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# Automation of civil engineering surveying with distance measuring sensor and wireless technology

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## Abstract

**Objectives**: To automate the surveying practices, which are done manually and are not highly accurate, by the assemblage of the distance measuring sensor, wireless technology, and computerized data processing.
**Method**: With the help of distance measuring sensor, various observations are obtained from the field based on the required objectives (area measurement, fly leveling etc), the data is transmitted from the field to the computer with the help of wireless technology and the data obtained is processed with the computer software to get the desired results.
**Findings**: This method completely eliminates the use of the equipment which is in practice and it overcomes various drawbacks in conventional methods such as poor accuracy, the necessity of skilled labors, less automation, no compaction in equipment etc. With this proposed idea/technique, all the methodology for various surveying practices have been proposed and a sample of fly leveling (taking a small ramp) has been carried out with this technique.
**Applications**: The main applications in civil engineering surveying are Measurement of horizontal distance, Measurement of vertical elevation, Measurement of area, Fly leveling, Grid Contouring, and Radial Contouring. Apart from these applications, it also includes secondary applications, such as using the sensor and add-on equipment, it can also be applied to ensure the verticality of the building, checking the RL of the roads, De-alignment in Railway tracks, Getting the profile of the bridges.

***Keywords***: Civil engineering, Contouring, Fly leveling, Labview, Sensors, Surveying.

## 1. Introduction

Civil engineering projects like construction of residential and commercial buildings, laying of pipelines, Forming cricket grounds, Airport, Railways etc needs surveying and leveling.

It involves Distance measurement, Measurement of Area of the land (definite or irregular shapes), Measurement of vertical height, Perform Fly leveling, Grid contouring, Radial contouring.

For all these objectives of surveying, there is different equipment for different needs. For example, in order to find the area, it needs chain/tape, cross staff etc. For leveling and obtaining contour lines, Dumpy level along with leveling-staff is used. Moreover, it has other drawbacks such as it needs to perform calculations after observation, needs a large number of labors and less accuracy. This project proposal involves the introduction of a product which is used to perform all these activities by eliminating the drawbacks of conventional methods.

## 2. A review on conventional methods

### 2.1. Linear distance measurement

It is simply defined as the distance between any two surveying points. These two points can either be horizontal or vertical or inclined or curved. The instruments used for linear distance measurement is chain, tape, electromagnetic waves (advanced).

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**2.2. Area**

The valuation is based on unit price and the number of units. The unit mentioned here is the plan area of the land. Normally the plan area of the land is irregular in shape. It is calculated by dividing it into triangles with the help of Cross staff, chain, tapes, and compass.

**2.3. Fly leveling**

Any number of change points is established as required during leveling. This method is known as fly leveling [1, 2].

It is adopted to find the difference in level between two points, when

(i) The two points are too far away
(ii) The difference in elevation between two points is large
(iii) There are no barriers in between the two points concerned.

**2.4. Contouring**

It is the process of determining the elevation of various points on the field, probably in the hilly areas or deep valleys, and intersecting the points which have the same elevation. This line, which joins the points of equal elevation is called as contour line [3, 2]. Contouring can be done either as grid contouring or radial contouring.

## 3. Introduction to the new product

Broadly, the product has three major parts,
A Mechanical setup
An Electronic kit, and
Application software

**3.1. Mechanical setup**

This acts as a platform for the electronic kit, where a distance measuring sensor is attached, in the ground for making observations.

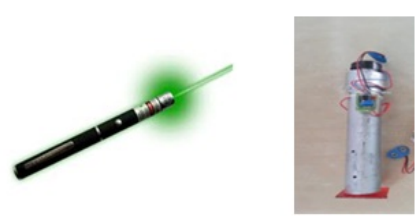
**3.1.1. *Post***

2 No of posts are used. The posts are designed in such a way that the height can be adjusted, like a telescopic post. The bottom part of the post has a '+' shaped base so that they can be adjusted for uneven grounds also. The main usage of the post is to tie the string between the posts so that the profile in between them will be obtained. The distance to be surveyed can be known by the markings in the string. This can also be used for ranging purposes. The material of the post is steel. A bolt and nut arrangement is provided in the base post so that the height can be fixed.

**3.1.2. *Laser and detector***

Since the level between two posts may differ, a laser light and a detector, as shown in figure 1 are used to ensure the perpendicularity and true horizontal. A laser light is emitted from one post and the height of the other post is adjusted to receive the laser. The laser detector produces a beep sound so that the surveyor can obtain perpendicularity and horizontality. The type of laser is called green laser which has more intensity in both day and night time. This is used particularly to differentiate from sunlight.

*Figure 1. Laser and detector*



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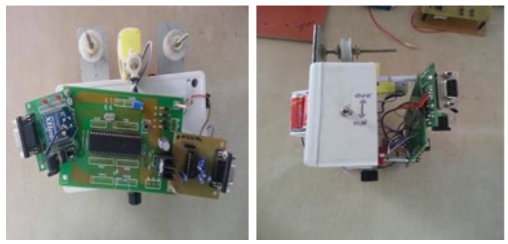
### 3.1.3. *Electronic kit*

Figure 2 shows the electronic kit. A string will be tied between the posts. A robot has been created. At the top of it, it has a wheel which is connected to a motor and there are two supporting wheels on either side of the motor. The motor rotates when the button in the remote is switched on. The motor rotates at the speed of 30 rpm. In order to do fly leveling, grid Contouring or radial contouring, the sensor is attached at the bottom of the electronic kit, so that it is pointed towards the earth. Whereas in the measurement of the plan area, it is attached to the side of the robot box. Transmitter kit [4, 5] is attached at one of the sides. A battery is also attached to control both the transmitter kit and the motor.

*Figure 2. Electronic kit with sensor, transmitter and motor*



#### 3.1.3.1. *Ultrasonic sensor*

The sensor used here is the ultrasonic EZ1 sensor [6]. Figure 3 shows the equipment of ultrasonic sensor. The sensor emits the ultrasonic waves. The velocity of the ultrasonic waves is quite common. It is similar to the velocity of light 3x $10^8$ m/s. when the ultrasonic wave is emitted and when it obstructs any objects; it measures the time it reaches the obstacle. By multiplying the velocity and time, it measures the distance and it can be transmitted to the computer by the electronic kit. By using this sensor values as input, the following requirements will be carried out.

*Figure 3. Ultrasonic sensor*

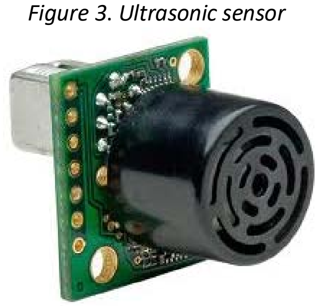


Figure 3 shows the ultrasonic sensor. The black part of it emits the ultrasonic waves and circuit behind it reads the values.

An ultrasonic sensor attached to the electronic kit gets the distance/elevation of the sensor from the ground. Thus it is the Reduced level (R.L) of the ground. This is the required observation, used for various requirements. This distance, in the form of electronic signal, is transmitted by the transmitter kit (from the ground/field) wirelessly and it is received by the receiver kit (office) and then to the computer. Application software is used to obtain the desired results.

### 3.1.4. *Computer software*

The software used here is programmed using the LABVIEW software technology [7]. This project particularly involves the combination of hardware and software. When such things arise, it is needed to go for embedded systems. i.e., the signal from the hardware is to be input to the computer and perform various calculations. 'LABVIEW' software technology is well suited for this requirement. The algorithms for the requirements of surveying are described below under their corresponding methodology.

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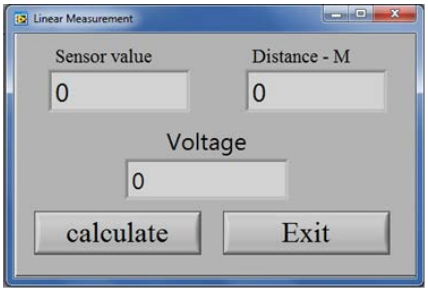
## 4. Methodology

### 4.1. Horizontal distance

In order to measure the distance between two surveying points, say A and B, keep the sensor at point A and focused towards B and by keeping obstructions on B, the distance between A and B can be obtained. The linear distance is the direct value of the sensor, as shown in figure 4. The 'sensor value' text box gives the desired result.

*Figure 4. Result of horizontal distance*

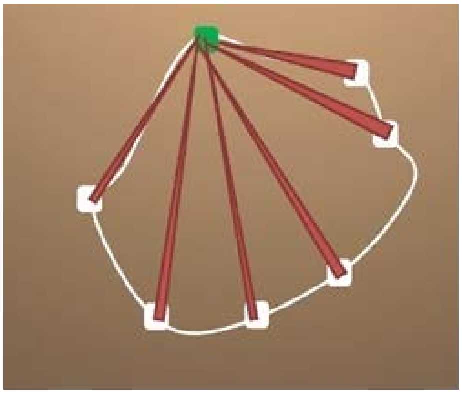



### 4.2. Area measurement

For a regular shape like square, rectangular or a polygon, distances of the edges can be calculated using the sensor and by entering angle manually in the computer, the software displays the desired result.

For non-regular shapes, as shown in figure 5, the white boxes in the figure indicate the critical points chosen. These critical points can be taken by finding any deviation in the land. The green box indicates the sensor. The sensor then is focused on the extreme points, so that the distance between the sensor and the extreme point will be obtained on the computer. Similarly, it should be focused on all the points established. The angle in between them should also be noted, by placing a protractor below the sensor. The area will be obtained in the software.

*Figure 5. Methodology of area measurement*



### 4.3. Vertical height

In case the top edge of the building or any other structure is accessible, the height can be obtained directly using the sensor.

In case, if it is not available, the sensor is placed at a certain distance as shown in Figure 6, and the horizontal distance will be obtained. By entering the vertical angles, the vertical height of the building will be obtained in the software as shown in Figure 7.

*Figure 6. Methodology of vertical height*

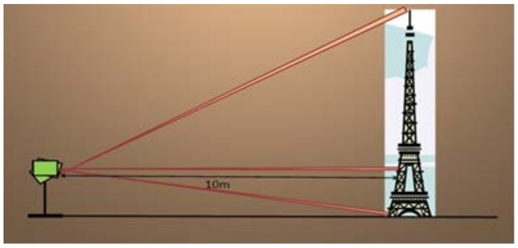
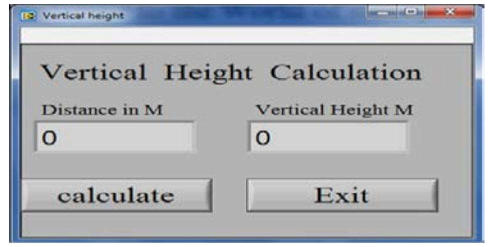



*Figure 7. Result of vertical height*




### 4.4. Fly leveling

The objective of fly leveling is to obtain the ground in the form of a line of the profile. In order to achieve this, the methodology as shown in figure 8 is to be adopted. The posts are placed and the string is connected between the posts. By the length of this rope, the distance between the posts is known. The electronic kit is then suspended on the rope. The sensor is attached to the robot and faced towards the ground. When the sensor is switched on, it determines the elevation of the sensor with respect to the ground. The electronic kit is moved along the string using the remote control so that the elevation of the sensor changes with respect to the ground. The value of the elevation is noted continuously and it is transferred automatically [4, 5] to the computer by the transmitter and it is received by receiver kit and then to the computer by a RS232 cable. Now the software attains the elevation and the graph is plotted as it moves. Thus gives the profile of the ground.

Once when the sensor moves to the other end, the profile will be obtained in the computer as shown in Figure 9, without any calculations. This result can be saved and can be retrieved for later use. These values can also be transferred to the MS Excel sheet and the details of 'cutting and filling' will be obtained.

*Figure 8. Methodology of Fly leveling*

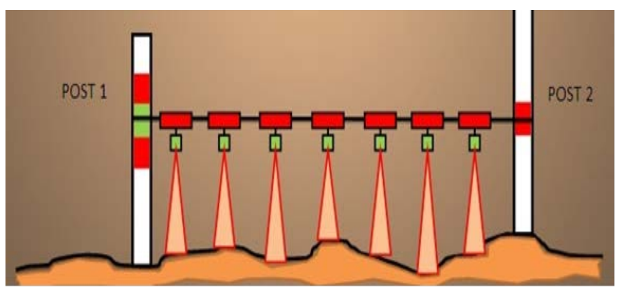
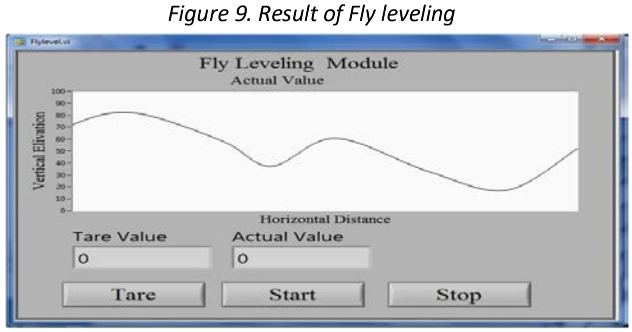



*Figure 9. Result of Fly leveling*




### 4.5. Grid contouring

As shown in Figure 10, initially, the surface is divided into grids. The procedure similar to the fly leveling is carried out in the lines of the grid in both the axes of the ground. So that the elevation of the sensor with respect to the ground is obtained and plotted continuously. In the fly leveling module, the graph will be obtained automatically. Whereas in grid contouring module, since it is unnecessary, the software will delete the graph and only the values (elevation) will be stored. Thus for one grid line, the values of elevation will be specified along with the line. When this procedure is done for all the grid lines the graph showing the grid interval and their elevation are obtained and the contour lines are plotted automatically in the software.

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Now, these values of the elevation can be obtained as a data in a spreadsheet, thereby grid contouring is obtained as shown in Figure 11.

*Figure 10. Methodology of grid contouring*

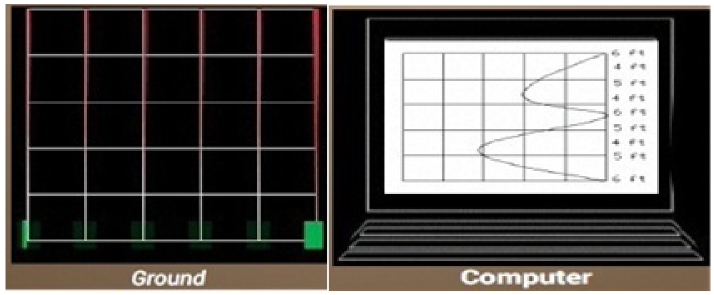
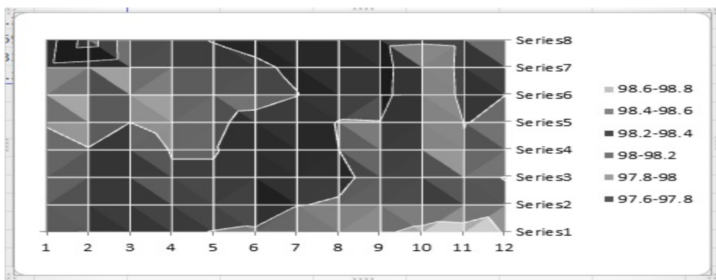



*Figure 11. Result of grid contouring*




### 4.6. Radial contouring

Here, the surface is divided into radial or polar lines. The procedure similar to the fly leveling is carried out in one line. So that the elevation of the sensor with respect to the ground is obtained and plotted continuously. When this procedure is done for all the polar lines the graph showing the polar interval and their elevation are obtained and the contour lines are plotted automatically in the software.

Figure 12 shows the plan view. The green box indicates the sensor and it is moved along the polar lines so that the values of the elevation will be obtained for every polar line.

Now, these values of the elevation can be obtained as a data in a spreadsheet, thereby grid contouring is obtained as shown in Figure 13.

*Figure 12. Methodology of radial contouring*

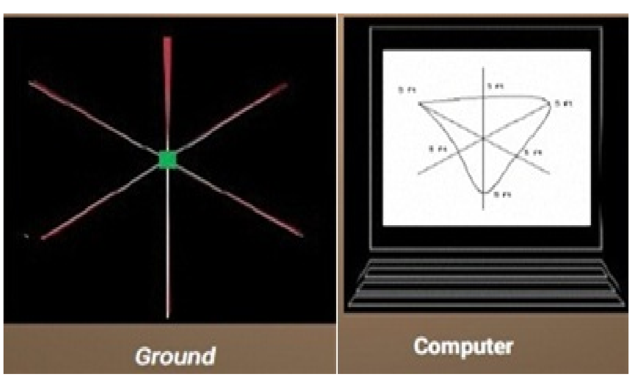
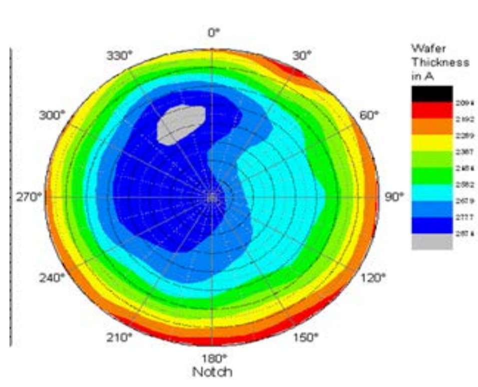



*Figure 13. Result of radial contouring*



## 5. Advantages

The following are the advantages of this idea/concept over the conventional method:

1. The conventional methods involve the observation of the readings in the field followed by the manual calculation in the office to get the desired results [8]. But in this proposed method, as soon as when the work is carried out in the field, the desired result will be obtained in the computer. Thus it is automated.
2. The equipment such as a theodolite, dumpy level, and total station is highly costly. Whereas this method uses only the electronic instruments, it is highly economical to carry out surveying practices.
3. The required number of labors is less when compared to conventional methods, hence it reduces labor cost.
4. In conventional methods, observation of the readings in the field and calculation thereafter requires more time. Since it is automated, it requires less time.
5. No supervision from the skilled labor is required as in the conventional methods.
6. Since it involves only smaller electronic components, the equipment is compact to use.
7. Since it doesn't involve any errors such as manual errors, temporary errors, errors in the calculation, natural errors etc., and it involves only the electronic instruments (sensor and computer) to carry out all the works, the accuracy will be quite high.

## 6. Conclusion

A distance measuring sensor, which is a small electronic instrument that simply gets the digital pulse of the distance between that sensor and an object which obstructs its signal, is used to carry out all the requirements of civil engineering surveying. The details of the equipment used and the methodology for every requirement are described in detail. Without any manual calculations, the desired results will be obtained in the computer system, as soon as the work is carried out on the field.

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