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Design and Development of a Package Delivery Robot

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ABSTRACT: This research focuses on the design and development of a package delivery robot, comprising an electronic housing and a storage unit. The robot is remotely controlled through a website, equipped with obstacle detection capabilities, and capable of unlocking the storage unit. However, movement is limited when the storage unit is installed on the electronic housing. The objective of this project was to build a package delivery robot that could operate in organised environments, such as universities and estates. The project commenced with extensive research on existing delivery robots, analysing their strengths and weaknesses. Based on this analysis, a set of design requirements was formulated, emphasising compact size, lightweight construction, and user-friendly operation. A custom control system was developed, enabling robot navigation, while sensors were integrated to facilitate obstacle avoidance and pedestrian safety. The first chassis of the robot was constructed using lightweight sheet metal, but turned out to be too heavy for the motors to drive, so the chassis was reconstructed using corrugated cardboard. To evaluate its performance, the robot underwent rigorous testing in a simulated urban environment. The robot has a speed of 0.5 m/s, and receives commands at a speed of 0.0068 nano seconds. It also consumes a power of 120 watts. While the robot demonstrated below-average performance in these aspects, limitations were identified, such as the inability to make left or right turns due to the shaft that connects the tyre and the motor being short. In conclusion, this research introduces a package delivery robot that has the potential to significantly enhance the customer delivery experience in urban environments. The robot represents progress in delivery system development and provides valuable insights into the challenges and opportunities within the field of mechatronics. The introduction, methodology, results, and conclusion framework used in this project offers a comprehensive understanding of the research and development process, the robot's performance, and its impact on the field.

KEYWORDS: Robot, Package, Delivery, obstacle detection, corrugated cardboard

I. INTRODUCTION

The use of delivery robots is becoming increasingly popular as a way to improve the speed, efficiency, and reliability of package delivery. In recent years, there has been a rapid increase in the development of delivery robots, with many companies and research institutions exploring the potential of this technology (Ekpo, D. D. 2019). However, the design and development of delivery robots is a complex and challenging task that requires a deep understanding of the technical and operational requirements of the delivery process.

To understand the state-of-the-art in delivery robots, a comprehensive review of the relevant literature was conducted (Diji, C. J et al 2013). This included a review of academic papers, industry reports, and patent applications. The review focused on identifying the key design requirements and constraints for delivery robots, including mobility, payload capacity, energy efficiency, safety, and reliability (Diji C. J. et al 2013). The study provided a solid foundation for the design and development of the package delivery robot, and it helped to ensure that we worked towards building a final product that meets the needs of the delivery industry and the requirements of the end-user. Package delivery robots are a rapidly growing technology that can transform the delivery industry (Olatunbosun, D. et al 2014). These robots are designed to operate with little or no human intervention and can deliver packages directly to customers. The adoption of delivery robots is driven by the increasing demand for fast, reliable, and cost-effective delivery services. Advances in artificial intelligence, machine learning, and robotics have made it possible to bring these robots to the market (Huang et al., 2019).

Robots are programmable machines that can perform tasks autonomously or with minimal human intervention (Ekpo, D. D. et al 2012). They are designed to interact with the physical world and carry out a wide range of functions. The field of robotics encompasses a vast array of robotic systems, each with its own set of capabilities and applications (Kaminka and Frenkel, 2005).

At their core, robots are composed of hardware components and software algorithms that enable them to sense, think, and act in their environment (Ekpo, D. D. 2012). The hardware includes sensors to gather information about the surroundings, actuators to manipulate objects or move the robot itself, and a computational system to process data and make decisions. The software encompasses the algorithms and programming that govern the robot's behaviour and control its actions (Kretzschmar et al., 2016).

Robots are often created to address specific tasks or challenges, as they mainly made of electric motors (Okpo and Nkan., 2016). They can be found in various domains, including industrial settings, healthcare, transportation, exploration, entertainment, and more. Industrial robots, for instance, are designed to automate repetitive and labour-intensive tasks on assembly lines, contributing to increased efficiency and productivity in manufacturing processes. In healthcare, robots can assist in surgeries, perform delicate procedures, or provide physical therapy (Villani et al., 2018).

One of the key advantages of robots is their ability to operate autonomously. Depending on their level of autonomy, robots can carry out complex tasks without continuous human guidance. Autonomous robots utilise sensors, such as cameras, lidar, and proximity sensors, to perceive their environment and make informed decisions based on the gathered data (Okoro et al., 2022). This enables them to adapt to changing conditions, navigate through obstacles, and interact with their surroundings effectively (Vasquez et al., 2016). Robots are constantly evolving as technology advances. With the integration of artificial intelligence, machine learning, and computer vision, robots can enhance their capabilities, learn from experience, and improve their performance over time. Additionally, robots can communicate and collaborate with humans and other robots, enabling them to work cooperatively in various settings (Villani et al., 2018).

Robots are sophisticated machines designed to autonomously or semi-autonomously perform tasks in a wide range of fields. Their ability to interact with the physical world and adapt to different environments makes them valuable tools in improving efficiency, productivity, and safety across industries (Okpo et al., 2021). The continuous advancements in robotics technology hold great potential for the future, opening up new possibilities and applications for these intelligent machines (Guizzo and Ackerman, 2012).

II. SYSTEM DESIGN

The system design focused on the design of the package delivery robot system, including the mechanical, electrical, and software components that make up the system. The system design stage of the project lays the foundation for the development of the package delivery robot system.

The system design is divided into several parts, including planning, modelling, and designing the system architecture. The first step in the system design was to analyse the requirements of the system. This analysis helped to determine the necessary components and functions that the package delivery robot system should have. The next step was to design the system's interfaces, which include the user interface, communication interfaces, and data interfaces.

A. Design Requirements

The design requirements focus on defining the specific requirements that the package delivery robot system should meet. The design requirements were determined through careful analysis and evaluation of the project objectives, including the desired functionality and performance of the system.

Table 1 - Design Requirements, Specifications, and Values

Design Requirement	Specification	Value
Power source	Battery voltage	7.4V
Maximum payload capacity	Weight limit	20kg
Range of the robot	Distance covered on a single charge	1km
Accuracy of sensors	Positioning accuracy of GPS sensor	+/- 5m
Speed of the robot	Maximum speed	5 m/s
Ability to navigate around obstacles	Minimum obstacle clearance	20cm
Safety features	Emergency stop button	Yes
	Obstacle detection and avoidance	Yes

B. Conceptual Design

For the conceptual design, we presented the initial ideas and concepts for the robot's design, including its form, function, and overall architecture. To develop the conceptual design, we first conducted a thorough analysis of the design requirements defined in the previous subtopic. Based on this analysis, we created several initial design concepts and evaluated them against the design requirements and project objectives.

Once the initial concepts were developed, we then evaluated their feasibility and selected the most promising design concepts for further development. This involved creating detailed design sketches and 3D models.

Figure 1 - 3D Model of the Robot

III. HARDWARE IMPLEMENTATION

The hardware components of the robot are responsible for its physical operation and ability to move from one location to another. The hardware implementation involves selecting the appropriate components for the robot and ensuring that they work together to achieve the desired functionality.

The main hardware components of the package delivery robot include the chassis, motors, wheels, batteries, sensors, and microcontrollers. The chassis provides the framework for the robot and supports all other components. The motors and wheels are responsible for the robot's movement and ability to navigate through different terrains. The batteries provide the necessary power for the motors and other components. The sensors detect obstacles, measure distance, and provide feedback for the robot's movements. The microcontrollers process the sensor data and control the motors and other components.

A. Circuit Design

This involves the development of a system of interconnected electronic components that communicate and work together to achieve the objectives of the robot. The circuit design can be divided into two major parts: the power circuit and the control circuit. The power circuit is responsible for supplying the required voltage and current to the components that drive the robot. The voltage and current required by each component vary, and the power circuit must be designed to meet the specific requirements of each component. The power circuit includes voltage regulators, batteries, and capacitors. Voltage regulators are used to maintain a constant voltage level, while batteries and capacitors are used to store energy for the robot's operation.

The control circuit, on the other hand, is responsible for managing the robot's movement, speed, and other parameters. The control circuit includes microcontrollers, sensors, motor drivers, and other electronic components that communicate with each other to provide control and feedback to the robot. The microcontroller is the brain of the robot, and it is responsible for executing the instructions that guide the robot's behaviour. The sensors provide feedback to the microcontroller about the environment, while the motor drivers provide the necessary current to move the motors that drive the robot's wheels.

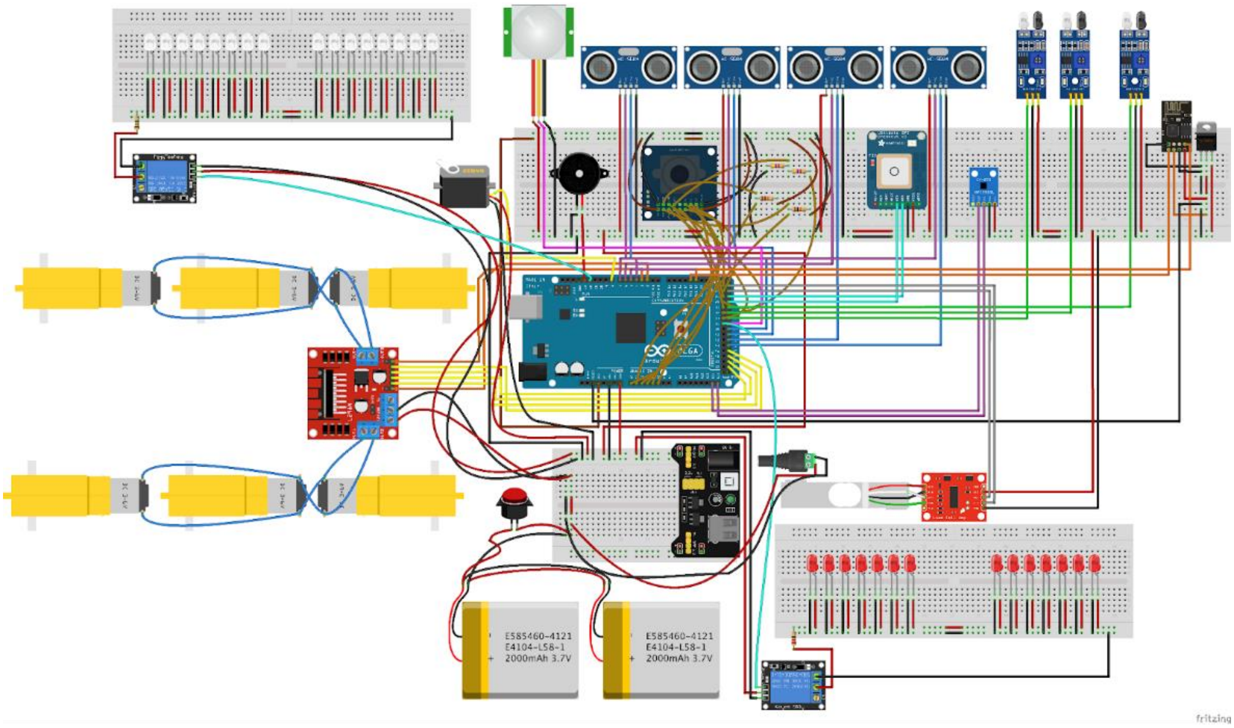

Figure 2: Electronic Design

B. Assembly and Testing

The assembly and testing stage involved the physical construction of the hardware components and software integration. The components were assembled according to the design specifications and circuit diagrams developed in the previous stages. The testing process was carried out to ensure that the system operated optimally, and all components worked together seamlessly.

Figure 3: Electronic Installation Setup

Figure 4: Electronic Installation

Figure 5: Assembly Stage of the Robot

IV. SOFTWARE IMPLEMENTATION

The software is responsible for controlling the robot's movement, picking up and dropping off packages, and interfacing with other components of the system. The software design was based on a modular architecture to allow for scalability, maintainability, and ease of development.

The software implementation involved the use of different programming languages, including C++ and JavaScript. C++ was used for low-level programming tasks, such as interfacing with the robot's hardware components and for navigation and path planning while JavaScript was used for the development of the web-based interface that allows users to interact with the system.

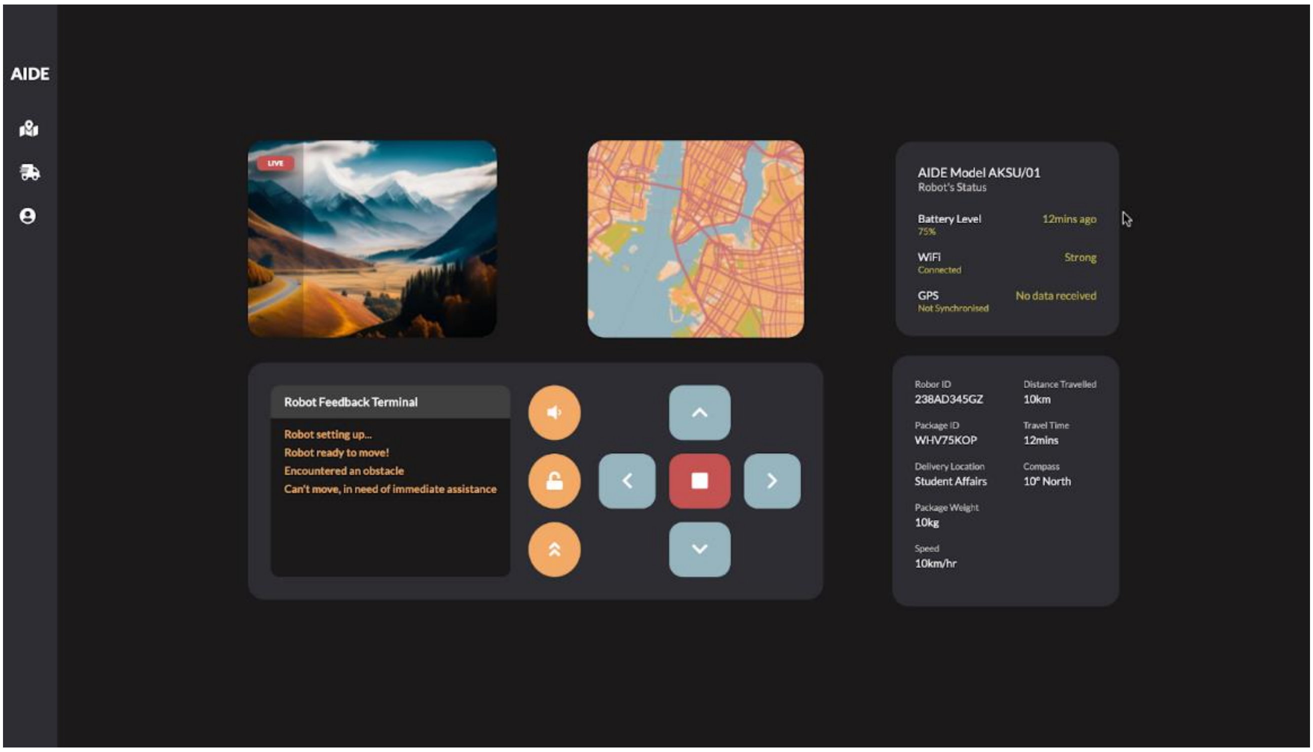

Figure 6: Robot Control Web Interface

A. Programming Languages and Tools

The software for the package delivery robot was implemented using two programming languages, C++ and JavaScript. C++ was used for the high-level control of the robot and for programming the microcontroller. JavaScript was used for developing the web-based user interface for the robot. Both languages were chosen for their efficiency, versatility, and ease of use.

The C++ code was developed using the Arduino integrated development environment (IDE), which provided an easy-to-use platform for programming the microcontroller. The code was written to control the robot's sensors, motors, and other hardware components. The C++ code was also responsible for processing sensor data, navigating the robot, and controlling the robot's overall behaviour.

JavaScript was used to create a web-based user interface that allowed users to interact with the robot. The user interface provided real-time feedback on the robot's status and allowed users to set parameters such as the robot's destination and delivery speed. JavaScript was chosen for its versatility and ease of use, as well as its compatibility with modern web technologies.

B. Algorithms and Flowcharts

The algorithm and flowchart are essential components of the package delivery robot project. They provide a detailed outline of the robot's behaviour and functionality, enabling developers to create efficient and effective code.

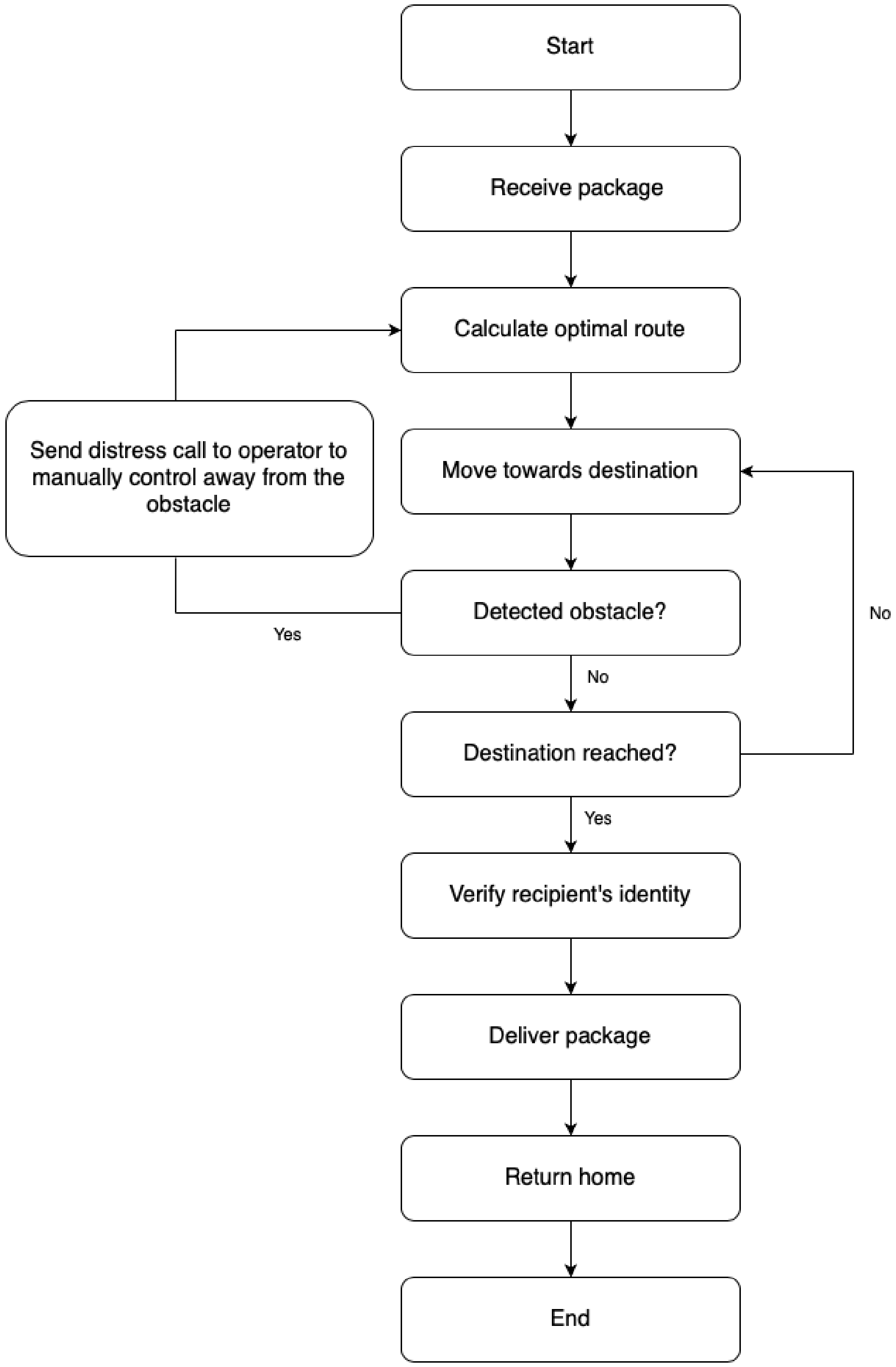

Figure 7: Flowchart for the Package Delivery Robot

V. RESULTS AND CONCLUSION

The results of the performance evaluation were analyzed to assess the effectiveness of the package delivery robot. Several metrics such as distance travelled, delivery time, accuracy, and energy consumption were used to evaluate the performance of the robot. The analysis involved comparing the performance of the robot under different scenarios and identifying areas of improvement.

The results showed that the package delivery robot succeeded in certain aspects but struggled in other areas. The robot was able to deliver packages to the designated location within the expected time frame when controlled by an operator. The energy consumption of the robot was also optimized, ensuring that it can operate for an extended period without the need for frequent recharging. The analysis also identified areas where the robot could be improved, such as the speed of the robot, the material used for the fabrication of the chassis, and the efficiency of the obstacle avoidance algorithm. These areas were noted, and recommendations for future improvements were made. The comparison of our package delivery robot system with other existing systems was conducted to evaluate its performance, strengths, and weaknesses. The comparison was based on various parameters such as cost, power consumption, payload capacity, speed, navigation accuracy, and obstacle avoidance capability.

After conducting extensive research, we identified some existing package delivery robot systems, such as the Amazon Scout, Starship Technologies, and Robby Technologies. We evaluated our system's performance against these systems based on the identified parameters. We found that our system had a lower payload capacity and speed as the Amazon Scout and Starship Technologies systems. Our system consumed more power than the Amazon Scout, making it less energy-efficient.

Additionally, our robot had a slightly less efficient obstacle avoidance capability than Robby Technologies, which relied on a remote-control centre to monitor the robot's movement. However, we discovered that the compared systems used higher technologies than ours, therefore making theirs faster and more effective than ours. Finally, the design and implementation of the package delivery robot were successful, achieving the project's objectives and meeting the design requirements. The robot's performance was evaluated and found to be satisfactory, providing an excellent platform for future work and improvements in package delivery systems.

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