

GPS GUIDED TRASH COLLECTION ROBOT WITH AUTOMATIC SEGREGATION

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Abstract: Rapid urbanization has greatly increased the need for efficient and hygienic municipal solid waste management systems. Traditional waste collection at the door still depends largely on manual work, fixed schedules, and there is no segregation of waste at the source which leads to operational inefficiencies and environmental problems. This paper discusses the design and development of a GPS, guided autonomous trash collection robot with automatic waste segregation. The proposed system makes use of an Arduino Uno microcontroller as the main control unit, coupled with a GPS module and a digital compass to enable accurate navigation outdoors. The robot receives user, defined pickup locations through a Bluetooth, enabled mobile application. Once the robot arrives at the location, it notifies the user and collects the waste which is automatically divided into wet and dry categories by a moisture, based sensing system. Waste segregation is further facilitated by a servo, actuated unit that directs the different wastes into the appropriate compartments. Testing the prototype confirms the excellent navigation of the robot, accurate waste separation, and no, fuss collecting of the garbage by the drone. The proposed system provides an economically viable and scalable alternative to conventional methods of waste management and is very likely to be adopted by both residential and institutional environments.

Keywords: Autonomous robot, Waste management, GPS navigation, Automatic waste segregation, Arduino Uno, Smart cities, Mobile robotics.

I. INTRODUCTION

Rapid urbanization and population growth have led to a significant increase in municipal solid waste generation, resulting in serious environmental, economic, and public health challenges. Conventional waste collection systems primarily rely on manual door-to-door collection using fixed routes and schedules. These methods are often inefficient, leading to increased operational costs, irregular collection cycles, and unhygienic conditions due to delayed waste removal. Furthermore, the lack of waste segregation at the source reduces recycling efficiency and contributes to the growing dependence on landfills.

Recent advancements in robotics, embedded systems, and wireless communication technologies have enabled the development of intelligent and automated solutions for urban waste management. Automation can improve collection efficiency, promote source-level waste segregation, and reduce reliance on manual labor. Autonomous mobile robots equipped with navigation and sensing technologies offer a promising approach for modernizing residential waste collection systems.

This project presents a GPS-based Garbage Collection Robot with an automated waste segregation mechanism. The system is built around an Arduino Uno microcontroller and incorporates GPS navigation along with a digital compass for accurate positioning and route guidance. Users can communicate with the robot through a Bluetooth-enabled mobile application to request waste pickup services.

Upon reaching the designated location, the robot collects waste and uses a moisture sensor to identify whether the waste is wet or dry. Based on the sensor readings, a servo motor automatically directs the waste into the appropriate compartment, ensuring effective segregation at the source.

The proposed system aims to provide a low-cost, reliable, and efficient solution for automated waste collection and segregation. By integrating navigation, sensing, and actuation technologies into a compact robotic platform, this project contributes toward the development of smart and environmentally sustainable waste management systems suitable for future smart cities.

II. PROBLEM DEFINITION

In urban and semi, urban areas, municipal solid waste management mainly relies on manually, operated, schedule, based door, to, door collection systems. Such traditional methods have been riddled with a number of issues like planning inefficiently the routes, using more fuel than necessary, running up the operational costs, and providing the service in an inconsistent manner. The lack of waste segregation at the source is another problem as it results in the mixing of the wet and dry waste, thus contaminating the recyclable materials and making the recycling processes less efficient. This way, landfilling is excessively done, the environment is polluted, and the valuable materials are lost.

Besides the inefficiencies in operations, the manual handling of waste puts the workers who do sanitation at risk of exposure to unclean and possibly dangerous situations that can have a negative impact on their health and safety. The present smart waste management systems mainly concentrate on monitoring individual bins or improving the efficiency of routes but they do not often have integrated autonomous collection and real, time segregation functionalities. Hence, the demand for an advanced, automated, and inexpensive waste collection system is paramount. It should be capable of independently navigating through user, provided directions, picking up the waste at the doorstep, and ensuring segregation at the source while at the same time, limiting the extent of human intervention.

In addition, the high growth in urban population and spectrum consumption patterns have both significantly contributed to the increment in the amount and nature of the municipal solid waste. The majority of the current collection systems do not have the capacity to effectively handle such huge expansion hence giving rise to such effects as erratic collection times, overfilled bins and increased littering in the street and home environments. The issues are aggravated by the lack of on, demand collection on the basis of the real, time situation whereby waste is collected despite unnecessaryness of the same, thus, creating unnecessary traffic movement and increased amount of carbon emissions.

In addition to these difficulties, there is yet another very serious limitation of conventional waste management techniques since the lack of responsibility and data, motivated decision-making. The manual systems are unable to provide the correct data regarding the waste production tendencies, the frequency of the collection, the segregation rate, etc. The inaccessibility of reliable data severely restricts the ability of the local governments to handle resources in a more resourceful way, more advancement in recycling, and execution of environmental regulations clamping down that becomes effective. Also, hiring monotonous and physically taxing work requires human labor, which increases the risks of operations, especially when there is a labor shortage or some disaster, such as a disease outbreak.

In addition to that, the alleviating smart waste solutions are primarily dedicated to isolated capabilities like bin, level detection or route optimization and do not take into account the whole lifecycle of the waste collection. The lack of connection between the processes of navigation, collection, and segregation serves as the obstacle to their application in the real and life situations. In addition, high, tech sensors and reliance on a network can render such systems impracticable merely since very few areas have such an extensive infrastructure network that can sustain such system to the maximum possible manner, much less in developing areas.

That is why it is very important to have a smart integrated waste management system that can do autonomous navigation, on, demand doorstep collection, and real, time segregation all in a single platform. The system also has to be cheap, scalable, and work with minimal human supervision. Only by facing these challenges will it be possible to increase the efficiency of waste management, lower its ecological footprint, and help the creation of sustainable and smart urban environments.

III.LITERATURE SURVEY

Introduction

Rapid urbanization and population growth have resulted in a substantial increase in the generation of municipal solid waste, creating significant environmental, economic, and public health challenges for local governments. Traditional waste collection systems primarily depend on manual door-to-door collection conducted along fixed routes and schedules. These methods often lead to inefficient resource utilization, increased operational costs, irregular collection

cycles, and greater exposure of workers and residents to unhygienic conditions. Furthermore, the absence of waste segregation at the source significantly reduces recycling efficiency and contributes to the rapid expansion of landfill sites.

Advancements in robotics, embedded systems, and wireless communication technologies have enabled the development of intelligent and automated solutions for urban infrastructure management. The integration of automation into waste management systems can improve operational efficiency, promote source-level waste segregation, and reduce dependence on manual labor. Autonomous mobile robots equipped with navigation and sensing technologies provide a scalable and effective alternative to conventional waste collection methods, particularly in residential and institutional environments.

This project presents the design and development of a GPS-enabled autonomous garbage collection robot with an automated waste segregation mechanism. The system is built around an Arduino Uno microcontroller, which serves as the primary control unit. A GPS module is incorporated to facilitate accurate outdoor navigation, while a digital compass provides precise directional guidance. Communication between the user and the robot is established through a Bluetooth-enabled smartphone application, allowing users to send pickup requests and location information directly to the system.

Upon reaching the designated location, the robot collects the waste and performs automatic segregation based on moisture content. A moisture sensor is used to distinguish between wet and dry waste materials. Based on the sensor readings, a servo motor actuates the segregation mechanism, directing the waste into the appropriate compartment.

The primary objective of this project is to develop a compact, low-cost, reliable, and efficient prototype capable of performing doorstep waste collection and source-level waste segregation. By integrating navigation, sensing, and actuation technologies into a single robotic platform, the proposed system contributes toward the development of smart and sustainable waste management solutions suitable for future smart city applications.

IV. PROPOSED SYSTEM

The robot proposed is a trash collecting robot that works autonomously through a GPS system. Its main feature is to be able to perform waste collection directly at the customers door with automatic segregation of waste materials. The purpose of the system is to help the process of municipal solid waste by combining navigation, communication, sensing, and actuation modules through a centralized embedded control architecture, to make it more efficient, hygienic, and reliable. The most important goal of the system is to limit human involvement in primary waste collection and at the same time to guarantee wet and dry waste segregation.

Arduino Uno microcontroller is used as the main component of the robotic platform. The microcontroller manages all the robot's activities such as evaluating sensor signals, deciding upon the route, commanding the motors and controlling the separation system. The energy of the system is provided by a rechargeable 12 V lithium, ion battery. A voltage regulator, that takes power from the battery, feeds electronic components that require a lower voltage (5 V). The robot will be able to operate uninterruptedly and in a safe way with this electrical power supply.

For autonomous navigation, the system uses a GPS module to get the real, time geographical coordinates and a digital compass to figure out the robot's heading direction. Through a Bluetooth, enabled mobile application, the user, defined pickup locations are sent to the robot. The microcontroller constantly keeps track of the current position versus the target coordinates and, when necessary, generates motor control signals to lead the robot to the destination.

When the robot gets to the specified location, it stops and turns on the audible alert to let the user know. The waste collection and segregation mechanism becomes a part of the mobile platform. A sensor employing the moisture property is used for waste classification into wet or dry by measuring the difference in conductivity. Depending on the sensor's output, the microcontroller commands a servo motor that moves the waste to the correct compartment. With this automatic separation right at the collection point, recycling efficiency is boosted and the contamination of recyclable materials is minimized.

The proposed system works on, demand and hence waste gets collected only when a user requests it. That way, waste collection vehicles waste less of their time and fuel, they use less fuel, and the company can save on operational costs while they get two times more drops as compared to fixed, route collection methods. Furthermore, the modular design of the system enables it to be easily maintained and upgraded in the future with features like obstacle detection, enhanced localization accuracy, and smart waste classification.

In general, the proposed system represents a low, cost, scalable, and highly efficient solution for smart waste management

applications. By integrating autonomous navigation with real, time waste segregation, it overcomes the main drawbacks of the traditional waste collection methods and paves the way for sustainable and smart urban living.

V. METHADODOLOGY

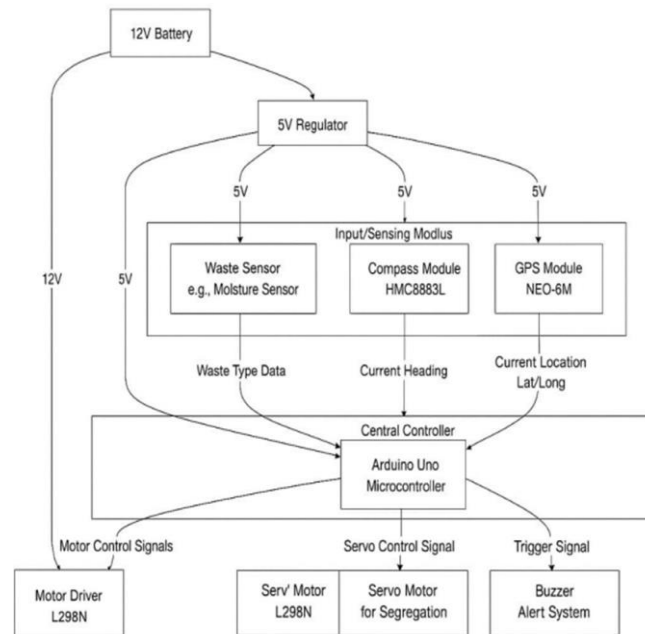


Fig. 1. Architecture diagram

The proposed system architecture of the GPS-enabled Autonomous Garbage Collection and Segregation Robot is illustrated in Fig. 1. The system is designed around a centralized control approach in which all sensing, navigation, communication, and actuation functions are coordinated by a single controller. For efficient operation and modularity, the architecture is divided into four major sections: Power Supply Unit, Input and Sensing Module, Central Control Unit, and Actuation and Alert Mechanisms. This modular design improves system integration, reliability, maintainability, and scalability.

Power Supply Unit

The power supply unit consists of a 12 V rechargeable battery that serves as the primary power source for the entire robotic system. Since different components require different operating voltages, a voltage regulator is used to step down the 12 V supply to a stable 5 V output suitable for the Arduino Uno, sensors, and communication modules. The regulated power supply ensures reliable system operation, protects sensitive electronic components from voltage fluctuations, and enhances overall system stability.

Input and Sensing Module

The input and sensing module comprises a GPS module (NEO-6M), a digital compass sensor (HMC5883L), and a moisture sensor for waste classification. The GPS module continuously provides latitude and longitude coordinates, enabling accurate outdoor positioning and navigation. The digital compass sensor supplies heading information, allowing the robot to determine its orientation and perform directional corrections during movement.

The moisture sensor is used to analyze the moisture content of collected waste and classify it as either wet or dry waste. All sensor data are transmitted to the central controller, where they are processed to support navigation, waste segregation, and decision-making operations.

Central Control Unit

The Arduino Uno microcontroller functions as the central control unit of the system. It receives data from the GPS

module, compass sensor, moisture sensor, and Bluetooth communication interface. User commands and pickup requests are transmitted to the robot through a Bluetooth-enabled smartphone application.

After processing the received inputs, the microcontroller executes navigation and control algorithms to determine the robot's actions. It then generates the appropriate control signals required for movement, waste segregation, and user notification. This centralized processing ensures synchronized operation of all system components and improves overall performance.

Actuation and Alert Mechanisms

The actuation and output section consists of an L298N motor driver module, DC motors, a servo motor, and a buzzer alert system. The motor driver receives control signals from the Arduino Uno and drives the DC motors, enabling the robot to move forward, turn, and stop as required during navigation.

The servo motor operates the waste segregation mechanism. Based on the moisture sensor readings, the servo directs the collected waste into the appropriate compartment for wet or dry waste. The buzzer serves as an alert mechanism, providing audible notifications when the robot reaches the pickup location or completes a designated task.

Together, these components enable the robot to navigate autonomously, perform real-time waste segregation, and communicate operational status effectively to users, thereby enhancing the efficiency and reliability of the waste collection process.

VI. RESULTS AND DISCUSSION

Fig. 2 can be viewed as the hardware prototype of the GPS-guided garbage collection robot with automatic segregation that is already developed. One can observe the mobile robotic platform in the air in the picture with all the major electronic parts attached to a small chassy.

It has an Arduino Uno microcontroller at its core, acting as a basic control unit and connected to the motor driver, Bluetooth module and all the sensors. To supply the control circuit and DC motors, the chassis has attached to the back a lithium-ion battery pack. The whole construction is a sign of low and modular design philosophy, due to which may be easily joined and serviced. The motor movement controlling was precise and the robot was in a smooth movement during the test. The DC motors were used to motorize the wheels through L298N motor driver module (which can be seen in the picture next to the Arduino board).

The links between the motor driver and the controller were with wiring and this enabled that the robot moved forward in line with the turns, moved backward and turned. During the testing, the robot was able to travel the flat indoors grounds without any major instances of instability, hence, the torque was sufficient and the weight was distributed evenly. Besides, the position of the battery next to the motor driver was used to reduce the voltage drops throughout the process. It was possible to have credible close, range wireless communicational with a mobile application with the help of the Bluetooth communication module installed near the controller. Instructions such as start, stop, and directional movement were despatched and executed with an extremely low delay. Thus, we can easily see that the user can provide efficient criteria to the robot to pick up wastes.

Experiments done within the building indicated that there was low GPS, based navigation accuracy. Nevertheless, the outdoor and semi, open environment tests, when GPS signals were accessible, the robot has always been heading in the right direction with regard to the set coordinates.

The waste segregation system was practically tested with using the wet and dry waste samples. The moisture, based sensor established the conductivity difference and transmitted the signal to arduino Uno which in turn opened the servo motor and physically divided the waste to go to the appropriate compartment. It was performed nearly immediately and the equipment continued to work properly even in the presence of the simplest forms of waste.

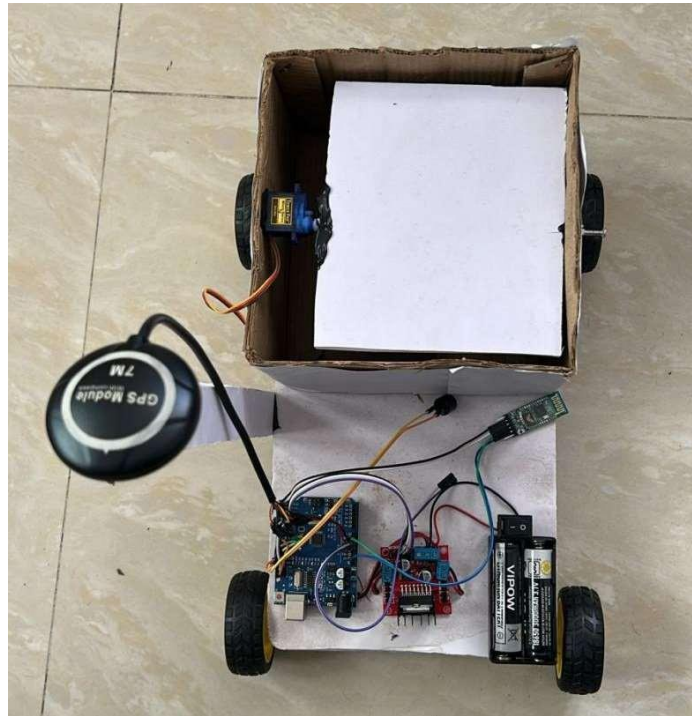


Fig. 2. GPS Guided Trash Collection Robot

In the image, the open servo motor wiring and control connections demonstrate the successful combination of sensing and actuation subsystems in a very small space.

In general, the prototype was quite consistent in its operations during different test cycles, showing coordinated performance of navigation, control, and segregation units. The picture shows that all subsystems power supply, control electronics, communication module, and drive system are neatly packed and working together on one mobile platform.

Even though the system is able to demonstrate the concept, there are still few limitations such as no obstacle detection, the dependence on the quality of the GPS signal, and fairly basic level of waste classification accuracy. These findings demonstrate that the proposed design is a working proof, of, concept and it is possible to add the advanced sensors, better localization methods, and smart waste classification algorithms for the real-world implementation.

VII. CONCLUSION

Research question was used to outline the conceptualization and the design of a self-governing GPS-directed garbage collection robot, which automatically separates garbage, in a bid to make the municipal solid waste management more effective and friendly to humans. The proposed system was able to integrate three major modules: the navigation, and sensing and communication; the system is controlled collaboratively by an Arduino Uno microcontroller and, as a result, was capable of moving without human assistance to a position designated by the user and isolate wastes in real time and time into two categories, wet and dry. The created prototype was experimentally tested and the obtained results proved that the prototype has the capabilities to navigate effectively, segregate wastes successfully, and minimize the number of human interventions during the stage of primary waste collection.

Other than the concept, the details that are presented in the design indicate that there is potential use of low and low-cost autonomous robotic systems at the local level in managing wastes at the level of the community. The system assists in bringing a more efficient recycling, reduced environmental pollution by attaining source, level segregation and expedient collection. Although the prototype is a proof of concept to date, there is a great range of opportunities in future development, including sensor fusion introduced in order to enhance localization precision, machine learning-based high-end waste classification, obstacle avoidance installation, and adhered to energy and efficient power usage. The concept, when refined and tested on a larger scale would have the potential to be turned into an effective and scalable part of the smart city garbage management system.

The local communities can have waste collected by the use of cheap robots. Such system assists in recycle improvedly and minimizes pollution. It separates wastes according to their types and gathers them promptly. The existing model is merely a prototype. We can enhance it by providing sensors to locate things in a better manner. Machine learning can also be used to sort waste more efficiently. We are capable of including capabilities to prevent challenges and conserve energy. With better optimization and testing, it may become a helpful component of intelligent city waste systems.

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