GPS-Guided Autonomous Rover

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Abstract— This paper is an effort that has been put to serves the needs of land survey. Here, a robot is developed to conduct land survey, specifically to calculate the area of a given land and to divide it into subplots. The process involves two parts- Survey Robot and area measurement module. The Rover is controlled through the Arduino & Compass module to move about the entire plot. The destination coordinates are already given in the code. Once the current location is fixed, it calculates the distance and heading between the two points. The compass module tells the current heading of the rover. The final heading is calculated by taking the difference between actual heading and current heading. With the help of final heading angle, the rover moves towards its desired location. As the rover moves close to the destination the distance reduces. Once the distance is less the rover stops, assuming it has reached to the destination location.

Key words: Area Measurement, Land Survey, Survey Robot

I. Introduction

Land measurement is a general terminology which is used to describe, in best possible manner, the theory and application of measurement of land. This also includes land conversion that can be known as the procedure by which land or property is measured. It is the process which explains how the land or property is converted from one unit to another. To put it in more specific terms how much of land is one acre and so on. Land surveying forms an integral part of this conversion. GPS Guided Autonomous Rover, also referred as SURVOBOT is being designed keeping in mind the complexities that are involved in present techniques of area measurement and land survey. In conventional survey operations, a primary requirement of the survey party is to determine distance between two points. The surveyor has many devices that are used to determine distance. These range from the 30-meter steel tape to electronic instruments. Distance measurement is a basic operation that every surveyor must be able to perform with the tools available. Some of the surveying methods and equipments used to measure area of land are described below:

A. Horizontal Taping

Horizontal taping is used in conventional surveys. In this method, all measurements are made with the tape held horizontally. Measure the horizontal distance between the rear station and the forward station. Usually the distance between stations is more than a full tape length. The taping team determines the distance by measuring successive full tape lengths. When the distance remaining is less than a full tape length, the team measures the partial tape length. The total distance between the stations is determined by multiplying the number of full tape lengths by the length of the tape and adding the partial tape length.

B. EDM

Survey sections equipped with the EDM (Electronic Distance Measurement) can measure distances in minimum time. The EDM is a compact, lightweight, economical, and simple-to-operate instrument that is especially suitable for short- and medium-range survey operations. The EDM consists of the distance meter and the retro reflector prisms. These units mount on any universal tripod. The distance meter and the retro reflectors are packaged and transported in separate carrying cases--the distance meter case and the retro reflector cases.

II. Need for GPS Guided Autonomous Rover

The present surveying technique used is EDM. The disadvantage of EDM is that it has heavy equipments that are to be carried and combined together every time for the set up. This set up takes a considerable amount of time. Also, if the plot is in terms of hectares, then carrying the entire equipment will become an issue. After the measurement of the sides, the obtained sides have to be transmitted to total station wherein the further calculations are done. So, for the measurement of sides, at least two people have to move on the plot continuously that increases the labour time.

Here comes the need for GPS Guided Autonomous Rover. To avoid the tiring procedure of area calculation that involves separate side measurement, carrying of the equipment and sending the obtained side to total station, we incorporate Autonomous rover which combines all these features. In other words, it performs three most important tasks. Firstly, it can be freely moved about the plot when given a desired direction using GPS module. Secondly, it obtains the length of any desired plot as it moves and transmits the length. This transmitted length is stored in the PC and then an area measurement module is used to find the area. Thirdly, if the user wishes to subdivide his entire plot then we just need to program the rover appropriately and the subdivision of plot is done in a very less duration.

GPS Guided Autonomous Rover replaces the conventional techniques of area measurement and the complexities involved with it, by automating the entire process.

III. Design Instability

The performance of the rover is heavily susceptible to wind resistance and uneven surfaces. The small trackball in the front can get lodged in a crack in the surface of the track thus altering the direction of movement. More calculations need to be done in order to get the rover back on track as it is no longer moving along its desired path.

The Battery pack is large and heavy and puts a great deal of strain on the servos. The battery is located slightly forward on the chassis. Ideally one would like to have a 50:50 weight distribution but as a result of the vibration caused by the uneven surface, the weight is constantly shifted and the rover can topple backwards. A support bar protruding from the rear of the rover prevents the rover from toppling backwards if the weight is shifted drastically.

The wheels need to be perfectly aligned as a slight degree of inaccuracy can cause a large change in direction when travelling over large distances. This takes copious trials and error. Additionally the servos can be tweaked by altering their variable resistors; this can slow down a servo independently allowing the rover to tend towards a certain direction. This is used for correction of alignment and compensation of independent speed inaccuracy.

IV. DESIGN APPROACH

When comparing the constraints and requirements of the design the following two options for the drive mechanism of the rover are presented. One way is to use a single continuous rotation servo to produce the driving force acting on the rear axle of the rover and to use a 0-180° semi rotational servo to direct the front wheel which controls the direction. Another way is to use two continuous rotation servos to drive each wheel independently. This would allow us to turn on our axis by rotating the wheels in opposite directions. The latter option became the chosen one as the rover needs to make immediate turns when advancing passed coordinates.

The choice of the arduino used is dependent on a number of factors. The arduino must contain enough memory to house our entire code. The processing speed must be enough to calculate in real time before the rover crosses the next point. The micro must contain enough input/output pins so that the GPS and servo motors can be connected.

A. *Components Required*

1) Arduino Mega 2560 R3 (ATMega 2560)
2) HMC5883L Module Electronic Compass
3) Sparkfun Monster Moto Shield
4) NEO-6M GPS Module
5) 4 Wheel Robot Chassis and DC motors
6) 12V Battery for power supply to motors.
7) 9V Battery to power Arduino Mega

1) Arduino mega microcontroller:

In this project Arduino Mega microcontroller is used, the main purpose of the Arduino is to connect different electronic devices that can communicate with each other and perform various operations as per user requirement. The Arduino platform has a build-in integrated development environment called IDE. We have selected this board because it supports C and C++ programming language which are the basis of all other programming languages. The board comes with an onboard microcontroller and also various input ports to connect different components to it. The Arduino Mega 2560 R3 board has a USB port that is used to connect it with computers . It has onboard LED that becomes ON when connected to a power source. This board can be powered up using an AC to DC adapter or a battery. This board comes with 54 digital input/output pins of which 15 are used as PWM outputs, 16 analog pins, 4 USARTs hardware serial ports, a power jack, a USB connection, a 16 MHz Crystal oscillator, ICSP header and a reset button.

2) Compass:

We have use HMC5883L electronic compass, to guide the rover in the desired direction. It is important to first know which direction the robot is currently moving. To know its current heading compass is one of the options. The HMC5883L includes high resolution HMC118X series magneto-resistive sensors, automatic degaussing strap driver, offset calculation cancellation that enables the accuracy of heading in the range of 1 o to 2o which is very good for this project [10]. It has 3-axis magneto resistive sensors to calculate the current heading of the robot. There is no onboard regulator, so a regulated voltage of 2.16 - 3.3VDC is applied from Arduino board. The I2C serial bus is essential for easy communication and very simple to interface with Arduino. The two logic connections SDA and SCL are used for the communication and to read the data from the compass module. The output from the compass shows the position of the robot in 3 dimensional i.e. in X-axis, Y-axis and Z-axis. Comparing the entire dimension the current heading of the robot is calculated.

3) Motor Shield:

In order for the rover to move from place to place motors are required and These motors cannot be directly connected to the Arduino board since they require a large amount of voltage and also draw a high amount of current which can damage the Arduino board and other components connected with Arduino. With the help of the header pins motor shield can be directly placed on the Arduino Mega.

By using this motor shield, motors can be connected to Arduino board. Motor shield can also be used to drive multiple motors in both the direction. Monster Moto Shield has overvoltage and under voltage protection which can shut down the motors if any problem occurs.

4) NEO-6M GPS Module:

The Global Positioning System (GPS) is a satellite-based navigation system made up of at least 24 satellites. GPS works in any weather conditions, anywhere in the world, 24 hours a day, with no subscription fees or setup charges. To calculate your 2-D position (latitude and longitude) and track movement, a GPS receiver must be locked on to the signal of at least 3 satellites. With 4 or more satellites in view, the receiver can determine your 3-D position (latitude, longitude and altitude). Generally, a GPS receiver will track 8 or more satellites, but that depends on the time of day and where you are on the earth. We need to install required libraries for GPS to work in Arduino IDE.

1) Software Serial library
2) Tiny GPS library.

V. INTERFACING MOTOR SHIELD WITH ARDUINO, COMPASS AND GPS MODULE

For programming purpose, I used USB cable to power the Arduino. Further, Monster Moto shield is installed on the Arduino Mega. The motor outputs from both the sides of the robot are connected to the left and right screw terminals mounted on the shield. The shield is also connected to an external battery to power the motors as they require a high amount of current and voltage. After the above part is done the GPS module along with the antenna is mounted on the robot. The GPS module is powered with 3.3V from the

Arduino board and Tx Rx pin is connected to 46 and 48 pins on Arduino board respectively. Lastly, the compass module is placed on top of the robot. The compass is also powered from Arduino board and the communication pins SDA and SCL are connected to Arduino board to read the output from the compass.

A. Interfacing Arduino Mega and GPS Module

In this part, the GPS module is first interfaced with Arduino. It is essential to know the connection pins used for the serial communication. Tiny GPS Library is used to test the module and check whether the coordinates are being transmitted to the Arduino board. The sample program is written in Arduino IDE software using TinyGPS library

The pin connections to connect GPS module with Arduino Mega are given below.

1) The GND pin of GPS module is connected to any GND pin in Arduino board.
2) The GPS module needs 3.3V which is connected to 3.3V pin on Arduino.
3) The TX pin of GPD module is connected to pin 48 on Arduino board.
4) The Arduino board is connected to a computer using USB cable.

B. Implementing Distance formula

For a robot to how much to travel it is necessary to calculate the Distance between the current position and the target. For this project, haversin distance formula is being implemented. The significance of this formula is it calculates spherical distance on earth using trigonometric functions. On a spherical surface, the shortest path between two points is along an arc of a great circle. It is a circle drawn on earth with the same radius as that of the earth. Any 19 two points that lie on a unique great circle divide the arc into two arcs. The shortest path between the points is along the shortest arc among the two arcs.

The haversin function is defined as below.

$haver(\theta) = sin2(\theta/2)$

The haversin distance formula is given as follows.

$haversin\ (d2R) = havers(\emptyset 2 - \emptyset 1) + \cos(\emptyset 1)\ \cos(\emptyset 2)\ haversin(\lambda 2 - \lambda 1)$

Solving for d we get the distance formula

$d = 2R \sin{-1}\ (\sqrt{sin2\ (\emptyset 2 - \emptyset 12) + \cos(\emptyset 1) \cos(\emptyset 2)\ sin2\ (\lambda 2 - \lambda 12)}\ )$

Here, d is the distance between two co-ordinates,

R is the radius of earth i.e. 6371 km or 3961 miles

$\emptyset 1$, $\emptyset 2$ are latitudes of point 1 and latitude of point 2

$\lambda 1$, $\lambda 2$ are longitude of point 1 and longitude of point 2

VI. Improvements

The rover's improvements can be made in the form of additional sensors such as sonar or a gyroscope. The sonar sensor can measure the distance to an object in its path and hence trigger an object avoidance algorithm. An example of this algorithm is shown in Appendix D. The gyroscope can be used to measure the angle of rotation. This would be preferable as the current design requires the rover to move forward and retrieve new coordinates and hence calculate its angle.

The rover build quality was of high standard but the uneven surface can cause undesired results. The rover can be built with a wider base and thicker tires to absorb bumps in the track.

An antenna can be added to improve the GPS signal and therefore reduce the time taken to retrieve coordinates; this would noticeably speed up the rover's algorithm. To add theses improvements the connection diagram in Appendix E can be used for reference.

VII. Conclusion

A GPS guided autonomous rover was designed, constructed and tested. The system followed a strict set of constraints with regards to the structure of the Rover as well as the implementation. The employed system autonomously navigates its way through a path set out in GPS coordinates powered by a single 6.3V battery pack. The accuracy of the GPS module was questioned and the desired outcome was hindered. The algorithm that was initially drafted in Matlab did not function as well as expected when converted to 'c', but the overall construction and implementation produced the required result. This project is a prime example of an intelligent autonomous vehicle.