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Design and Development of GPS Guided Autonomous Ground Vehicle for Precision Farming

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Abstract: An autonomous robot is a self-piloted vehicle that does not require an operator to navigate and accomplish its tasks. My GPS controlled autonomous ground vehicle is presented which employs a GPS Receiver Module to capture the GPS signal and determine the current location of the vehicle. The system is controlled using an Arduino Due microcontroller which interfaces to a GPS receiver, a magnetic compass sensor and DC motors. The compass sensor determines the vehicle direction by continuously providing measurement of heading. The microcontroller drives the DC motors to move the vehicle to a manually entered destination coordinates. Obstacle detection and avoidance are achieved by incorporating an ultrasonic sensor to measure the distance between the vehicle and the obstacle and avoidance is implemented by the microcontroller. The designed GPS autonomous vehicle is able to navigate itself independently from one location to a second, user-prescribed location, using GPS-location data. The vehicle measures the bearing angle and changes its heading towards the destination and repeats the process as it moves to the destination. The performance of the vehicle is enhanced with a capability to detect and avoid unexpected obstructions placed in its path. To navigate a vehicle autonomously, the control system must have the ability to determine its present location and direction of travel. Location can be determined either from an outside source with technology such as the Global Positioning System (GPS), or by calculating a traveled path from a known starting point with the use of electronic compasses, inclinometers and rotational counters. While neither option is perfect, GPS offers the benefit of retrieving location information that has no bearing upon previous results. This prevents calculation errors from accumulating throughout the path. For this reason, low cost and ease of use, GPS was selected as the method of location retrieval for this autonomous vehicle project. However, limitations in satellite signal reception will limit the use of GPS systems for navigation. These limitations, May in part, be overcome by utilizing differential GPS but at additional expense. GPS data being utilized in this project includes latitude and longitude formatted as an ASCII text string "ddmm.mmmm" representing degrees, minutes and fractions of minutes as well as GPS quality indication, antenna height above or below mean sea level (meters), speed over ground (knots),and course over ground (degrees).Parsing these strings puts the relevant data into usable variables. Absolute position is accurate to within five meters.

Key words: GPS receiver · Vehicle guidance · Autonomous navigation · Obstacle avoidance · Parsing

INTRODUCTION

The GPS receiver is the main component of the navigation system of the autonomous ground vehicle. The GPS [1] receiver supports the NMEA 0183 protocol. The NMEA protocol standard defines a number of sentences to GPS device. The NMEA sentence gives the current location of the AGV. The destination location is given in terms of latitudes and longitudes. The navigation [2] of ground vehicle from one location to another requires three modules namely,

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- Global perception,
- Local perception and
- Vehicle control.

Global Perception: The global perception system identifies the vehicle position with respect to an available global map which is usually represented in terms of latitudes and longitudes. It also determines a path which the vehicle has to track. However, because of the dynamic environment in real driving, the global perception system alone is not enough to maneuver the vehicle to move to its destination. In order to identify the pose and orientation of the Autonomous [3] Ground Vehicle (AGV), an electromagnetic compass is deployed in addition, which gives the angle of deviation of the axis of Autonomous Ground Vehicle (AGV) from the primary N-S directions. Therefore, the intelligent vehicle also uses information from the local perception to avoid any static and dynamic obstacles that block the vehicle path. Finally, the vehicle control system integrates information from the global and local perception systems and then determines an appropriate action for the vehicle Global perception system involves vehicle localization. It allows the vehicle to know its position and direction with respect to the real world. It gives a series of position coordinates to the vehicle in order to reach its destination. Besides the military, advances in manufacturing and automation have also increased demand for unmanned vehicles in factories, warehouses and hazardous environments. One of the ways to provide automatic control to these vehicles is machine vision. However, vision-based tracking control can be slow and or expensive due to substantial demand for memory, data processing speed and vision interpretation.

In GPS based system, satellites will send the signals at regular intervals of time. These signals would be picked up by the GPS module. Using these signals the delay of signal could be calculated. This delay is proportional to the distance of the module from the satellite. GPS receiver compares the time when the signal was sent by the satellite with the time the signal was received. From this time difference the distance between receiver and satellite can be calculated. If data from other satellites are taken into account, the present position can be calculated by triangulation method. This means that at least three satellites are required to determine the position of the GPS receiver on the earth surface. By means of four or more satellites, an absolute position in a three dimensional space can be determined. More the reference points, smaller the triangle they will form and higher the accuracy. A 3D-position fix also gives the height above the earth surface as a result.

Local Perception: The local perception system consists of a digital magnetometer IC. The magnetometer measures the angle of deviation of the vehicle's axis with respect to geographic North Pole. It works on the basic principle that, when current flows through a wire, a magnetic field is created. The direction of Earth's magnetic fields affects the flow of electrons in the sensor and those changes in current can be measured and calculated to derive a compass heading. This information is used to align the autonomous ground vehicle towards the heading direction.

Vehicle Control: The vehicle control system consists of Arduino Due microcontroller and motor controller. The inputs to this system are from GPS module and magnetometer and the output is PWMto motor controller. The controller executes an algorithm that calculates the heading angle and distance between the current location and destination location using Haversine law.

The law of haversines:

$$d = 2r\arcsin\left(\sqrt{\sin^2\frac{(\emptyset_2-\emptyset_1)}{2}+\cos(\emptyset_2)\cos(\emptyset_1)\sin^2\frac{(\lambda_2-\lambda_1)}{2}}\right)$$

d = Distance between the two geographic locations.

r = Radius of the Earth (6,371 km).
$\emptyset_1$, $\emptyset_2$= Latitude of point 1 and point 2.
λ_1, λ_2 = Longitude of point 1 and point 2.

$$\Theta = \arctan\left(\frac{\sin(\lambda_2-\lambda_1)\cos(\emptyset_2)}{\sqrt{(\sin(\emptyset_2-\emptyset_1)\cos(\lambda_2-\lambda_1))^2+(\sin(\lambda_2)\cos(\emptyset_2))^2}+\sin(\emptyset_2-\emptyset_1)\cos(\lambda_2-\lambda_1)}\right)$$

Θ = heading angle.

The controller sends PWM signals to the DC motor in order to align towards the heading direction and to move towards the destination location. The magnetometer angle and the heading angle should be same for forward motion. If there is any difference between the heading angle and magnetometer angle then the vehicle turns to align itself towards the heading direction. The heading angle and distance are calculated continuously for each GPS reading.

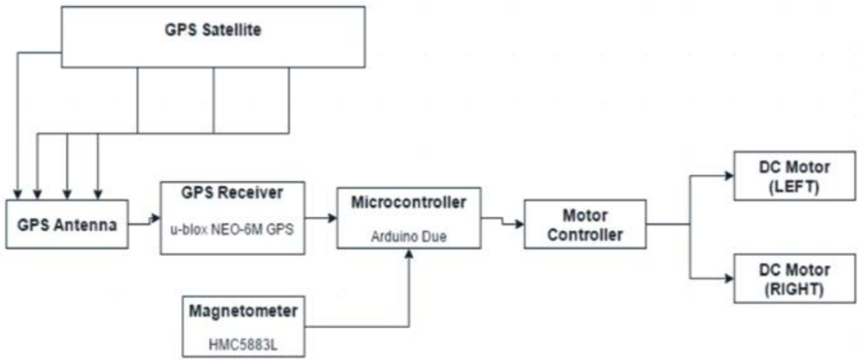

Fig. 1: Functional block diagram of AGV

Section 1

Working Principle of GPS: GPS is a worldwide navigation system from a constellation of 24 satellites and the associated ground stations. GPS calculates its position by using the triangulation method.

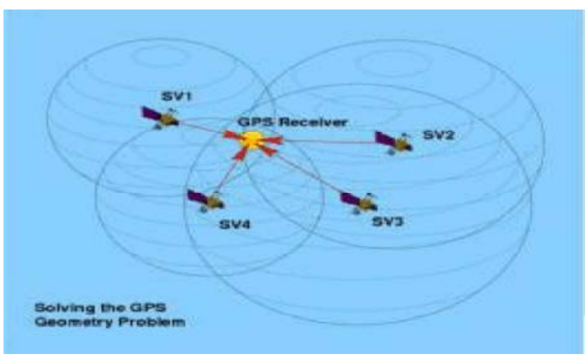

Fig. 2: Working principle of GPS

Each satellite is sending out signals with the following content: Satellite is X, Its position is Y and this information was sent at time Z. In addition to its own position, each satellite sends data about the position of other satellites. These orbit data are stored by the GPS receiver for later calculations. For the determination of its position on earth, the GPS receiver compares the time when the signal was sent by the satellite with the time the signal was received. From this time difference the distance between receiver and satellite can be calculated. If data from other satellites are taken into account, the present position can be calculated by triangulation method. This means that at least three satellites are required to determine the position of the GPS receiver on the earth surface. By means of four or more satellites, an absolute position in a three dimensional space can be determined. More the reference points, smaller the triangle they will form and higher the accuracy. A 3D-position fix also gives the height above the earth surface as a result.

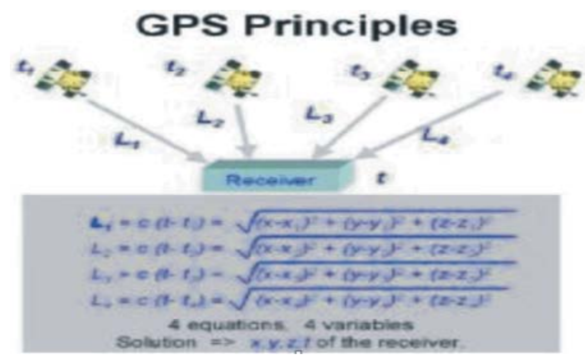

Fig. 3: GPS position calculation

GPS devices may also have additional capabilities such as: Containing maps, this may be displayed in human readable format via text or in an l format.

- Providing suggested directions to a human in charge of a vehicle or vessel via text or speech.
- Providing directions directly to an autonomous vehicle such as a robotic probe.
- Providing information on traffic conditions (either via historical or real time data) and suggesting alternative directions.
- Providing information on nearby amenities such as restaurants, fueling stations.

Applications:

- Precision Farming
- Automotive Navigator Tracking
- Automotive and Marine Navigation
- Geographic Surveying
- Personal Positioning
- Sporting and Recreation
- Embedded applications
- Mapping devices application
- Emergency Locator

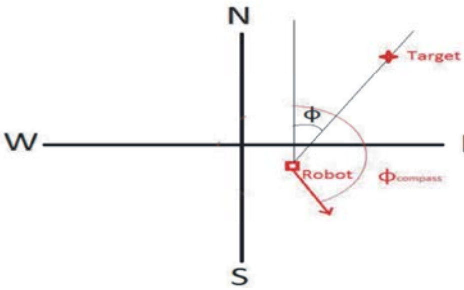

Fig. 4: Direction decision to face the Target

Section 2

Direction Decision: The first step toward getting to the target is to have the robot facing the direction of the target. It uses the "get GPS readings" program to obtain the value of the compass reading then compares the value to the calculated bearing angle. Next, the robot will rotated clockwise (CW) or counter clockwise (CCW) depending on the bearing angle until the compass reading matches the bearing angle which indicates that the robot is heading the right direction and it's ready to move forward. The equation to calculate the bearing angle is shown in Equation 1.

$$\theta = arctan2(\sin(\Delta longitude)\cos\ latitude_2\ , \cos\ latitude_1\ \sin\ latitude_2 - \sin\ latitude_1\ \cos(latitude_2)\cos(\Delta longitude))$$

Equ. 1: Formula to Calculate Angle Relative to Northfrom Robot to Target

In Figure 4, the robot is represented in the red square and the target is represented in the red star. □compass is the direction of the robot relative to north (which is also the compass reading) and □ is the angle relative to north of the robot and the target. As shown in Figure 4, when the □compass is equal to □, the robot is heading the direction of the target. The Direction Decisions program allows the robot to decide which direction to turn (CW/CCW) to face the target.

Section 3

Position Decisions: Next, the robot will move forward for a short distance. While doing so, it will compute the distance between its current location and the target. Given the robot current coordinates (from the GPS readings) and the target coordinates (preset target), the distance to the target is obtained by using Haversine Formula as shown in Equation 2 (R is Earth's radius).

$$a = sin^2\frac{\Delta latitude}{2} + \cos\ latitude_1\ \cos\ latitude_2\ sin^2\frac{\Delta longitude}{2}$$

$$c = 2arctan2(\sqrt{a}, \sqrt{1-a})$$

$$distance = Rc$$

Eq. 2: Haversine Formula

After moving forward for a short distance, if the distance calculated between the robot current location and the target is above certain value, the robot is not at

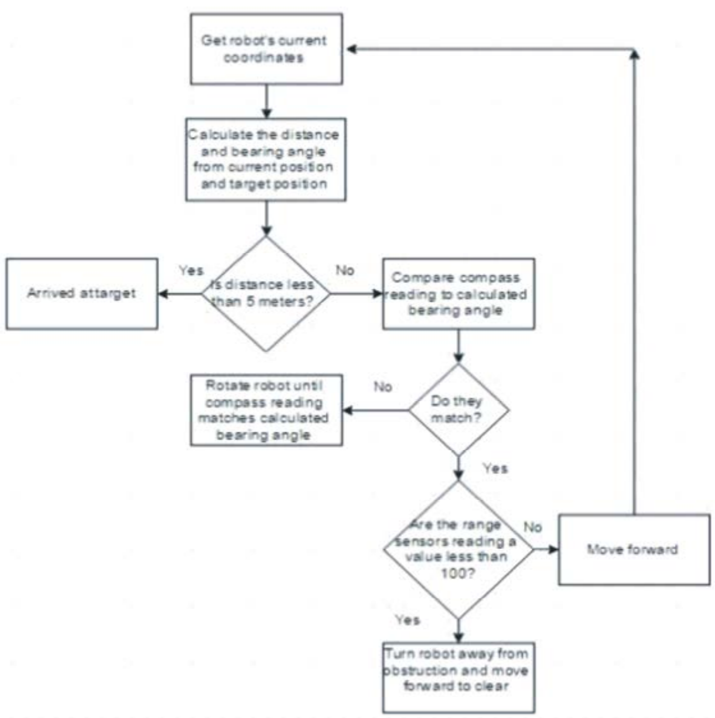

Fig. 5: Navigation program flowchart

the target and it has to call Direction Decisions program again to adjust its heading toward the target. The robot will keep cycling through the Direction and Position Decision programs until the distance between it and the target is less than 5 meters which indicates that the robot has arrived at the target.

Section 4

Auto Navigation: Figure 5 shows the working of Auto-Navigation program. The robot first obtains its' current coordinates from the GPS readings. Next, the robot computes its' distance away from the target. If the distance is less than 5 meters, the robot will determine that it has arrived at the target. On the other hand, if the distance is greater than 5 meters the robot will get the compass reading from the GPS then compare the compass reading with the calculated bearing angle. If the angles are matched, the robot will proceed to the next command to check for obstacles in front of it. If the angles are not matched, the robot will makes necessary adjustment by rotating clockwise or counter clockwise to face the target. Next the robot will check for the reading from the range Sensors. If either the left or right range sensor returns a value less than 100, which indicates that there is an obstacle in front of the robot within 1 meter, the robot will call the Avoid Object program to instruct the robot to get around the object and move forward for a short distance. If there are no obstacles in front of the robot, it will move forward for a short distance without turning around an object. Then the robot will return to the beginning of the Auto-Navigation program, update its' current coordinate and repeat the entire procedure until it arrived at the target.

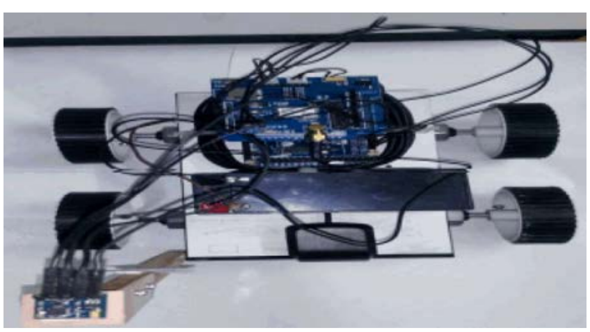

Figure 6 – Top view of designed AVG

CONCLUSION

The purpose of this chapter is to develop autonomous ground vehicle for precision farming, which can be used for transportation of food grains from the farm to storage area. The overall goal of this work is to navigate the vehicle autonomously to its destination. Equipped with various sensors, the vehicle has the capability of navigating in complex environments avoiding the obstacles in its way and reaching the target. The complexity of the system is reduced by making it modular i.e., more modules can easily be added to system by setting their priority level in the main controller.

REFERENCES

1. Francisco Javier Gomez-Gil, Jaime Gomez-Gil, Ruben Ruiz-Gonzalez and Sergio Alonso-Garcia, 2013. 'A Kalman Filter Implementation for Precision Improvement in Low-Cost GPS Positioning of Tractors', Multidisciplinary Digital Publishing Institute.
2. Kalaimagal, S. and Dr. C. Sivaramakrishnan, 2012. 'Navigation Of Autonomous Ground Vehicle Using GPS System', International Journal for Engineering Research and Technology (IJERT), 1(7).
3. Anupama, J., S. Harsha, M. Karthick and A. Kavitha, 2012. 'Design and Development of AutonomousGround Vehicle for Wildlife Monitoring', International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), 2(5).