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Design and Implementation of a Land Surveying Robot

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***Abstract*---Land measurement is a general nomenclature which is used to explain, in the absolute manner, the knowledge and application of measurement of land. This conjointly includes land conversion that can be known as the procedure by which land or property is measured. It is the technique using which a piece of land or property is converted from one unit to a different one.**

The proposed design is to make the land survey by using a robot using the updated technology. Here, a robot is designed and programmed to conduct land survey, specifically to calculate the length traversed and area of a given land followed by subdividing the given plot it into subplots if required.The survey robot traverses along the given path and sends the values for the distance measured and area calculated. After optimizing the power given to the motors for proper simulation the speed of the robot was brought down to 0.5 meters per second which was desirable for effective control of the robot and subplotting. After the ASCII code for the plotting details was sent to the survey robot through the bluetooth application, the robot successfully decoded by the micro controller and the subplotting was accomplished. A 3% error has been observed while calculating the distance measured and 6% error while calculating the area measured.

***Keywords*---Embedded Systems, Microcontroller, Sensors, Robotics, Land Surveying**

I. INTRODUCTION

Surveying or land surveying is a technique of determining the terrestrial or three-dimensional positions of points and therefore the distances and angles between them. The points are typically on the surface of the land. They are often accustomed to establish maps and bounds for ownership, locations, like the designed positions of structural components for construction or the surface location of subsurface features or for property sales. A professional is termed a land surveyor. Surveying has been an integral part of the development of the human environment since the start of recorded history. The design and execution of most types of construction require it. It is also employed in transport, communications, mapping, and definition of legal boundaries for land ownership, and is a crucial tool for research in many other scientific disciplines.

In recent times, from manufacturing to finance, every industry is becoming more and more automated. Although it's not talked about as often, field surveying is additionally becoming increasingly automated with the employment of advanced robots.

The first surveying robots were developed more than two decades ago. They were bots mounted with total stations and other surveying gear that allowed them to find the dimensions of a region with greater precision than a human surveyor. While a number of today's robots have identical functionality, surveyors have more advanced models at their disposal. Many reputable surveying companies employ aerial drones to capture a holistic view of a locality. Additionally, getting a broad view of the land we're surveying, drones allow us to perform a 3D boundary analysis. The downside of drones is that they can't navigate interior structures, which could be a crucial requirement for some surveying projects. Nowadays, surveyors can mount a 360-degree camera to their hardhat that maps the region while tracking their steps using GPS. This blend of human interaction and robot automation is invaluable for any surveyor. The robotics company Boston Dynamics is building on a robot called SpotWalk that's more advanced than anything we've seen before. This machine is capable of moving around a plot with no assistance. While this may save a surveyor plenty of their time, it cuts out that crucial human element.

The following are the advantages of using a land survey robot:

1. Faster results: The faster a survey is completed, higher the efficiency. Because they're ready to perform tasks much quicker than an individual could, robots can speed up any surveying project. Faster results are better for surveyors as well as their clients.
2. Enhanced accuracy:Thankfully, we don't have to worry about using robots for our surveys. With robots,

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there's no chance of human error that leads to an inaccurate survey.

3. Consistent results: Unless the machine malfunctions, we are able to depend on our robots to deliver consistent results on every occasion we put them on the field. This consistency allows us to keep a tab on a project's development when we bring it to a construction site.

As many companies look ahead for simple and innovative ways to seek out safer, more sustainable solutions that make our jobs easier, robotic survey techniques could become an integral part in the long run.

II. METHODOLOGY

The robot built must be able to find the shortest path to navigate through the terrain for better efficiency and cost reduction. To achieve this, a heuristic algorithm is designed.

The traveling salesman problem is an NP-hard problem in computational optimization, important in theoretical computer science and operations research. The same problem is applicable to achieve shortest path calculation by the robot. The concept of heuristics is used to solve this problem.

A heuristic or heuristic technique, is an approach to problem solving which uses a practical technique that cannot guarantee to be optimal, successful, or rational, but is nevertheless enough for achieving an immediate, short-term goal. Heuristic methods can be used to speed up the process of finding a satisfactory solution where finding an optimal solution is impossible or impractical. Heuristics ease the cognitive load in taking a decision.

A. Hardware Components:

1. ATmega328P Microcontroller

The ATmega328P is a high performance, low power 8-bit microcontroller.. The device achieves throughputs approaching one MIPS per MHz by executing powerful instructions in a single clock cycle, balancing power consumption and processing speed. It supports capacitive touch buttons, sliders and wheels and upto 64 sense channels.

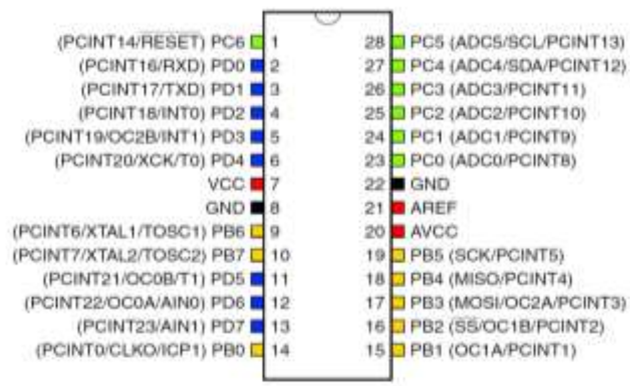

Figure: Pin Diagram of ATmega 328P

2. L293D Motor Driver

L293D is a motor driver IC that lets DC motor to rotate either in clockwise or anti-clockwise direction. L293D is a 16-pin integrated circuit that can handle a set of two DC motors in any direction, at the same time. The l293d can handle small and large big motors as well. For its own internal operation, VCC is the voltage that is supplied to it. It does not utilize this voltage for driving the motor. For driving the motors, it has a separate provision to provide motor supply VSS (V supply) voltage. It has a maximum current flow of 600mA per channel.

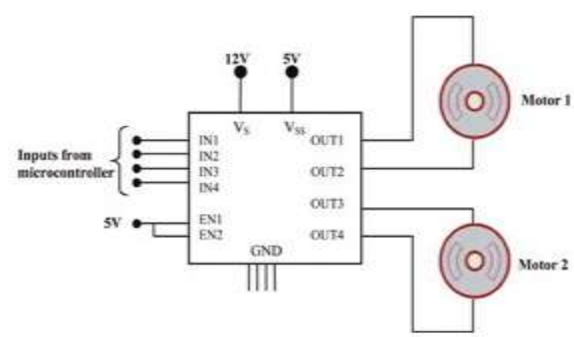

Figure: Connection diagram of L23D motor driver to DC motors.

3. HC-05 Bluetooth Module

Wireless communication is becoming increasingly preferred around the world compared to wired connection in the case of electronics and communication. The HC-05 board designed to replace wired connections with ease for short range communication uses serial communication to communicate with the electronics. Usually, this module is used to connect small devices like mobile phones or tablets or any android enabled hand-held devices using a short-range wireless connection to

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exchange files. It uses the 2.45GHz frequency band. The transfer rate of the data is quite high and can vary up to 1 Mbps and is in the range of 10 meters to 15 meters. This Bluetooth board can be operated within 4 V to 6 V of power supply. It supports multiple baud rates of 9600, 19200, 38400,57600, etc. The most important thing about this module is that it can be operated in Master-Slave mode which means it is secure from interference from external sources.

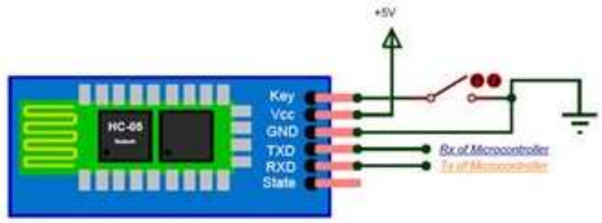

Figure: HC05 Bluetooth Module

4. DC Motors

Direct current motors, geared or ungeared, find useful applications in various types of control systems . DC motor torque and speed control is all related to the change of the drive speed to a value desired by the user or required by the system to perform a work process . DC motors are made up of two main parts namely a stator, which is the stationary part as the name suggests and the rotor, the rotating part located inside the stator, also called the armature.

The rotational speed and torque accomplished by a DC motor depends on the working together of the two magnetic fields set up by the stator's stationary permanently fixed magnets and the armature's freely rotating electromagnets. By controlling this particular interaction, we can control the speed of rotation of the motor. The speed of a motor can be controlled in many ways. One of the simple way is the use of pulse width modulation(PWM technique), which is achieved by driving the DC motor with fast changing of "on" and "off" pulses and varying the frequency of the pulses while the frequency is kept at a fixed value.

Figure: DC Motor

B. Software Interface

Initially when the user opens the user interface, he is provided with four options to choose from, namely:

Module 1: Movement of the robot.

The user has to enter one of the following options to move the robot in the desired direction.

1. To move forward, press 'F'
2. To rotate left, press 'L'
3. To rotate right, press 'R'
4. To end the moving operation, press 'S'
5. To cancel a move operation, press 'E'

Once the move operation is performed, the user will enter into the previous interface where he can again make choices amongst Module 1,2,3 or 4.

Module 2: Distance calculation.

We can enter the length measurement module by typing 'M' in the bluetooth application. Once the robot is preset into length measurement mode the user can freely move the robot in desired direction and path.

Once the robot is moved along the path whose distance is to be measured the user can press M again to end the length measurement mode. The robot calculates the distance travelled by multiplying the set speed of the robot by the time travelled forward.

After the session terminates, the length is transmitted to the android device via HC-05. The lengths are represented in terms of units and not meters where each unit is 0.5 meters.

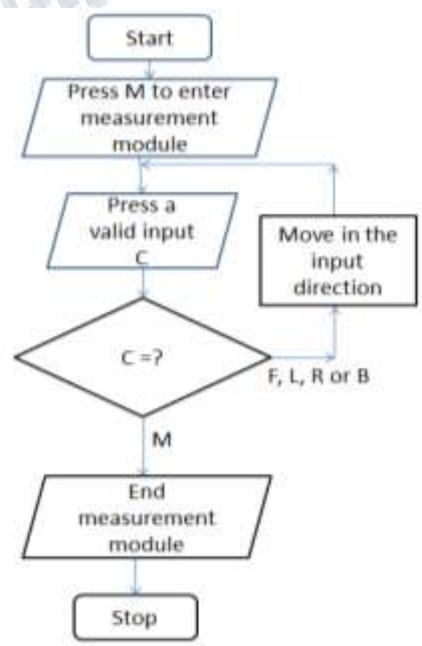

Figure: Flow Diagram of Module 2

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Module 3: Area calculation.

Once the user presses the A from the android device, the module for area calculation appears. Then the survey robot has to be placed at a vertex of the plot. The application asks for the details of the shape of the plot . The user has 3 options to choose from by mentioning the number of sides to be measured.

- When the user presses 1, the shape of the plot is taken as square and the robot goes into length measurement mode to measure any side of the plot.
- When the user presses 2, the shape of the plot is taken as a rectangle. For this plot the number of sides to be measured is 2 and the user needs to measure 2 of the sides using the robot.
- When the user presses 3, the shape is taken as a triangle. The 3 sides of the triangle are measured using the robot by moving it along all the sides of the triangle.

After the session terminates, the lengths are transmitted to the android device via HC-05. The lengths are represented in terms of units and not meters where each unit has been set as 0.5 meters. So, for a square plot of 1m x 1m, the output shown will be as follows.

1 unit = 0.5 meters

=> 1 meter = 2 units

So, 1m x 1m = 2 x 2 units = 4 sq. Units.

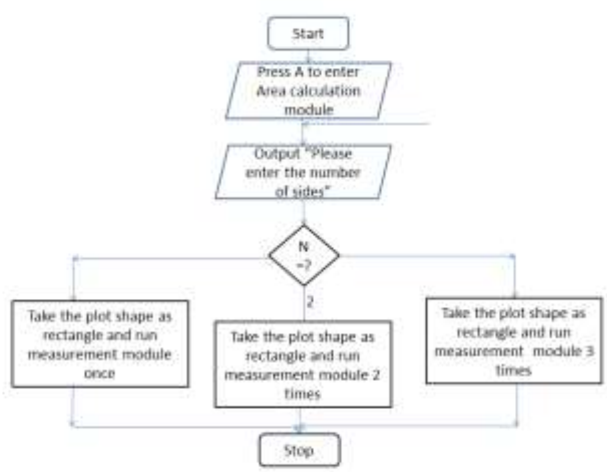

Figure: Flow Diagram of Module 3

Module 4: Subdivision of a plot

After going into the sub-plotting module by typing'P', the user has to give numerical input from the phone if he wishes to subdivide a plot.

A plot of land that a buyer purchases can be of any dimension. If a commercialized plot is obtained in terms of acres or hectares, the builder or civil engineer may propose the construction of apartments or villas. To achieve this, subdivision of the plot is required.

When in sub-plotting mode, the application asks for the coordinates of all the intersections of the subplots. The user inputs the coordinates of the points taking the present position of the robot as the origin in a 2D x-y plane.These coordinates are entered in the form of ASCII code leaving a space between each of the points. The distance between all of these points is calculated by the micro controller and then sorted in ascending order. Now the multi-fragment heuristic algorithm is used to calculate the shortest route across all these points.

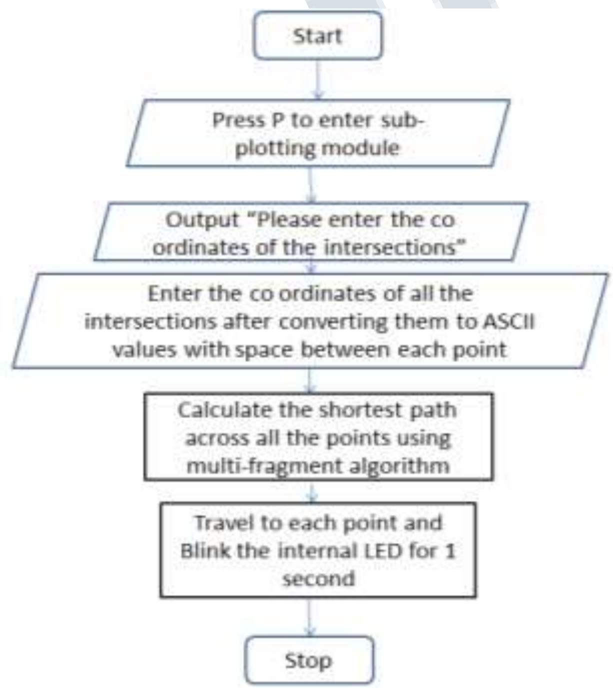

Figure: Flow Diagram of Module 4

C. Prototype

The material used for the chassis is plywood. A battery of 4 cells each of 1.5 volts each is used to power the whole robot. The microcontroller is mounted at the back of the robot with a properly fitting mechanism.The jumper wires are used to provide required connections between different modules of the robot. The RX and TX ports of the microcontroller have been used to communicate with the HC-05 bluetooth module. The USART port of the microcontroller is faced outward for easy program loading. The wheels are made of rubber and provide proper elevation from the ground to keep the connections and different modules from touching the ground.

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III. III. RESULTS

The robot successfully moved about the plot and finished subplotting the given area when the information about the plot was entered into the bluetooth application by the user.Emulation results were obtained such as speed of the robot versus voltage provided to the DC motors. Average error in measuring the length and area were calculated from the information collected from multiple plotting cycles. Graphs have been plotted for speed vs voltage given, Expected area and length values vs the values collected from the robot.

A. Bluetooth Application

Figure: Screenshot of the HC-05 Mobile Interface

The user needs to first encode the instruction into a single ASCII character. As shown, the input instruction is sent by typing the corresponding ASCII code into the available space at the bottom of the screen. Every input provided by the user is printed at the right side scroll-able space. The dark space at the top half of the screen shows all the information that is given to the user with the help of SerialPrint command.

1. Distance Measurement

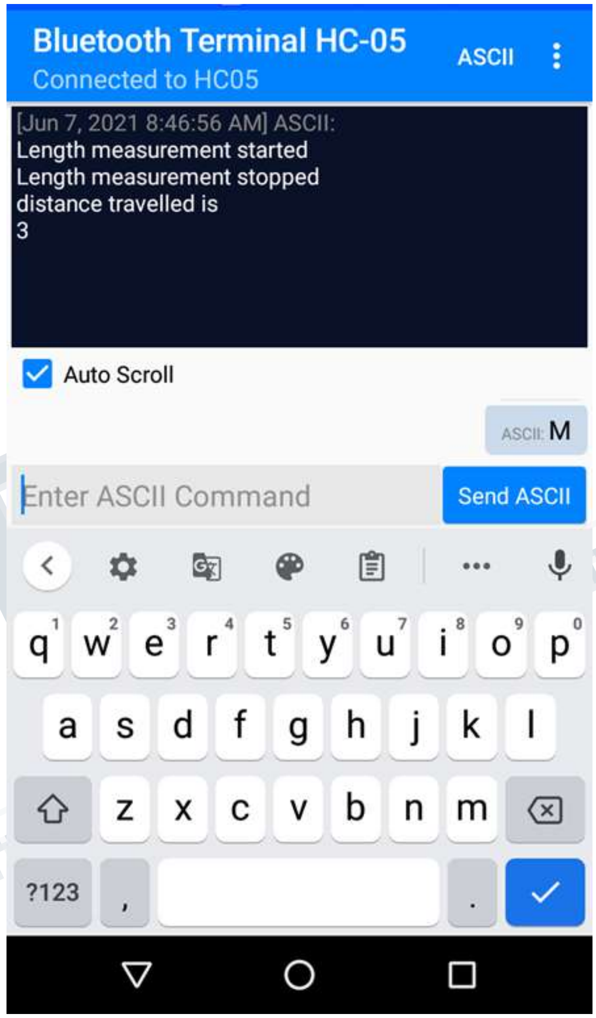

Figure: Screenshot of the Distance Measurement Results

The length measurement module is initiated by typing 'M' in the bluetooth application. Once the robot is preset into length measurement mode the user can freely move the robot in desired direction and path. Once the robot is moved along the path whose distance is to be measured the user can press M again to end the length measurement mode. The robot calculates the distance travelled by multiplying the set speed of the robot by the time travelled forward. After the session terminates, the length is transmitted to the android device via HC-05. The lengths are represented in terms of units and not meters where each unit is 0.5 meters.

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2. Area Calculation

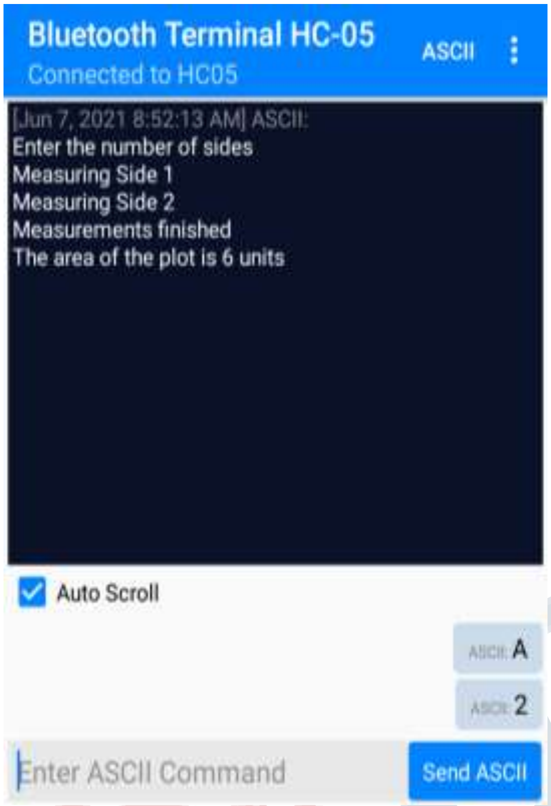

Figure: Screenshot of Area Calculation Results

Once the user types 'A' from the android device, the module for area calculation appears. Then the survey robot has to be placed at a vertex of the plot. The application asks for the details of the shape of the plot . The user has 3 options to choose from by mentioning the number of sides to be measured.

- When the user presses 1, the shape of the plot is taken as square and the robot goes into length measurement mode to measure any side of the plot.
- When the user presses 2, the shape of the plot is taken as a rectangle. For this plot the number of sides to be measured is 2 and the user needs to measure 2 of the sides using the robot.
- When the user presses 3, the shape is taken as a triangle. The 3 sides of the triangle are measured using the robot by moving it along all the sides of the triangle.

After the session terminates, the lengths are transmitted to the android device via HC-05 and the resulting area is displayed on the application.

3. Subdivision of Plots

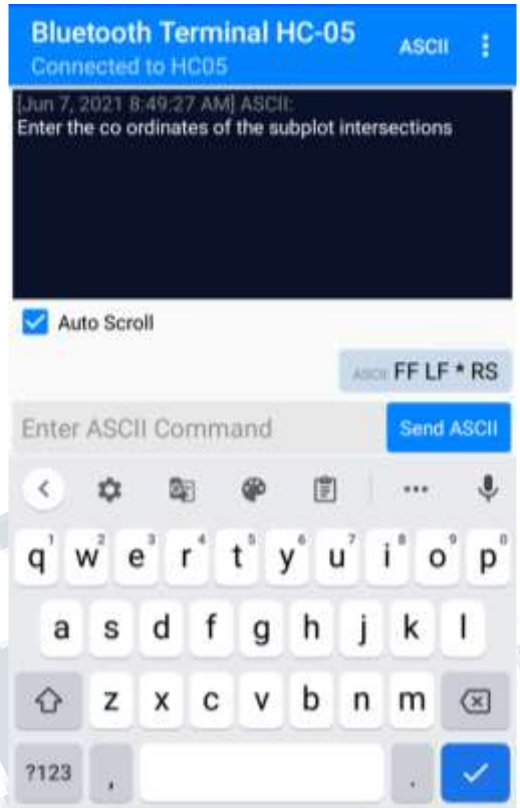

Figure: Screenshot of the Subdivision of Plot

After going into the sub-plotting module by typing'P', the user has to give numerical input from the phone if he wishes to subdivide a plot. These coordinates are entered in the form of ASCII code leaving a space between each of the points. The distance between all of these points is calculated by the micro controller and then sorted in ascending order. Now the multi-fragment heuristic algorithm is used to calculate the shortest route across all these points.

B. Performance Analysis

The initial speed of the robot was averaging at 1.2 meters per second, which is higher than the desired speed required to simulate the subplotting of a small rectangular area. The voltage input to the L23D driver was reduced by modulating the power from the microcontroller reducing the speed to 0.5 meters per second. The construction of the robot was done with plywood chassis and rubber wheels resulting in slight error in distance measurement and area measurement.

The average of the distances travelled versus distance expected to travel is taken and the error is calculated to average at 3%. Due to there being inconsistencies in turning the robot using the wheels which were on different axles, there was error in the area measurement of different shapes of plots. The average of the errors in the areas calculated came out to be 6%. The sub-plotting is slightly inaccurate because of the misalignment of the DC motors. The robot is slightly wobbly and unbalanced due to the construction being sub-optimal and not constructed with high quality metal/plastic.

1. Speed v/s Voltage

The power of 6 volts was given from the battery, the robot moved at a very fast speed of 0.9 meters per second. This was not desired for emulation of subplotting. Therefore, the power given to the motor driver board from the microcontroller was modulated to acquire the graph between voltage given and speed of the robot. A speed of 0.5 meters per second was optimal for proper subplotting emulation, so the voltage given was reduced to 1.5 volts and then given as an input to the driver board. This reduced the speed of the robot to the desired 0.5 meters per second.

SL no	Voltage provided(V)	Speed measured(units/s)
1	1	0.6
2	1.5	1
3	3	1.5
4	4.5	2.0
5	6	2.4

Table: Robot Speed w.r.t Input Voltage

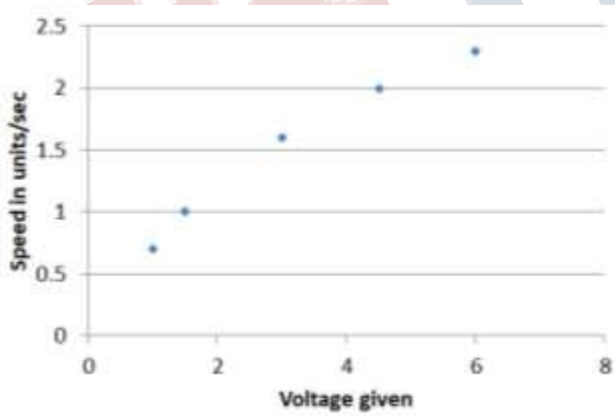

Figure: A Graph of Robot Speed v/s Input Voltage

2. Measured Length v/s Actual Length

Due to the design and build of the robot there was a slight error witnessed while measuring the length A graph between the length acquired from the bluetooth module versus the distance measured has been plotted to calculate the value of error. After plotting the graph the error has been calculated to be 3%. This error is observed to change slightly with the distance measured.

SL no	Actual Length(units)	Measured Length(units)	Error percentage
1	5	4.825	3.5
2	10	9.7	3
3	15	14.61	2.6
4	20	19.54	2.3

Table: Error Calculation in Length Measurement

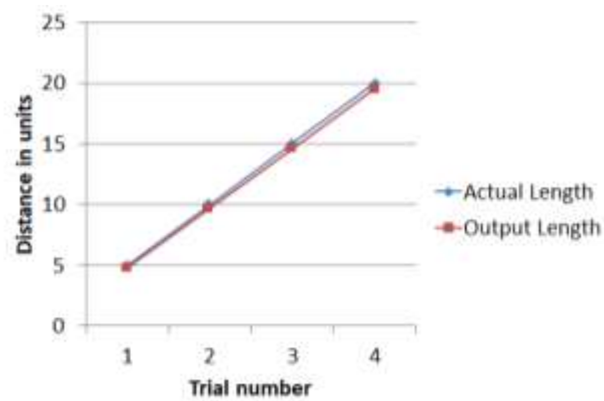

Figure: A Graph of Measured Length v/s Actual Length

3. Calculated Area v/s Actual Area

The area measurement module was affected by the error from length measurement.To find more information about this error, we plotted the graph between the area value acquired from the Bluetooth module and the actual area of the plot measured by taping the sides of the plot. After plotting the graph the error in the area measurement was different for triangle and square. The average of this error was calculated and found out to be 6%. This error changed with the size and shape of the plot and hence cannot be nullified by the use of the program.

SL no	Actual Area(units)	Measured Area(units)	Error percentage
1	1	0.9216	7.84
2	4	3.7536	6.16
3	9	8.4681	5.91
4	16	15.1476	5.33

Table: Error Calculation for Area Measurement

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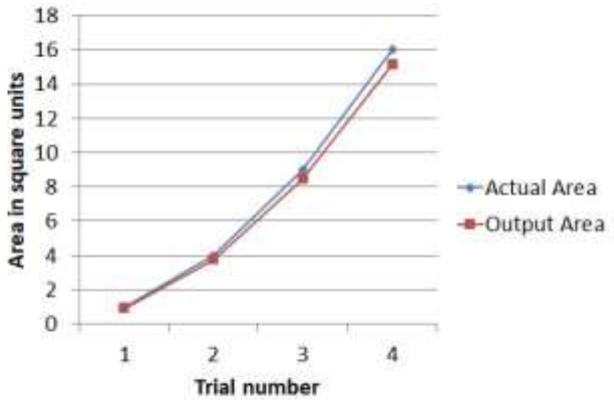

Figure: A Graph of Actual Area v/s Measured Area for Square Plot

IV. CONCLUSION

The value measured by the robot was displayed on the given LCD screen connected to the bluetooth enabled device. For controlling the robot an android application written in java was generated to control the movement of the robot directions such as forward, backward, left, right. The survey robot traversed along the given path and sent the values for the distance measured and area calculated. After optimizing the power given to the motors for proper simulation the speed of the robot was brought down to 0.5 meters per second which was desirable for effective control of the robot and subplotting. After the ASCII code for the plotting details was sent to the survey robot through the bluetooth application, the robot successfully decoded by the micro controller and the subplotting was accomplished by the survey robot by activating the buzzer whenever it reached an intersection between the vertical and horizontal plotting lines.

There was a 3% error while calculating the distance measured and 6% error while rotating the robot left or right. Thus, the designed robot specializes in finding the size of the area of a commercial space. This means that in the study, the robot may be for the benefit of those who took part in the major real estate developments in the major towns and cities. Since the dawn of time, to measure the normal size of the field or another, it has required a lot more work and human resource. This is mainly because there are a variety of tools that are involved in this process, such as measuring tape, rulers, etc. and the human resource required to use these tools, So at least two people have to work together in order to measure each and every part of the site. These measured values are then noted down by a third party. Then, the total area is calculated manually. Therefore, the modern, manage, or measurement methods are boring and dull.

On the other hand, the main advantages of survey robots is that manpower required and equipment used are less. The time taken for area measurement is relatively less compared to the traditional technique and it has better accuracy, making reprogramming easier. It is cost effective as well. Also, robots have now become a serious part of today's technological advancements. Hence we've designed and implemented a robot which will solve this disadvantage of present surveying techniques and reduce manual labor . The topic of land surveying using emerging technologies has a great scope for improvement.

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