e – Surveyor: Electronic Surveying Using Ultrasonic Rays

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ABSTRACT *Surveying has to do with the determination of the relative spatial location of points on or near the surface of surveyed area. It is the art of measuring horizontal and vertical distances, measuring angles between lines, of determining the direction of lines, and of establishing points by predetermined angular and linear measurements, along with the actual survey measurements. Survey data is portrayed graphically by the construction of maps, profiles and diagrams. This is about surveying process and it is same for regardless of coverage of large, medium or small area.*
'Electronic Surveying' is the automated surveying process for relatively flat and large size indoor area. Word 'Electronic' implies to the fully automated process of measuring distances, storing the data, preparing and displaying a map and calculating further parameters. In either way Electronic surveyor is a typical embedded system, consist of microcontroller, memory, display and input device(s). Each element has its own special function(s) and all together accomplishes the process of surveying. An efficient algorithm drives whole surveying process.

I. INTRODUCTION

In surveying, distance measurement is the key function, as all other functionalities are based on this parameter. Conventional surveying method uses physical distance measuring instruments like measure tap, chain [1]. It also requires time, human effort and expertise to get accurate results.

On contrary, Electronic surveying device is a typical embedded system which survey the indoor area of house, office or building using ultrasonic range finder (ranges up to 4 meters and uses invisible electromagnetic rays) as path finder and infrared sensor (ranges up to 10 to 12 cm) as obstacle detector. From band of electromagnetic rays, LASER (Light Amplification by Stimulated Emission and Radiation), ultrasonic and infrared band are capable for distance measurement purpose. Among these three types LASER have highest range of few kilometres, while ultrasonic can reach up to 5m and infrared up to 100cms. The vast difference of range is due to their operating frequency, power and directivity.

Fig. 1 LASER range finder and Ultrasonic sensor

In general, LASER is first choice for accurate and long range outdoor surveying applications. It can be used same for indoor surveying, but the following comparisons may change it to ultrasonic rays [2].

Surveying using LASER	Surveying using Ultrasonic
One point measurement, as LASER can cover large area in only one scan of 360^0	Measurement through extreme boundary, as ultrasonic can't reach beyond 5m

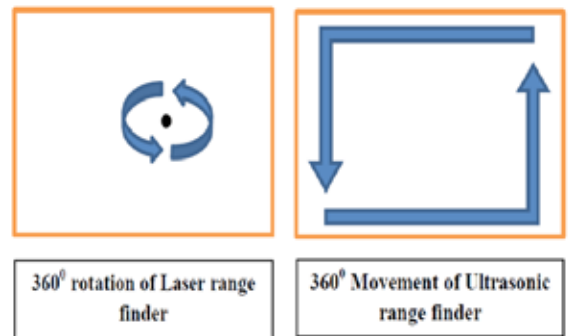| Operating frequency – 140-7500GHz	Operating frequency – 20kHz-200MHz
Accuracy of range of mm	Accuracy of range of cm
Very high speed operation – 200 samples/sec	Medium speed operation – 30 samples/sec
Requires perfectly pointed towards target	Not required, as it do not affect the calculation of distance
LASER transmission and reception hardware makes system bulky	Ultrasonic transmitter and receiver are very compact (40mmx20mmx15mm) and light in weight(15gms)
Consume more power for operation of LASER	Efficient power usage of few mW
Complex of generation of LASER and detection mechanism makes system very costly	Easy operation makes system very cheap
Unsafe operation – may damage human eyes	Safe operation

Table 1: comparison between Laser and Ultrasonic Techniques

360^0 rotation of Laser range finder

360^0 Movement of Ultrasonic range finder

Fig. 2 Different methods to survey the topology

Operation of both techniques is shown in above figure. In LASER range finder technique, surveyor is kept steady at

a centre of topology. As LASER has very long range, it can measure distance to all points of topology from a single 360⁰ rotation. So, it makes surveying very easy, fast and most accurate. While in case of ultrasonic range finder technique, a surveyor has to move around the topology as its range is limited to 4m.

From comparison table we can strongly conclude that Laser range finder is the best in all ways, but Ultrasonic range finder is the efficient, simple, accurate, safe and low cost solution. That's why ultrasonic range finder is very useful for indoor surveying purpose.

II. HOW TO USE ULTRASONIC RAYS FOR SURVEYING?

Practical range of ultrasonic rays is only up to 3m with accuracy of 1 cm.[2] This is the reason why ultrasonic rays can't be used for direct distance measurement. A technique "Measurement through extreme boundary" uses ultrasonic rays efficiently for indirect distance measurement. In this technique whole topology is divided into single straight sessions. An ultrasonic sensor is used to guide surveyor or autonomous device to continuously follow the extreme boundary of an area to survey. The surveyor has two wheels driven by stepper motors, whose rotations are used for calculating distance. Movement of surveyor is also controlled by stepper motors. So, actual distance is measured from stepper motors not from ultrasonic sensor. Ultrasonic sensor decides operation of stepper motors.

Major functional partitions of whole surveying process are,
* Survey the topology
* Store the data of survey
* Transform the data to create a map
* Display a map
* GUI for selection of points on map and further calculations

From these partitions, "Survey the topology" deal with ultrasonic sensor, stepper motors and an algorithm to operate them properly. Its outcome is data of survey like a sequence of distance and orientation of a session. While next three partitions deal with "digit to dot" operation, means conversion and transformation of 'digital' survey data to 'dots (pixels)' on display. Last partition provides control for selecting points on display for manipulating other parameters.

III. HOW TO SURVEY THE AREA?

Assuming flat and non-curved topology, surveying process is divided into number of sessions per each straight line in topology. A step wise process is described for following topology.
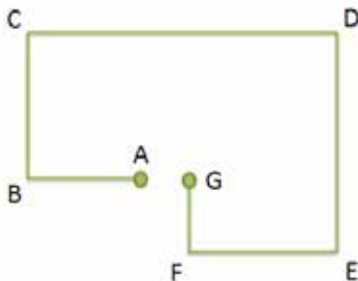

Fig. 3 Example of topology divided into several sessions

Starting from point A, Ultrasonic sensor continuously sends burst signals[2] toward wall and check distance of surveyor from wall. As 10-12 cm of clearance is required between wall and surveyor, microcontroller will always keep it on a track of 10-12 cm away from wall. IR sensor at the front of surveyor continuously checks for wall and obstacle on the track. Surveyor follows the wall until IR and ultrasonic sensor notify microcontroller for corner or obstacle or nothing in front of

surveying. As soon as surveyor finds a corner at point B, it will first estimate exact clearance from corner, for next session to align surveyor on a track for consecutive session. After setting position, microcontroller store number of rotations of stepper motor(s) into its memory along with a flag indicating left or right turn, which is decided by combination of IR and ultrasonic sensor [3][4]. These values are the actual survey data for a single session. After storing data, surveyor rotates according to the corner either right or left. Here the first session ends and all sessions from B to G complete the surveying process with same logic used in first session. In the last session at stopping point G, an external command is given to the top side IR sensor to notify microcontroller for stopping the surveying process and arranging the data in optimize format, as it is directly used for consecutive operations like to create and display a map.

After stopping the operation, microcontroller contains a log in its memory, which holds the survey data of the topology. Data log of survey is converted into proper format for displaying a map either on a Graphic LCD or a computer screen. [4][5]

Some assumptions made to limit indoor operation with simple and less complex surveying process are,

* Topology has only right angles both left side or right side, and has no curved shape. This assumption is made to decrease complexities of a curved topology. To overcome this limitation a smart and efficient algorithm is required.
* Topology has plane floor plan. It will not respond to any slope or step while representing on actual MAP.
* Each straight path in the topology is denoted by session and whole process is collection of all individual session.
* Minimum 4 inches (approximately 11-12 cm) of separation is required between surveyor and extreme boundary. Surveyor will always maintain this clearance throughout the surveying process, as it essential to make corners.
* After getting acknowledgement of turn, Surveyor will store the distance and other required information.
* External command will make surveyor to start and stop its operation.

IV. APPLICATIONS

Electronic surveyor prepares a digital 2D image of topology in a single survey. So it provides "single survey multiple measurement" facility. Following are some applications where use of e-surveyor may play good role with reducing effort, time and skilled man-power.

* Office or home wiring applications
  A suitable application for electrician is to estimate length of wire with less error. For an instance an electrician has to wire between twenty different points in a room. So, he need to measure different distances at least "20 TIMES". These procedures become very simple, easy, time efficient and accurate without help of other person and it takes only one measure. Electrician has option to determine best path for connection without actually measuring distance. Same procedure is also applicable for establishing a computer network in an office where large numbers of computers are interconnected to each other.
* **To prepare** 3D view **of topology**
  2-D map is the direct outcome of e-Surveyor. So, only height parameter is required to generate 3D view of topology. Though it is a computer aided application, it may very useful in applications like installing WLAN (wireless computer network) in office. Software product such as SitePlanner, allow engineers to rapidly determine the best placements for repeaters and required DAS (distributed antenna systems)network, while simultaneously computing the available traffic and associated cost of the installation.[6] e-Surveyor may use to generate 3-D view for such a software.

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