultrasonic Satellite

the delivering time. TOF (Time of Flight) is defined as the time difference between transmitter and receiver as shown on Fig.3. The distance is determined in Eq.2 and sound velocity is represented as a function of temperature.

$$TOF = T2\ \ T1, \tag{1}$$

$$d = \upsilon(Temp) \times TOF\ , \tag{2}$$

where d is distance and $\upsilon(Temp)$ is sound velocity in the air temperature of Temp.

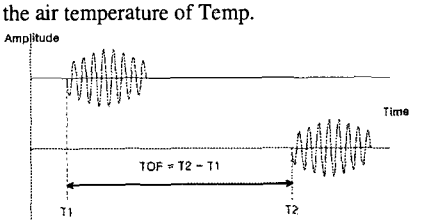

Fig. 3 Definition of TOF

The detection accuracy is about 2mm by the ultrasonic detection method and the distance between separated transmitter and receiver is calculated by direct ultrasonic waves. In order to calculate the distance using ultrasonic waves, the time when ultrasonic satellite radiates ultrasonic waves must be measured. The transmission time is known by using RF signal since UPS does not inform the transmission time. We assumed that there is no time delay during receiving RF signal and UPS calculates the distance by measuring the time when the ultrasonic waves is received. At specific period of 83ms, Ultrasonic satellite 1 transfers synchronized RF signals to other satellites and receiver. The other satellites 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.

As shown in Fig. 4, the distance d1, d2, d3 and d4 from the satellite 1 (x1, y1, y2), 2 (x2, y2, z2), 3 (x3, y3, z3), 4 (x4, y4, z4) to the receiver can be calculated by using the Eq3, Eq4, Eq5 and Eq6 after UPS receiver receives ultrasonic waves which are radiated ultrasonic satellites respectively.

$$d\ 1 = (x\text{-}x1)^2 + (y\text{-}y1)^2 + (z\text{-}z1)^2 \tag{3}$$

$$d\ 2 = (x\text{-}x2)^2 + (y\text{-}y2)^2 + (z\text{-}z2)^2 \tag{4}$$

$$d3 = (x-x3)^2+(y-y3)^2+(z-z3)^2 \quad (5)$$

$$d4 = (x-x4)^2+(y-y4)^2+(z-z4)^2 \quad (6)$$

The maximum range of the four satellites is 7 meter X 7 meter and the response of each ultrasonic transmitter is 0.4 second. Fig. 5 shows the timing diagram for ultrasonic receiver to be synchronized by RF signaland the distance h1, h2, h3, and h4 are known. The coordinate of the ultrasonic receiver can be obtained by Least Mean Square method. The sampling time of GPS is 1Hz while that of UPS is 3Hz shown in Fig. 5. Since UPS is more flexible and faster than GPS, it can frequently acquire the position information.

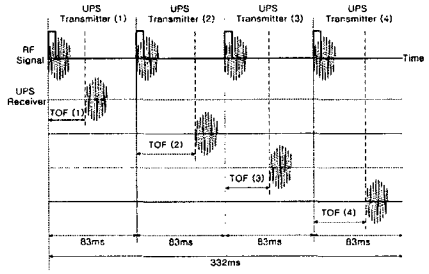

Fig. 4 Timing Diagram

III. UPS as a 3D free-hand writing or drawing tool.

In this experiment, UPS is used as 3D free-hand writing or drawing tool and the experimental results regarding the efficiency and effectiveness of using UPS as 3D free-hand writing or drawing tool is further displayed in the section below. The experimental result is received in serial communication and it is the relative position to the coordinate of the UPS transmitters. First and foremost, the four UPS satellites are connected to each other by using different cables and a radio broadcasting flag with 9V adapter connected is connected to the Ultrasonic satellite 1 as the way to provide RF same flag signal transmission between the other satellites. The ultrasonic receiver is connected to the local PC via a standard RS232 serial connection. A 9V alkaline battery is used to supply voltage to

the ultrasonic receiver. The ultrasonic receiver is placed inside the UPS network formed by the four ultrasonic satellites and the radio broadcasting flag, as shown in Fig. 5

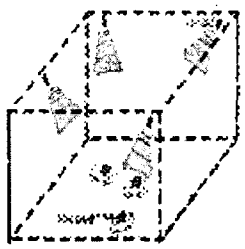

Fig. 5 Ultrasonic receiver is placed inside the UPS network

The four ultrasonic transmitters will radiate ultrasonic waves by turns and the ultrasonic receiver will determine the position after it finishes receiving the signals from all four transmitters respectively. A terminal emulator, Fig. 6, is used as the way to communicate with the UPS via RS232.

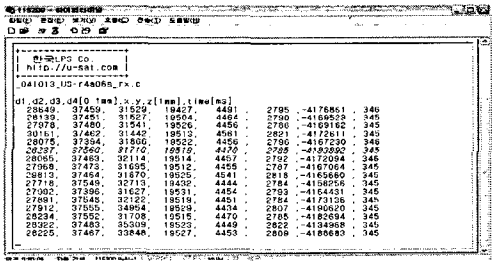

Fig. 6 Terminal emulator

In Fig. 6, distance from the four satellites to the receiver, d1, d2, d3, and d4 are displayed on the terminal emulator. The coordinate of receiver in x, y, z direction, and the time of transmission are also displayed in the emulator. The result of d1, d2, d3, and d4 are calculated in 0.1mm, the result of x, y, and z are calculated in 1mm, and the result of time is calculated in ms.

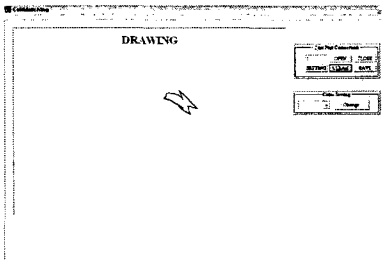

Fig. 7 A 3D free-hand drawing

Fig. 7 is the experimental result which generated by using C++ MFC software. When the button "Open"is

clicked, by moving the ultrasonic receiver in any position in the air, a picture like a bird, as shown in Fig. 7, can be drawn respectively. As mentioned earlier, the objective of this paper is to implement the UPS inside an existing E-classroom system, in which a lecturer could uses an electronic pen with an ultrasonic receiver attached to it, to write down the important notes or explanations direct in the air during every class. The movement of the ultrasonic receiver in any direction in the air can be detected and the result will be further displayed by the software.

IV. Limitation of UPS

Since the four UPS transmitters radiate ultrasonic waves by turns, the receiver can determine the position after UPS receiver finishes receiving the signals from all four transmitters. Therefore, the errors of UPS are influenced by the speed. It causes many problems at the high speed. As the way to solve this problem, the sampling time of the system should be change or more UPS transmitters have 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 basic limitation of using UPS as a 3D free-hand writing or drawing tool is the noise generated when the ultrasonic receiver is blocked from an obstacle from receiving the signals from all four transmitters. In other words, the receiver receives the signal from the transmitters in high-speed mood, when the receiver is blocked by an obstacle; the drawing generated will be as shown in Fig. 8.

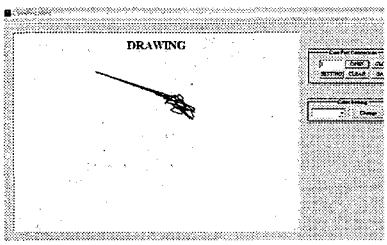

Fig. 8 Result generated when ultrasonic receiver is blocked by an obstacle

V. Conclusions

In this paper, the performance of using UPS as a 3D free-hand writing and drawing tool has been evaluated and the idea of using UPS in any existing E-classroom system can be further implemented. In case of efficiency and effectiveness, the position information guarantees very stable performance. In addition, it is more accurate and cheaper to use UPS to replace GPS in determining the coordinates in the place where GPS is not available. 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. This paper aims to provide an idea of using UPS in any E-classroom system.

V. Acknowledgement

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