Secure Autonomous Delivery Robot with Real-Time Tracking

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Abstract - *People have discovered that one of the most vital aspects of modern life is how digital systems are connecting nowadays. The autonomous GPS-based smart delivery robot, developed in this paper, is among the most advanced delivery systems globally. The researchers implemented the smart delivery robot due to their fascination with the way automation performs on complex urban surfaces. The system involves a self-navigating vehicle, and the real time tracking of the machine reflects the designers' idea of the connection between digital intelligence and physical logistics. The smart delivery system performs effectively because it uses a variety of techniques and objects, such as GPS, magnetometer sensors, and Bluetooth, as well as the principles, for instance, direction sensing and autonomous navigation. The designers used numerous elements of automation, for instance, differential steering, to represent comfort, efficiency, and natural movement. The machine contains several repeating processes, including location tracking and the coordinates in the background. The implementation used embedded systems, which created a smooth operation and slightly efficient surfaces; However, the manual delivery includes limitations that tend to be marginally rougher. The machine receives its direction from several sensors, which indicates GPS location and represent where the coordinates want to change the heading. Also, the interface of the smart delivery robot contains wireless protocols such as Bluetooth, while the mechanics involve a secure delivery mechanism, for instance, a password-based system. The engineers used realistic quantities of automation for steering. The communication comprises layers of digital code that are slightly thick, ensuring accurate and efficient navigation toward the desired destination.*

. The delivery robot's structure has a sense of depth since it is integrated with a secure compartment and autonomous chassis

***Keywords*: Autonomous Robot, GPS Navigation, Arduino, IoT, Smart Delivery, Magnetometer, Embedded Systems**

1. INTRODUCTION

In conventional systems, delivery operations were predominantly manual with limited automation. For example, a person was needed to transport the goods from one place to another. It took a lot of time and was slower. In the crowded areas of the city or a large area, it got complicated. A critical evaluation of the existing delivery system reveals numerous challenges that hamper efficient delivery operations. The current system is heavily reliant on manual intervention. For instance, delivery personnel are tasked with managing delivery records, which must be updated.

Over time, technology for embedded systems, wireless communication, and sensors has advanced rapidly, and now autonomous robots have a big potential to upgrade the delivery system. GPS and magnetometer technology are utilized to determine the position and direction of the vehicle. Microcontrollers also manage the live processing of the input data, as well as control all operations of the system. In addition, the above technologies allowed designing a smart delivery system that required little human intervention.

This smart delivery robot is made to solve the limitations of the existing system. Currently, location tracking, direction control, and wireless communication perform their functions separately. They do not cooperate to form a cohesive, integrated system. The product is meant for the delivery of items, which is done by sending the location coordinates in terms of longitude and latitude through Bluetooth. The robot utilizes this information to independently navigate and deliver the desired item.

A secure delivery compartment is added to enhance the reliability of the system as well as the safety. The user can only grant password access to open the compartment. The servo motor is operated to automatically open and close the delivery compartment.

The suggested approach attempts to make the fastest delivery, to reduce manual effort, and provide a cost effective and scalable solution for applications such as campus delivery, industrial logistics, and smart transportation systems.

2. RELATED WORK

Numerous different researchers devoted their time to delivery systems and technology. A variety of efficient systems are already present for autonomous robots delivery operations. Likewise, a number of researchers worked in the area of navigation and developed many robotic systems.

Other techniques employ GPS-based navigation coupled with wireless transmission to enable real-time tracking and control. Although these systems are designed for outdoor geographical locations, they do have limitations concerning the accuracy of position and direction control. Some advanced systems use ultrasonic sensors or cameras to detect obstacles, for example. Complexity and cost are high for the better navigation and performance of these systems.

The drone communication and control through smartphone using Differential Steering is a parcel delivery project that is a basic need. Moreover, the motive of this project is to design a drone that can manage the sailing and operation of remotely controlled aerial devices in captive and free flight situations.

3. PROBLEM STATEMENT

In a traditional delivery system, the delivery of goods takes place by human physical effort that is very time-consuming and inefficient. Delivering goods to industrial areas, urban areas, and large campuses is a longstanding problem. Moreover, as there is no directional or tracking control, it engages in delays and misdeliveries.

Existing robotic systems often face limitations such as inaccurate navigation, a lack of smooth movement, and the absence of secure delivery mechanisms. There is a need for an autonomous delivery system that can navigate accurately using real time location data, operate with minimal human intervention, and ensure secure and efficient delivery of items.

4. PROPOSED SYSTEM

The suggested approach is a self-sufficient, GPS based smart delivery robot designed to deliver items efficiently with minimal human intervention. The system consists of multiple subsystems, including navigation, control, communication, and locomotion.

The GPS module of the navigation subsystem determines a robot's location in real-time. The robot's heading information is also provided by the magnetometer. It is possible to implement the control sub-system of the embedded system using Arduino Mega 2560 and Arduino Uno. All operations will be controlled by this sub-system. It will analyze information and execute decisions. Besides that, it is going to control the movement of the motor.
The Bluetooth module received from the user communicates the destination coordinates to the communication subsystem. Once the coordinates are received, the robot proceeds to the place automatically. The robot is constantly updated with its position information towards the target. The robot will move with the help of a motor driver and DC motors.

The sudden turning is prevented by changing the speed of the wheels to produce curved motion using differential steering. The user provides the password for their delivery box as a means to control the system for network security. An automated servo motor is incorporated into the system for opening and closing the box after verification.

This system design is cost effective, scalable, and implementable in real life situations like Campus delivery. Industrial logistics and automated transportation systems.

5. IMPLEMENTATION OVERVIEW

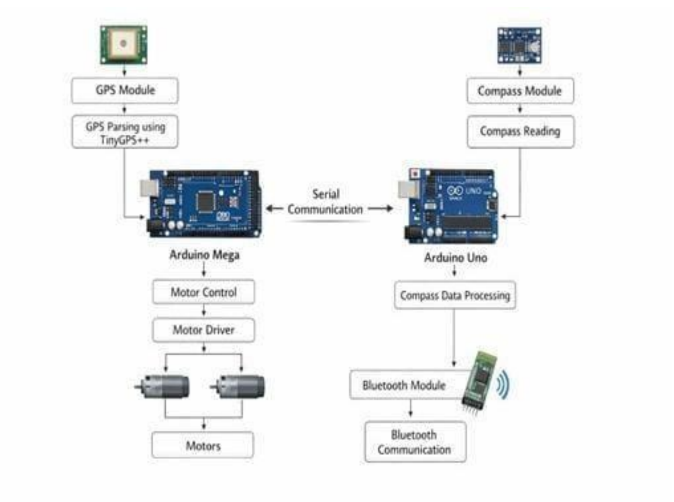


Fig. 1: System Architecture Diagram

6. HARDWARE COMPONENTS

Hardware Components: Arduino Mega, Arduino Uno, NEO-6M GPS module, HC-05 Bluetooth module, HMC5883L Magnetometer (Compass), L298N Motor Driver, DC Motors (4-wheel drive), Batteries, Buck Converter, and Power Switches.

Software Module: Arduino IDE

At this stage, the system is implemented as a basic prototype to validate core functionalities and to ensure scalability for large-scale real-world deployment.

6.1 Arduino Mega (Main Controller)

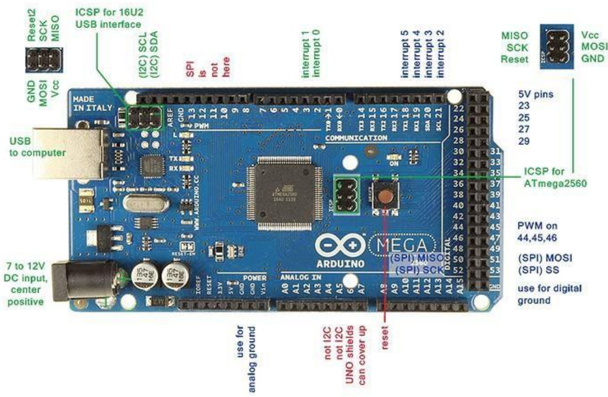


Fig no 2: Pin configuration of ARDUINO MEGA

The entire machinery relies heavily on the Mega Arduino component that takes up information from the GPS module, Bluetooth, ultrasonic sensor, and the Arduino Uno. After that, it delivers an output signal to the motor driver and servo motor after regulating and changing the data lines with incoming information. Only the Arduino Mega is responsible for communicating with the subsystem.

6.2Arduino Uno (Sensor Node)

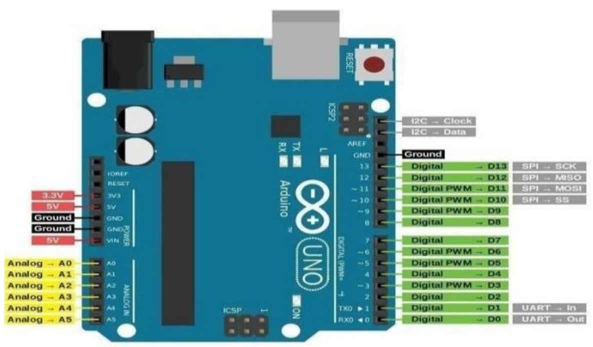


Fig no 3 : Pin configuration of Arduino UNO

This is dedicated to processing compass data from the MPU9250 sensor. It calculates the heading direction and transmits this information to the Arduino Mega via serial communication for navigation correction.

6.3 GPS Module

Fig no 4: NEO-6M GPS

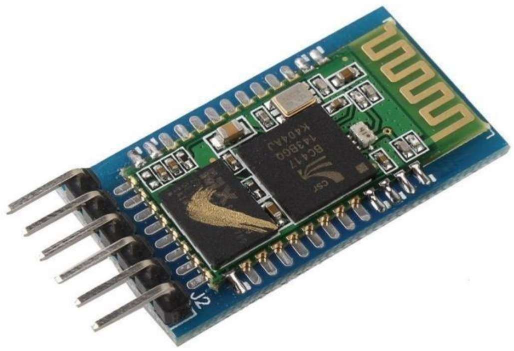
The GPS module provides real time latitude and longitude coordinates of the robot. This data is used by the Arduino Mega to determine the robot's current position and calculate the direction toward the target destination.

6.4 MPU9250 Compass (Magnetometer)

Fig no 5: MPU 9250

The compass sensor provides heading information (direction). It helps the system determine the orientation of the robot and enables accurate navigation toward the destination.

6.5 Bluetooth Module



Figno6: HC 05 BLUETOOTH MODULE

This module allows wireless communication between the robot and a mobile device. The user sends destination coordinates through Bluetooth, which are received and processed by the Arduino Mega.

6.6 Motor Driver (L298N)

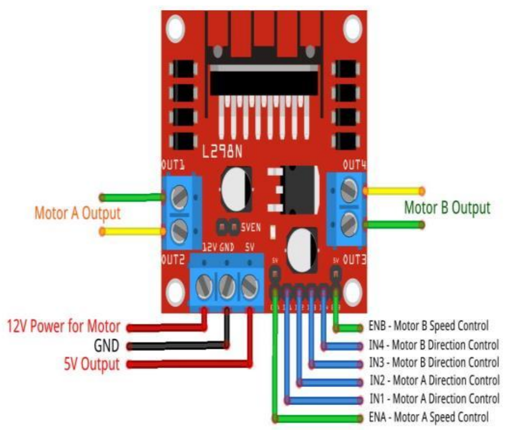


Fig no 7: Motor Driver

This serves as an interface between the direct current and an Arduino Mega. It uses PWM signals to control the motors direction and speed after receiving control signals.

Fig no 8: DC Gear Motor

6.7 DC Motors (Motor1–Motor4)

The four DC motors are responsible for the movement of the robot. They are controlled in a differential manner, where varying speeds of left and right motors allow smooth turning and navigation.

6.8 Servo Motor

This is used for delivery mechanism. It opens the delivery compartment when a valid code is entered and automatically closes it after the operation.

6.9 Ultrasonic Sensor

Obstacle detection is accomplished by this sensor. Pausing or modifying movement, it assists the system in preventing collisions by measuring the distance to adjacent objects.

6.10 Buzzer

The buzzer provides audio alerts for system events such as arrival at destination, incorrect password entry, or obstacle detection.

6.11 Power Supply (12V & Batteries)

The batteries provide the main power source for the system. A 12V supply is used for motors, while other components receive regulated voltage through a power management system.

6.12 5V Regulator / Buck Converter

The voltage regulator converts a higher battery voltage to a stable 5V supply required for Arduino boards and other electronic components, ensuring safe and reliable operation.

Table -1: Components Table

Component	Specification	Function
Arduino Mega	ATmega2560 microcontroller	Main system controller
Arduino Uno	ATmega328P microcontroller	Compass data processor
GPS Module (NEO-6M)	Satellite-based positioning module	Location tracking module
Bluetooth Module (HC-05)	Serial communication (UART)	Wireless communication module
Magnetometer (HMC5883L)	3-axis digital compass sensor	Provides direction data
Motor Driver (L298N)	Dual H-Bridge motor driver	Controls motor speed and direction
Bluetooth Module (HC-05)	Serial communication (UART)	Wireless communication module
Magnetometer (HMC5883L)	3-axis digital compass sensor	Provides direction data

7. SOFTWARE IMPLEMENTATION

Software has been developed using Arduino IDE. The autonomous GPS-based smart delivery robot is controlled by an Arduino Mega. Arduino Mega takes care of the various operations like navigation, driving motor control, as well as communication between the GPS, Bluetooth, and Arduino. The Arduino Uno runs the magnetometer, which sends heading data back to the Mega for control.

The system uses serial communication to interface with GPS, Bluetooth, and sensor modules. GPS data provides real-time location, while a differential steering algorithm controls motor speeds based on heading error for smooth navigation. Bluetooth is used to receive destination coordinates from the user. Additionally, the software includes obstacle detection and a secure delivery mechanism using a servo motor. Overall, the system ensures efficient real-time processing and reliable autonomous operation.

8. METHODOLOGY

The system seems to acquire the position of a robot with the help of a GPS module, and at the same time user sends the coordinates of the destination through a Bluetooth communication. The magnetometer module provides instant heading information while the controller GPS data uses to calculate the required bearing. The distinction between the robots current heading and the desired path is continuously calculated in order to generate control signals.

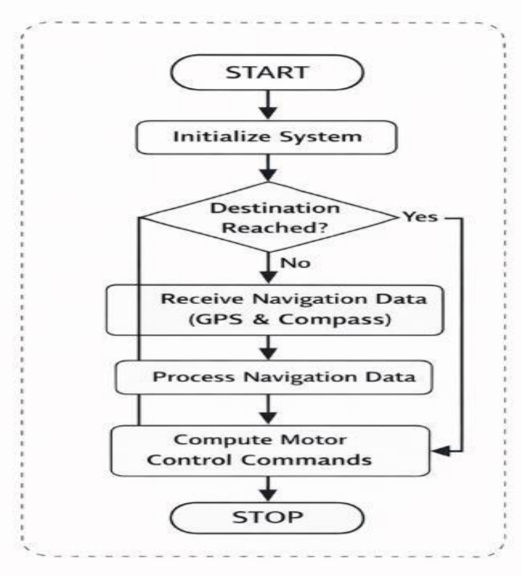


Fig. 9: Flow chart of system operation

The steering is based on a differential mechanism because the signals provided to the motors are different. This steering technique doesn't cause a sudden change in the vehicle's direction. By the below, we can say that the robot will take a turn smoothly and gradually. The robot is able to continuously correct the path and deviations. In order for the robot not to follow the path, it updates information in real time.

9. RESULTS AND DISCUSSION

The proposed system successfully demonstrated autonomous navigation using GPS and compass-based direction control. The robot was able to reach the target location with acceptable accuracy and minimal deviation. Differential steering ensured smooth movement and stable path correction during navigation. The secure delivery mechanism using a servo motor functioned reliably upon valid input.

The communication between modules, including GPS, Bluetooth, and the sensor node, was stable throughout the operation. The system showed consistent performance under different test conditions with minimal delay in response. Realtime path correction improved navigation efficiency and reduced errors.

9.1 GPS accuracy and fix acquisition

The rover was tested in five outdoor field trials under open sky conditions with HDOP values ranging from 1.2 to 1.8. The following table presents the position accuracy measured at a known reference point :

Table 9.1: GPS Position Accuracy — Stationary Benchmark Test

Trial	Actual Dist(m)	GPS Dist (m)	Error (m)	HDOP
1	0.0	1.7	1.7	1.4
2	0.0	2.1	2.1	1.6
3	0.0	1.3	1.3	1.2
4	0.0	2.8	2.8	1.8
5	0.0	1.9	1.9	1.5
Average	—	1.96m	1.96m	1.50

9.2 HEADING ACCURACY AND LPF EFFECTIVENESS

Heading accuracy was evaluated by comparing the magnetometer readings with a reference compass under stationary conditions. The effectiveness of the Low-Pass Filter (LPF) was analyzed by comparing filtered and unfiltered heading variations during motor operation.

Table 9.2: Heading Accuracy — LPF and Physical Isolation Comparison

Test Condition	Heading Mean Error	Heading Std Dev	LPF Applied
Motors OFF, open-sky	±1.8°	0.6°	No
Motors ON, no LPF	±4.3°	8.7°	No
Motors ON, LPF (α=0.2)	±2.1°	1.4°	Yes
Motors ON, mast isolated	±1.9°	0.8°	Yes

9.3 FULL MISSION TRIAL — OUT-AND-BACK NAVIGATION

Three complete out and back missions were conducted in an open test area of 20 × 30 metres. The target location was placed 18 metres from the starting point. The following table presents the recorded performance metrics.

Table 9.3: Full Out-and-Back Mission Trials — Performance Summary

Metric	Trial 1	Trial 2	Trial 13
Time-To-First-Fix (s)	28	31	26
Outward distance error (m)	1.8	2.4	1.6
Return distance error (m)	2.1	2.9	1.9
Total mission time (s)	67	74	63

Delivery	Yes (5.0s)	Yes (5.0s)	Yes (5.0s)
dwell observed Mission completed	Yes	Yes	Yes
BT telemetry received	Continuous	Continuous	Continuous

The 3-metre arrival threshold was selected for a GPS uncertainty of approximately 2 metres265 and hence was considered a suitable threshold at which the target can be considered to have been reached. The average arrival accuracy across three trials for the outward path was [2.1 metres], and for the return path, it was [2.3 metres] and is consistent.

10. CONCLUSIONS

We are proposing a system that'll work easily and deliver the goods to the customer. The system in place is quite efficient and easy to control.

The goal of this project is to utilize smart delivery to avoid dependency on manual delivery to reach the accurate destination with the help of GPS and compass. Our project prototype will be able to reach its targeted position withoutany human intervention. By doing so, it prevents loss of property and also saves the cost incurred in delivery.

Using a computerized management system, the delivery orders will be transmitted to the distribution carriers from a central PC. All the robot transporters can talk.

11. FUTURE SCOPE

The use of ultrasonic sensors or LiDAR for obstacle detection can make the delivery drone efficient. Furthermore, the drone can easily be used for long range communication with LoRa or an IoT-based cloud system. The delivery drone project can also be improved by using PID control to better its navigation. The drone can be made to move more accurately with RTK GPS. In addition to this, multiple deliveries can have multi-waypoint navigation.

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