Waypoint Navigation System Implementation via a Mobile Robot Using Global Positioning System (GPS) and Global System for Mobile Communications (GSM) Modems

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ABSTRACT:

This paper presents the use of Global Positioning Systems (GPS) as geographic information and navigational system for a ground based mobile robot. The proposed mobile robot contains a GPS system for navigation and sensors (LV-MaxSonar–EZ4) for obstacle avoidance system, and GSM Modem for communicating with user. The Mobile robot navigates to the waypoint specified by the user through the GSM Modem and avoids the obstacles in its way to destination. The experiments are carried out in the university lawn with a test bed mobile robot for point-to-point motion using a GPS.

KEYWORDS: *Navigation System; GPS; GSM; Mobile Robot, Waypoints*

I. INTRODUCTION

The navigation systems are concerned with the monitoring and controlling of the movements of a vehicle/craft in a physical space, and are very handy in situations where the human being can not operate or where it is hazard for the human beings to operate such as in mine detection and bomb disposal. Apart from the military usage, the artificial waypoint navigation systems are much effective in defining the artificial air ways. Based on its application scope, the navigation systems can be classified in different categories such as land, space, marine and aeronautic navigation systems [1]. The waypoints represent the sets of coordinates or the small regions that provide the salient information for the identification of a point in any physical space. The nature of co-ordinates is application dependent e.g. the longitude and latitude may be the possible co-ordinates set for a terrestrial navigation system. This set of co-ordinates provides the trajectory information to the robotic vehicle or craft to follow the correct route to destination.This work presents a low cost and efficient approach for chasing the co-ordinates given by the user to the Mobile Robot Vehicle using the GPS based navigation system. In order to make the system more accurate and visual the proposed work utilizes the Google Maps, which is a free web mapping service application and technology provide by Google. The main task of such mobile robots is to navigate from one co-ordinate to other co-ordinate avoiding the obstacles in its way and give feedback to the user.

II. RELATED WORK

The navigation systems are concerned with the monitoring and controlling the movements of a vehicle/craft in a physical space. For tracking the route, the navigation system utilizes the waypoints information such as presented by Millington et al. [2], in which they utilized the waypoint information for the navigation system in a vehicle. The co-ordinates information are used as route, and the waypoints information and the vehicle position are displayed on the screen with a feedback system for controlling the vehicle moments directions. The use of Global Positioning System (GPS) for the creation of waypoints i.e. set of co-ordinates in physical space for the navigation systems have been proved very effective. In Global Positioning System (GPS) based navigation systems, the trajectory of the vehicle or craft is determined through a series of waypoints and followed by navigating the next waypoints until the destination is reached such as presented in [3,4]. hoi et al. [3] provided autonomous mobile robot using GPS, the robot follows its trajectory with feedback through GPS receiver, and evade obstacles with the help of photo-sensors. Along with this, one can trace a Mobile robot with a wireless RF communication module. Hamid et al. [4] present another navigation system's implementation in a mobile robot in a different way using GPS for navigation and sonar sensors for obstacle avoidance. The beauty of this work is that they are using command loop daisy changing application method.
The similar work is presented in by sukkarieh et al. [5] for land vehicle applications. Their work combines the inertial measurement unit with global positioning system for the enhancement of integrity of the navigation

system by considering both the low frequency faults and high frequency faults in inertial measurement unit and PGS respectively during and before the fusion of inertial measurement unit and GPS. Bruch et al. [6] represent a land based navigation system for vehicles implemented on Man Portable Robotic System Urban Robot. This navigation system uses combination of Kalman filter, waypoint and some inexpensive sensors along with the GPS and implemented on an embedded processor.

III. ROBOTIC PRINCIPLE

To maximize the accuracy for the target position of the mobile robot, such an algorithm is needed that uses the basic principles of GPS receiver. Information about the position in the form of a string is loaded from the GPS receiver to the microcontroller through serial port. As the Garmin eTrex-H GPS is used in this work, the output string format is given in Figure 5. The mobile robot is sending that information through GSM modem to the system where it is received serially. The co-ordinates received are plotted in Google Map and on return sending targeted (desired) co-ordinates from the system through a GSM modem to the mobile robot, the GSM modem fixed in the mobile robot, gets the co-ordinates serially and compare that co-ordinates with the sent co-ordinates and travel to the position, by the way if there is an obstacle in the way it will be avoided through Sonar sensors.

IV. NAVIGATION

The transition of an artificial entity from one coordinate (position) to another is termed as navigation. The GPS based navigation system, originally developed for military purposes is formed from 24 satellites and is the most widely used navigation system all over the world. Nowadays, instead of the militarily usage, the GPS is used in health, communication and different other utilities related to motorcars, airplanes, ships, drones and could be apply to all other moving amenities. The figure 1 shows example of GPS based navigation system.

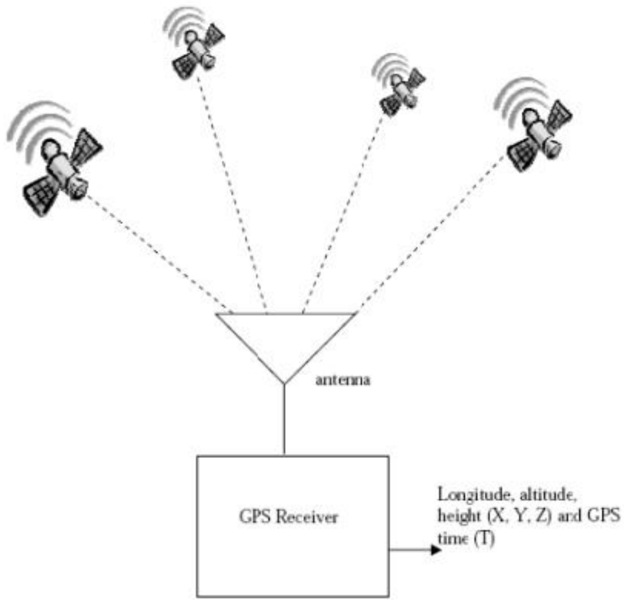

Fig.1. Determination of (x,y,z,t) from Four Coded Time Signal [7]

Many considerations have been made for the selection of GPS module for this particular application. After the study of all choices and considerations, the mobile robot designed for this application prefers the use of Garmin eTrex H for GPS receiver. The main reason is that the small size of the GPS receiver makes it light and this is 12 channel GPS receiver designed to operate with L1 frequency and the GPS receiver tracks and uses the signal to compute and update position. There are a number of output formats supported by this GPS receiver; however the proposed work uses the text output format. Text mode is a simple output mode that provides a string containing the information about time, position and velocity. An example is shown figure 2 given bellow.

@000607204655N6012249E01107556S015+00130E0021N001
8U0000
1st bit- show Start bit
2nd -12th bits show Time bits
13th -bit is Latitude Hemisphere ('N' or 'S')
14th -20th –bits shows Latitude position
21st –bit is Longitude Hemisphere ('E' or 'W')
22nd -29th –bits shows Longitude Position
30th –bit is Position Status
31st -33rd –bits shows Horizontal Position Error
34th –bit is Altitude Sign ('+' or '-')
35th – 39th –bits shows Altitude
40th –bit shows Velocity Direction ('E' or 'W')
41st -44th –bit shows Velocity magnitude(Meters per second in tenths)
45th –bit is Velocity Direction ('N' or 'S')
46th -49th –bit Velocity Magnitude(Meters per second in tenths)
50th –bit is Vertical Velocity Direction('up' or 'down')
51st -54th –bits shows Vertical velocity Magnitude(Meters per second in tenths)
55th -56th –bits shows Sentence End

Fig. 2. Text Output Formatof GARMIN eTrex H GPSReceiver

V. OBSTACLE AVOIDANCE

During the course of navigation from initial to the final waypoint there may be an obstacle which must have to be avoided. To achieve this purpose this project takes the advantage of sonar sensors to avoid an obstacles in its way. This project focused on the use of LV-MaxSonar–EZ4. We are using 2 sonar sensors implemented in front of mobile robot and 2 sonar sensors on back each with 11cm apart from each other. The choosing of the LV- MaxSonar–EZ4 Sonar Sensors based on the specification of the sensors. LV-MaxSonar-EZ4 is a low power i.e. 2.5V– 5.5V supply with 2mA typical current draw. It is 42 kHz Ultrasonic sensor. The rate of reading is 20Hz. LV-MaxSonar -EZ4 detect object from 0-inches to 254-inches (6.45 meters) with 1-inch of resolution. The interface output formats included are pulse width output, analog voltage output, and serial digital output. LV-MaxSonar –EZ4 are very low cost sonar range finder with reliable and stable range data with a quality beam characteristics.

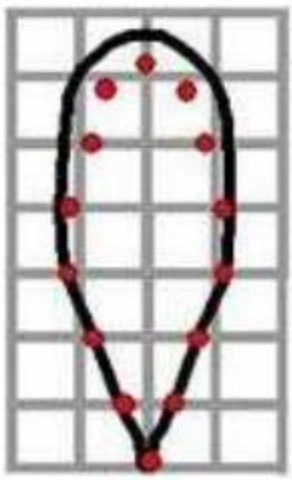

Fig. 3. Beam Charactristics Approximation of LV-MaxSonarEZ

As previously mentioned an extremely wide beam width is the characteristic of the most ultrasonic sensors. This is cause for concern, specifically when avoiding obstacles comes onto play. The beam width characteristic is shown in Figure 3. This shows the detection pattern for a 4-foot tall, 3.25-inch diameter post.
Figure 3 is the demonstration of a problem resulting from wide beams, producing a large distance ambiguity making an accurate location of an obstacle near impossible. The Figure 4 shows four different scenarios a sensor with a wide beam ma face, each of which returning the same analog output creating obstacle location ambiguity. Pulse data can be converted to centimeter or inches form equation (1) and (2).

$$Distance\ (cm) = \frac{microsecounds}{29} \qquad (1)$$

$$Distance\ (inches) = \frac{microsecounds}{74} \qquad (2)$$

VI. TARGET TECHNOLOGY

After detailed analysis of the proposed navigational system, the 89C51 is selected from the microcontroller suite for the implementation of the decision making module of the proposed mobile robot. 89C51 can execute 921,583 single-cycle instructions per second with a processing speed of 24 MHz. The on-chip Flash provides the reprogramming facility through both that the in-system and nonvolatile memory programmer. Instead of the high accuracy and flexibility, the 89C51 provides a cost effective solution in different applications.

The AT89C51 provides:

- ✓ 4Kbytes Flash Memory
- ✓ 128 bytes of RAM
- ✓ 32 I/O lines
- ✓ Two 16-bit timer/counters
- ✓ Five vector two-level interrupt architecture
- ✓ On-chip oscillator
- ✓ Full duplex serial port
- ✓ Clock circuitry

Additionally it provides two software selectable power saving modes.

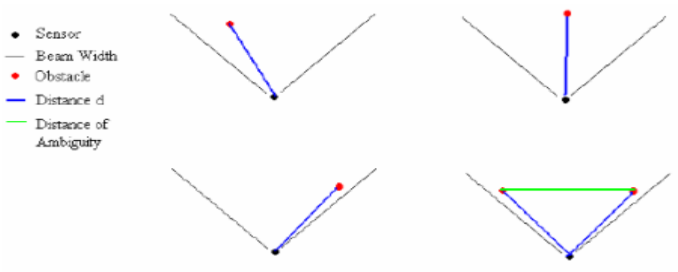

Fig.4. Different Scenarios returning the same Sensor Output [9]

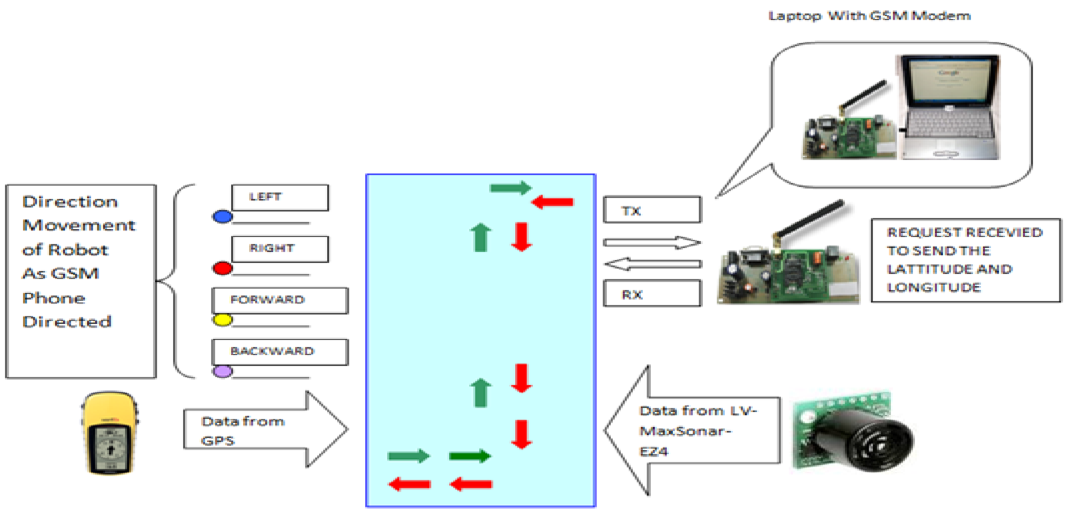

Fig.5. Block Diagram of Proposed Navigation System

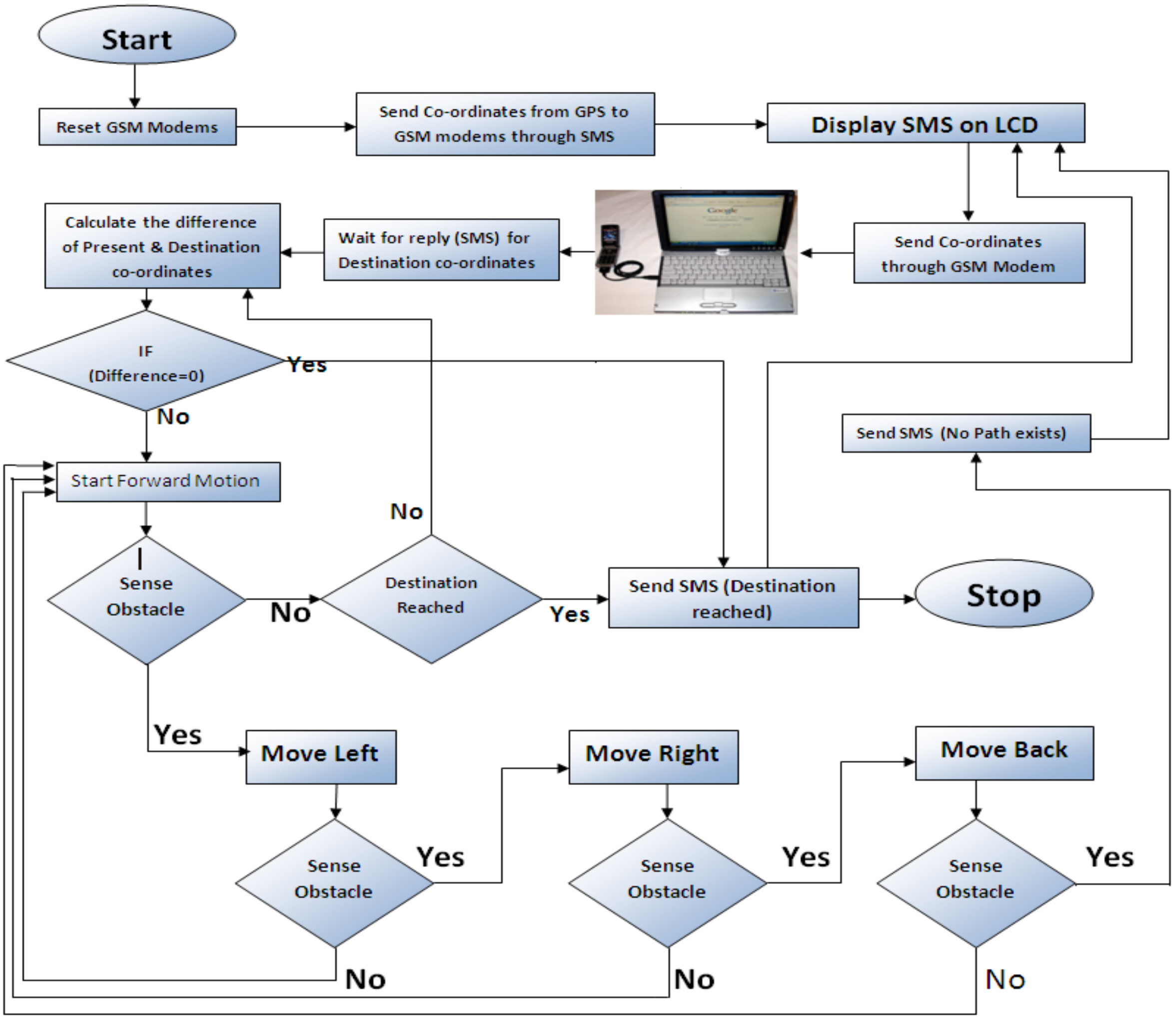

Fig.6. Flow Chart of the Proposed Decision Making Module

VII. DECISION MAKING MODULE

As our Navigation Robot contains GPS device, GSM modems and main circuitry, so first we reset the whole circuitry along with GPS & GSM modems. After resetting the Robot sends its current GPS co-ordinates to the GSM modem connected with a Laptop. The destination co-ordinates can be calculated from the Google map or from Google earth software and send to the Robot through the GSM connected with the Laptop. When the Robot receives the destination co-ordinates it drags a line between its current location and destination point. Also after receiving the destination co-ordinates it calculate the difference between these co-ordinates and store the result, and do a comparison (if difference = 0) it means the destination reached and it stops, but (if difference $\neq$ 0) it continue its motion and moves towards its destiny.

Now during its motion if an obstacle appears in its way the it changes its direction, if obstacle comes in forward direction it sends the co-ordinate and moves to left and sense the obstacle, if there is no obstacle in left it moves towards its destiny but if obstacle exists then again it sends the co-ordinates and moves towards Right, again it sense the obstacle in its way, if there is no obstacle it drags a line between its current position and its destiny and start motion but if obstacle exists then it sends the co-ordinates to the GSM connected with Laptop and moves in backward direction, again it sense the obstacle if there is no obstacle it moves for one minute and then change its direction and moves towards it destiny, but if obstacle exists its sends co-ordinates along with message “No path exists” . The distinguishing and more interesting point in our Navigation Robot from other Navigation Robot is that, that when it sends a co-ordinate to the GSM modem connected with Laptop we see the track of the Navigation Robot as we represented that by an arrow. Due to this track we can easily deduce that an obstacle appeared in its way and it changed its direction. And another interesting point is that, that whenever it receives a co-ordinate from the GPS it calculates the difference and compares that result with previous result to check “whether the current difference is larger than the previous one it means the Navigation system moving far away from its destination point and if smaller it means it moves towards its destiny”.

VIII. DESIGNED MODEL

Figure 5 shows the block diagram of the proposed navigation system while figure 7 shows the structure of the mobile robot truck model. The robot model used in this work is in dimension of 48 cm in length, 24 cm in width and 16 cm in height. The mobile robot truck consists of GPS receiver, GSM modem, the Ultrasonic sensors in front and the circuitry. The mobile front wheel acts as a steering and the back wheels for force, so the motors for forcing and steering are inside the mobile robot. The biggest challenge was that how to supply power to each part of the robot. The ultrasonic sensors need 2.5 – 5.5Volt and the other IC's need 5 volt i.e. NE555N, Relay, MAX232ACPE and L293D. This model uses 7805 as a Voltage regulator which provides a convenient power source for most TTL components. Output signal from GPS receiver and GSM Modem is RS-232 signal that can be changed to TTL signal by using converting circuit as shown in Figure 3. L293d is a dual H-Bridge motor driver, so with one IC interface two DC motors can be interfaced. These motors can be controlled in both clockwise and counter clockwise-direction.

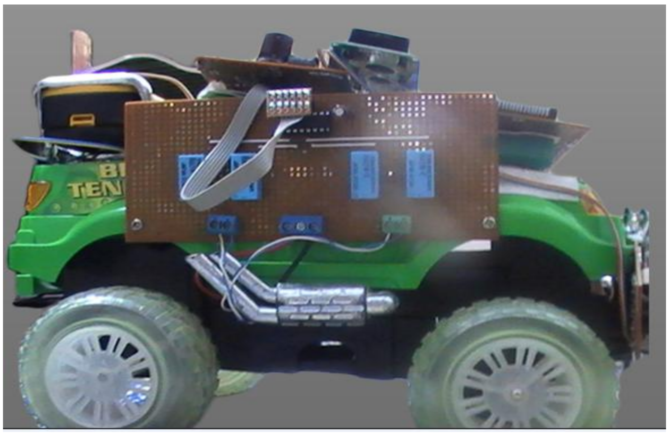

Fig.7. Model of the Proposed Robot

IX. CONCLUSION

The convenience and high performance makes the Global Positioning System a better choice for the navigation of a mobile robot. The results of Global Positioning System (GPS) on the mobile robot are probable. Based on the performance results of the GPS in different scenarios during this work, it can be concluded that Compare to other methods of navigation, GPS is simple, highly accurate and weather proof.

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