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Design A Wheeled Robot Prototype For Package Delivery

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Abstract
Autonomous delivery robots offer innovative solutions to modern logistics challenges. This research explores the integration of the latest technologies into delivery robots, including a machine learning based hand gesture recognition feature. The hand gesture recognition feature is used for robotic container security, ensuring that only the sender and recipient can open and access the contents of the container. This technology uses machine learning algorithms to accurately detect and interpret the user's hand gestures. This advanced security system provides an extra layer of protection against theft and unauthorised access. In addition, these delivery robots are designed to improve operational efficiency and reduce environmental impact, meeting society's need for fast and accurate delivery services. While offering many benefits, the implementation of this technology faces challenges in terms of community acceptance and operational safety. This study provides insights into how delivery robot technology can be effectively integrated into the global logistics system, shaping the future of more efficient, connected and secure delivery services.
Keywords: *autonomous robot, hand gesture recognition, machine learning, security*

Abstrak
Robot pengiriman autonomous menawarkan solusi inovatif untuk tantangan logistik modern. Penelitian ini mengeksplorasi integrasi teknologi terkini dalam robot pengiriman, termasuk fitur hand gesture recognition yang didukung oleh machine learning. Fitur hand gesture recognition digunakan untuk keamanan container robot, memastikan bahwa hanya pengirim barang dan penerima barang yang dapat membuka dan mengakses isi kontainer. Teknologi ini memanfaatkan algoritma machine learning untuk secara akurat mendeteksi dan menafsirkan gerakan tangan pengguna. Sistem keamanan canggih ini memberikan lapisan perlindungan tambahan terhadap pencurian dan akses tidak sah. Selain itu, robot pengiriman ini dirancang untuk meningkatkan efisiensi operasional dan mengurangi dampak lingkungan, memenuhi kebutuhan masyarakat akan layanan pengiriman yang cepat dan akurat. Meskipun menawarkan banyak manfaat, implementasi teknologi ini menghadapi tantangan dalam hal penerimaan masyarakat dan keamanan operasional. Studi ini memberikan wawasan tentang bagaimana teknologi robot pengiriman dapat diintegrasikan secara efektif dalam sistem logistik global, membentuk masa depan layanan pengiriman yang lebih efisien, terhubung, dan aman.
Kata kunci: *robot autonomous, machine learning, keamanan, hand gesture recognition*

1. Introduction

In the current technological development, the use of autonomous robots has included daily human tasks/jobs. Goods delivery services do have an important role in economic growth, especially in the delivery of goods using land vehicles where the workforce continues to decrease due to a decrease in the birth rate and the elderly population is increasing which requires the use of robots as a substitute for couriers or security officers housing each post in the delivery of goods (distribution to the intended address) by utilizing robotics, electronics and other technologies [1]. In the industrial world, robotics technology has been implemented on industrial machines, robotics technology was chosen because of several advantages including being fast, thorough, able to work fulltime and automatically [2].

The role of robots today is generally used as a toy for the upper economic class, but in the industrial sector, the role of robots is more than that. Industrial robots can do work that requires high precision and accuracy, even in small-scale work where the human eye can no longer see it. New approach that represents autonomous driving delivery robots [3].

2. Material and methods

Robot Rover

Rover or mobile robot is a robot structure characterized by having a wheel-shaped drive that moves the entire robot body so that the robot can move from one point to another[4]. In this project implementation, the rover robot is equipped with various components such as Pixhawk, servo motors, DC motors, remote control, GPS, and Ground Control Station using the Mission Planner application.

Figure 1. Robot Rover

Pixhawk

Pixhawk is an open-source autopilot that is widely used in the world of robotics, especially in drones and autonomous vehicles. Pixhawk flight control board running Ardupilot open source autopilot software equipped with several onboard sensors including a built-in compass and accelerometer [5].Pixhawk serves as the brain of the robot rover, integrating various sensors and actuators to control movement and perform navigation automatically.

Figure 2. Pixhawk 1

Servo Motor

A servo motor is a type of actuator used to control the angular position movement of a servo shaft with high precision. Servo motors are used for steering mechanisms, allowing the rover to move forward, turn, and overcome various obstacles in the terrain. In addition, there is a safety mechanism, the container cover on the robot is connected to the servo motor so that the container can open and close. This ensures the package in the robot container is safe.

Figure 3. MG996R Servo Motor

DC Motor

The DC motor is used to drive the wheels of the robot rover, providing power to move forward, backward, and turn. The synchro drive configuration is an appropriated configuration because, although there are three or more driven and steered wheels, only two actuators motors are utilized[6]. The DC motor is connected to a motor controller that receives signals from Pixhawk to set the speed and direction of rotation of the motor. The use of DC motors allows the rover to have enough thrust to move on different types of terrain.

Figure 4. DC motor 775

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Remote Control

Remote control or remote control is used to manually control the robot rover. The remote control works by sending radio signals to the receiver connected to the Pixhawk, allowing the operator to control the movement of the rover from a distance. The remote control can also be used as a safeguard, allowing manual intervention in case something goes wrong with the automated system.

Figure 5. Remote Control

Telemetry

Telemetry is the process of automatically measuring and transmitting data via wireless signals from a remote location. In general, telemetry operates in the following way: sensors mounted on a source measure electrical data, such as voltage and current, or physical data, such as temperature and pressure. This data is then sent by an electronic device to a different location for monitoring and analysis. Telemetry is a method for measuring electrical or physical data using a telemeter, a device that measures various metrics such as pressure, speed, and temperature. These measurements are converted into electrical signals, which are then combined by a multiplexer along with time data into a single data stream. This data stream is sent to a receiver at a remote location. The receiver then separates the data stream back into its original components, and the data is displayed and processed according to the user's needs, then the data is used as a reference[7] . In reference, [8] the data mentioned in Transmission of data from the vehicle to the Ground Control Station is done through a two-way telemetry system. The telemetry system itself uses 915MHz radio waves to send and receive signals from the vehicle and the Ground Control Station.

Figure 6. Telemetry Radio

GPS

GPS (Global Positioning System) is used to determine the geographical position of the robot rover with high precision. The GPS sensor periodically provides data information on where the robot is located, with the help of a compass sensor that provides the direction of the robot. The data information enters the data processor, then the data is used as a reference[9].

Figure 7. GPS

Ground Control Station

The Ground Control Station (GCS) is a control and monitoring center used to supervise and control the robot rover. The Mission Planner application is used as the GCS. Mission Planner is software that allows users to plan missions, assign waypoints, and monitor robot status in real-time. With Mission Planner, users can view various data, such as GPS position, speed, as well as manually or automatically control the rover.

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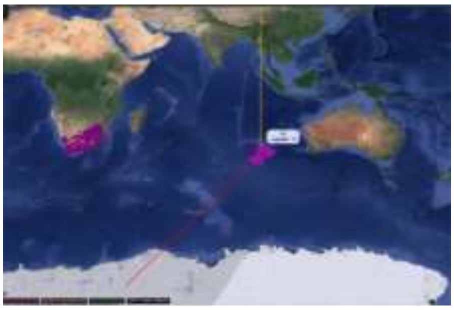

Figure 8. Mission Planner Application

Hand Gesture Recognition

The Gesture recognition is a topic in computer science and language technology aimed at allowing computers to understand human movements in general through hand gestures or facial gestures [10]. With this technology, every change that occurs in the image frame by frame is a challenge to be able to implement the right algorithm for real-time situations [11]. The application of gesture recognition to package delivery robots allows for an increased level of user security. This security allows users to open and access the robot container with predefined hand gestures, ensuring that only authorized individuals can open the delivered robot container. In addition, gesture recognition can also improve human-robot interaction, making the delivery process more intuitive and user-friendly. The use of this technology not only strengthens the security aspect but also speeds up the delivery process by minimizing the need for manual intervention.

Hand gesture recognition works using machine learning by combining the OpenCV library and Mediapipe developed by Google to recognize human hand objects and perform special segmentation for fingers on the hand[12].

OpenCV

OpenCV (Open Source Computer Vision Library) is an image processing library used in various vision applications, including hand tracking. Many computer vision developments use modules that have been provided by developers such as Intel, which provides the OpenCV module in open source that can be used for the Python and C++ programming languages[13]. OpenCV provides various functions for capturing, processing, and displaying images and videos. OpenCV provides functions for drawing shapes and text on images, which is useful for displaying hand and landmark detection results from MediaPipe. OpenCV in this study is only used to display the image sensor (webcam) display. The webcam acts as input from the user where the hand is displayed in front of the webcam and then the results are processed by the computer using the Mediapipe library.

MediaPipe

MediaPipe provides various machine learning models that have been trained, one of which is to detect and track reference points (landmarks) on the human hand. The points are divided into 21 sections that have been defined in the image. By using a combination of MediaPipe and OpenCV, the system can detect and interpret the user's hand movements to control the movement of the container on the robot.

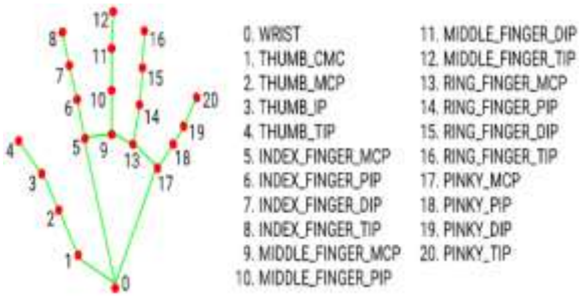

Figure 9. Hand landmarks

3. Results and Discussion

DC Motor Testing

DC Motor testing has a relationship between PWM and motor RPM which is proportional. This serves to determine the optimal setting of PWM to achieve the desired speed by considering the load given to the robot. Calculation of motor RPM is done by measuring the number of motor revolutions in a certain period of time. RPM is calculated by the formula:

$$RPM = \frac{Total\ rotation}{time(in\ minutes)}$$

GPS Testing

The GPS calibration process involves the GPS module, Pixhawk, and Mission Planner application by rotating and moving in all directions with the aim that GPS can receive signals under any circumstances until diagram 1 and diagram 2 in the mission planner application are met. With the function of GPS as a determination of coordinate points assisted by a compass as the cardinal direction. The coordinates obtained will be sent directly to the microcontroller [14]. In urban environments and dense vegetation, although the increase in accuracy is not as significant as in open areas, there is still a significant reduction in deviation. This discussion also includes an analysis of factors that affect the calibration results, such as satellite signal quality and environmental conditions.

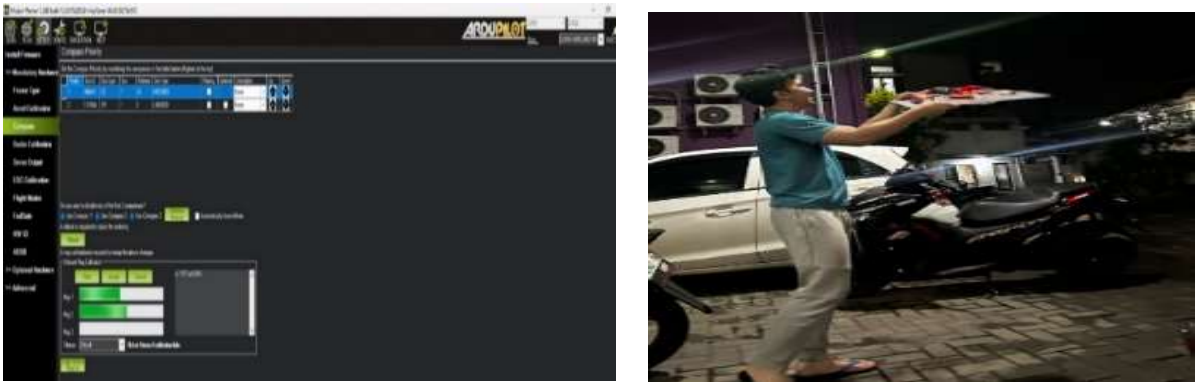

Figure 10. GPS testing process in Mission planner

Hand gesture recognition testing

Testing is done by placing the body position in front of the camera between 0 - 200cm where the user displays fingers 1 to 5 and clenches the hand for reading on the webcam. The reading results can be seen on the terminal in the form of numbers. Testing is also carried out in a place with bright and dark light intensity to determine the accuracy of the webcam in receiving input.

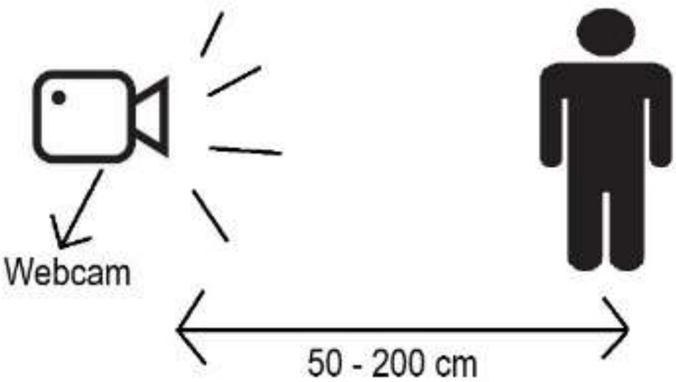

Figure 11. Testing method of hand gesture recognition

Taking the output data from the terminal is 10 data for each finger and clenching is 0 at the output. The data will be used to find the average value of the accuracy of the webcam input reading.

Robot Rover workflow

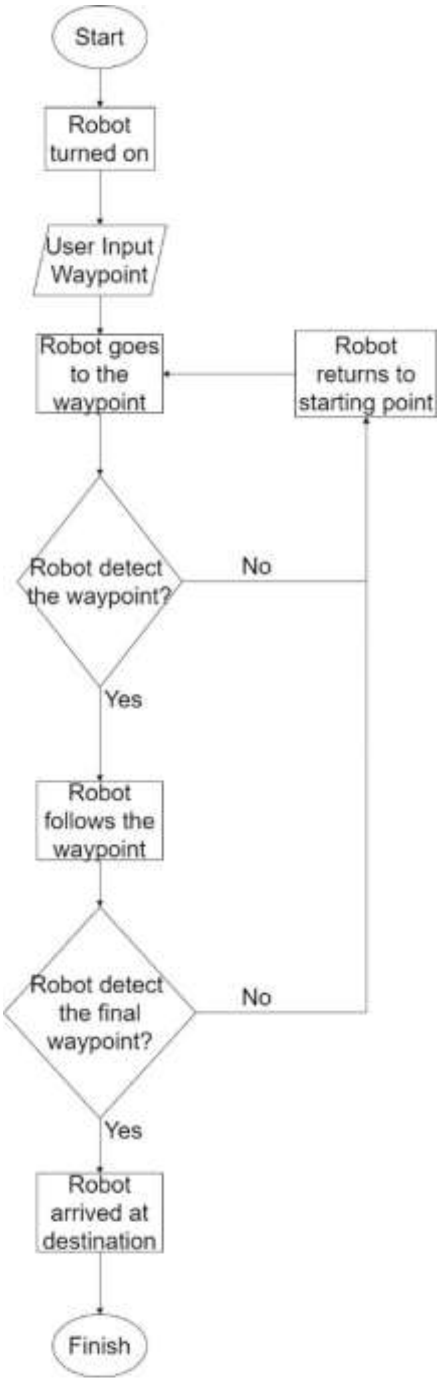

Figure 12. Flowchart of robot workflow

Figure 12 is a robot workflow where the robot will follow the path points that have been determined by the Mission Planner application to the destination. The first thing to do is to determine the point of the path that the robot will pass. Then the robot will follow the points of the path, if there is a point that is not passed then the robot will return to the starting point of departure and follow the path again. If all points have been passed, the robot will provide information to the Mission Planner that the robot has arrived at the destination.

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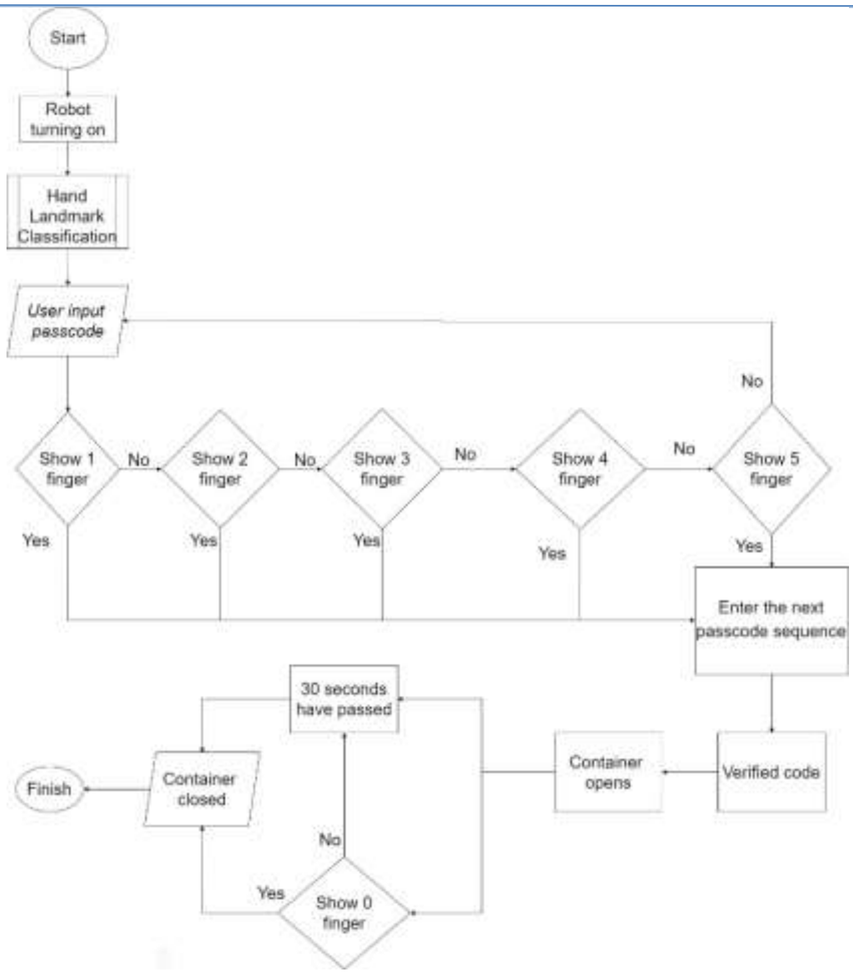

Figure 13. Flowchart of hand gesture recognition system

Figure 13 is a flowchart of the hand gesture recognition system used as the flow of the container security mechanism on the robot. When the robot turns on, the script for hand gesture recognition is active so that the system can receive input from the recipient of the goods. Then the recipient enters the password given by the sender of the goods, if the password entered is correct, the robot container will open. Meanwhile, if the password entered is wrong, then the recipient must repeat entering the password. After the goods are retrieved, the recipient can manually close the container again by making a fist towards the webcam. If the recipient forgets to close the container, then after 30 seconds the container will be closed automatically.

Pixhawk accelerometer

The test results show that the accelerometer calibration process was successfully performed using the Mission Planner application. The calibration process consists of six steps, in which the Pixhawk (Rover) is set in various positions, including normal, left tilt, right tilt, face down, face up, and upside down. All steps are controlled through the Mission Planner program and the aim is to ascertain whether the rover is in the correct position, including knowing whether the rover is tilted left, right, or upside down.

Figure 14. Pixhawk Accelerometer Testing

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Table 1. Accelerometer calibration details

Calibration	Details
Place Vehicle Level	Rover normal position
Place Vehicle Right	Rover position tilted to the right
Place Vehicle Nose Up	Rover position facing up
Place Vehicle Nose Down	Rover face-down position
Place Vehicle Back	Rover inverted position
Place Vehicle Left	Rover position to the left

DC Motor test results

In testing DC motors, the use of tools such as a Tachometer and Wattmeter is very important to get accurate data about the motor's performance. The Tachometer is used to measure the motor's rotation speed in units of RPM, which gives an idea of how fast the motor rotates. Meanwhile, a Wattmeter is used to measure the electrical power consumed by the motor, expressed in watts.

Table 2. Motor RPM test at a distance of 5.3 meters

Throttle	RPM	Current (Ampere)	Power (Watt)
30%	701	0.55	6.8
50%	2303	1.20	14.8
75%	3401	3.15	38
100%	3510	5.12	63

Figure 15. Tachometer and Wattmeter

PWM is increased gradually from 30% to 100%, the motor RPM increases linearly. This analysis is important to determine the optimal setting of PWM to achieve the desired speed considering the load applied to the robot. Based on table 2, the higher the load applied, the slower the RPM of the dc motor.

GPS Test Results

Figure 16. Calibrated GPS test results

Table 3. Coordinates that have been compared

No	Waypoint	Latitude	Longitude
1	1	-6.9759143	107.6304106
2	2	-6.9754813	107.6303208
3	3	-6.9759972	107.6302256

In **Table 3**, we can see the coordinates that have been compared by considering the factors that affect compass accuracy such as calibration, local magnetic disturbance, sensor resolution, and noise, we can analyze the results of this test to assess the directional accuracy of the GPS module. During the calibration process, the compass on the GPS module is optimized to reduce systematic errors and improve directional accuracy. If the GPS receiver is able to capture three satellite signals, it will receive data in the form of longitude and latitude. Meanwhile, if the GPS receiver is able to capture four or more signals from satellites, the GPS receiver is able to receive data in the form of longitude, lattitude[15]. By testing at various points (different longitudes and latitudes), we can see how consistent and accurate the direction shown by the compass is.

Remote control test result

In testing the remote control of the robot, calibration of various directions of movement using the remote control was carried out. The left throttle directed upwards caused the robot drive steering to move forward, while the right throttle directed to the right caused the servo steering to turn to the right. Conversely, the right throttle directed to the left causes the servo steering to turn to the left, and the left throttle directed downward causes the robot drive steering to move backward. Thus, the results of this test show that the remote control can effectively control various directions of robot movement, including forward, backward, right-turn, and left-turn, according to the instructions given by the user through the movement of the throttle and rudder.

Table 4. Remote control testing

Calibration	Details
Left throttle is directed Up	Drive steering goes forward
Right throttle is directed to the Right	Right-turn servo steering
Right throttle is directed to the Left	Left-turn servo steering
Left throttle is directed Down	Drive steering goes backward

Hand gesture Recognition

The analysis required 10 data reading values by the webcam generated by the computer. It is necessary to calibrate the calculation of the average value to take the best value of the webcam reading accuracy that has been tested using the mean formula (The correct value of 10 data divided by the total data on the computer terminal).

Figure 17. Webcam reading results

$$\bar{x} = \frac{\sum X}{n}$$

Details:
$\bar{x} = Mean$
$\sum X$ = Total of correct data
n = Total of taken data (10)

In bright conditions, 10 data from a distance of 50cm and 200cm are taken from the reading data value by the webcam to the computer: $\bar{x} = \frac{10}{10} x\ 100\%$, because the reading of 10 webcam data values generated by the computer in the test results above show all the data is correct, the percentage accuracy value obtained is 100%. Then in low light (dark) conditions, from 10 data from a distance of 50cm and 200cm taken from the reading data value by the webcam to the computer: $\bar{x} = \frac{7}{10} x\ 100\%$because the reading of the webcam data value generated by the computer in the test results above shows fingers 1, 3 and 5 at a distance of 50cm there is an input value that is less accurate and precise. The following are the results of testing the percentage of data accuracy of the output value of the VSCode terminal.

Table 5. Data values calculated from the average value of webcam readings in bright light conditions

Total Fingers	Distance 50cm(%)	Distance 200cm(%)
1	100	100
2	100	100
3	100	100
4	100	100
5	100	100

Table 6. Data values calculated from the average value of webcam readings in low light conditions

Total Fingers	Distance 50cm(%)	Distance 200cm(%)
1	60	90
2	100	100
3	60	100
4	100	100
5	50	100

In bright light conditions the sensor reads with the highest accuracy value, so light conditions greatly affect the webcam in converting digital signals and transferring data readings by the computer. Whereas in low light conditions sensor readings with inconsistent accuracy values, therefore this webcam reading really requires sufficient light to get the maximum data value.

4. Conclusion

Currently, the delivery system in housing still relies on human labor, which can undermine security level. This study aims at reducing the use of human labor in the process of package delivery by employing automated robots. Users only have to give waypoints for destination places and then the robot will move autonomously without direct control from a human being. The test results showed that the robot could deliver items to desired addresses with an adequate GPS accuracy, and that it was able to recognize and follow a sequence of waypoints in “Mission Planner” software appropriately. Furthermore, the robot could be monitored in real time even though it would lose its signal on screen once FPV Camera distance reached 200 meters away from GCS. Also, robot is capable of returning back to its starting point after delivery, accommodating thrust mass up to 2 kg with dimensions of 50 x 40 cm at PWM 30% and average speed of 3.384 km/h as well as having high accuracy levels for reading passcode hand tracking for security during pick-up and receipting as specified by the user.

However, a feature that can detect the presence of obstacles around the robot is still missing, so it needs to be developed by adding a lidar sensor so that the robot can avoid obstacles. In addition, the turning mechanism should be updated to use differential wheels that make the wheels sharpen at unequal rates on the left and right sides. This allows the robot to fold more accurately and efficiently and provides better maneuverability than servos.

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