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ORIGINAL RESEARCH ARTICLE

Optimizing Drone delivery: An efficient design for shipper applications

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ABSTRACT

The concept of using Unmanned Aerial Vehicles (UAVs) for package delivery is gaining momentum in recent times. These Drones are capable of transporting various types of packages, including medical supplies, food, and other goods to remote or hard-to-reach areas. With the increasing demand for rapid deliveries, Drones have become a viable solution for delivering items such as blood products, vaccines, pharmaceuticals, and medical samples. The use of Drones in food delivery is also on the rise, with pizzas, tacos, and frozen beverages being some of the popular items delivered via Drones. To ensure accurate and timely deliveries, this proposed Drone delivery system would employ GPS technology to track the package's location and reach its intended destination. To optimize the efficiency of the system, the Drone would pick up the package from the nearest warehouse to the delivery location, and both the customer and the dispatcher would have access to track the package's live location. In this proposed system, the Drone would pick up the package from the hub and proceed to the consumer's location, dropping the package once the consumer provides the correct OTP. To enhance the system's performance, intelligent control methods and smart sensors are used. Additionally, this system would also have the capability of verifying package delivery via facial recognition technology when handling confidential packages. The Intelligent controllers, sensors and Actuator makes the Drone delivery more optimal.

Keywords: Drone shipper; Unmanned Aerial Vehicles Drone weight optimization; rapid deliveries; facial recognition

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1. Introduction

The future of package delivery is here with the advent of Drone technology. Utilizing GPS tracking, our Drone delivery system can pinpoint the live location of consumers, ensuring packages are delivered accurately and on time to the intended recipient. As technology advances, the use of Drones for package and courier delivery is becoming increasingly necessary[1]. In addition to package delivery, Drones have the potential to revolutionize the food delivery industry. Through a study comparing the efficiency and effectiveness of three different delivery methods—Drone system, robot system and hybrid system[2–4]. The analysis includes the difficulties and advantages of each method in both remote and urban areas[5].

The medical field also stands to benefit greatly from Drone technology. In emergency situations, Drones can be used to efficiently and quickly deliver essential medications and medical supplies. To optimize fleet management and improve overall efficiency, our Drone delivery system employs a modular design[6–8]. In India, Drones have the potential to greatly benefit various fields such as security. By equipping Drones with high-quality cameras and less-lethal weapons for surveillance and crowd control, they can play a crucial role in maintaining safety and order[9–11]. Overall, the use of Drones in delivery and other industries is a promising advancement that can greatly enhance efficiency and convenience[12].

Recently many new and novel technologies have been proposed including lithium based component whose weight is low and performance is high[13–15]. Optimized-charging technologies is also adopted. Chen and Cheng used HSN to AGVs to minimize the cost involved in communication. It was identified that the cost of communication persists during the data, which is sent back to the server or data storage devices[16]. Garcia Lopez et al. used edge computing[17] where the processing of various datas are sent to the component that will process it immediately. This idea of machine learning technology is extended to various applications[18]. Khan et al. analyzed various microprocessors at the nodal level to improve the decision-making ability that helps to improve the speed and performance[19].

Internet of Things (IoT) is also considered for each node assessing in the search process to increase the speed and performance[20]. Various computing studies reveals that the device used for optimization focuses on the specific purpose of the design. In this case, additional equipment's shall be eliminated since it performs multitasking. The positions of all the Drones can be monitored and recorded using Flying Ad-hoc Networks and multi-tasking is analyzed[21]. The AGV datas are collected and are monitored to give instruction and necessary actions[22–24]. For visualizing the datas and scenarios, Grafana used the servers named as MongoDB and MariaDB that is well suited for real world applications. It is an open source that trains the information data[24–27]. The Drones are widely used as scouting[28–30] and also applied shipping purpose[31–33]. The Drone can also collect the air data for further analysis and gives weather report and pollution level[34,35].

The proposed project aims to revolutionize package delivery by introducing the use of Drones, which are controlled by GPS navigation and software that guides them to the customer's prescribed address. A display will be attached to the Drone for customers to acknowledge receipt of their package. Once the package has been delivered, the Drone will send a signal to a server (HOST), which will then notify the customer of the package's arrival. The customer will then need to come out and verify the package by matching their facial pattern captured by the camera on the Drone with the data provided by the server. Once the customer confirms the package is corrected by clicking the OK button on the display, the Drone will drop the package and return to the host address. In the event that the customer is not present to receive the package, the Drone will wait for a short period of time before departing. If the customer's facial recognition matches the data on file, the package will be handed over, otherwise it will not be released. To prevent unauthorized individuals from grabbing the package, the Drone is equipped with a mild shock function that will release the package if triggered and then proceed to its next delivery location. Drones is also called as Unmanned Aerial Vehicles as well as Unmanned Aircraft Systems. It is a type of flying robot, which is remotely controlled or operated autonomously with pre-programmed flight plans. They make use of sensors and Global Positioning Systems (GPS) to navigate and perform various tasks. There are various types of Drones with different sizes and capabilities that can be used for a variety of purposes.

One of the main types of Drones is fixed-wing Drones, which have a rigid wing that is designed to resemble an airplane. These Drones use lift to fly, rather than vertical lift rotors, which makes them energy-efficient. They are capable of covering long distances, mapping large areas, and monitoring points of interest for long periods. However, they can be expensive and require training to fly. Another type of Drones is single-rotor Drones, which are similar in structure and design to helicopters. These Drones have one rotor, a tail rotor, and a spinning wing, which makes them more efficient than multi-rotor Drones. However, they are also more complex and expensive to operate and maintain. Multi-rotor Drones, also known as quadcopters, are the most popular type of Drones and are known for their ease of use, affordability, and control. They have multiple rotors that allow for greater maneuverability, which makes them ideal for aerial photography and surveillance. However, their limited performance of endurance and speed makes their application narrow without expanding to aerial mapping and long-distance inspections. Lastly, there are hybrid Drones which are a combination of the above-mentioned types of Drones. They provide the best of both worlds and are most suitable for certain application and use cases.

2. Comprehensive theoretical basis

2.1. Drone design and model

The design of the quadrotor is based on simplicity and ease of control. By adjusting the speed of the rotor for each of the four driving motors, the quadrotor is able to control its attitude in roll, pitch and yaw. Among the four, two motors rotate in clockwise direction and the other two in anticlockwise direction. Thus balancing the torque and yaw direction. This eliminates the need for a mechanical pitch linkage and makes the quadrotor easy to operate. By varying the speed of all rotors of the motor, the thrust of the Drone is optimally controlled. The Drone configuration for the quadrotor was chosen to minimize weight and to optimize the control strategy, by considering various factors and parameters including structural stiffness. There are two options for the quadrotor's design: one option connects all the four motors to the central fuselage with dedicated composite bars, while the other option uses radial bars as shown in **Figure 1**.

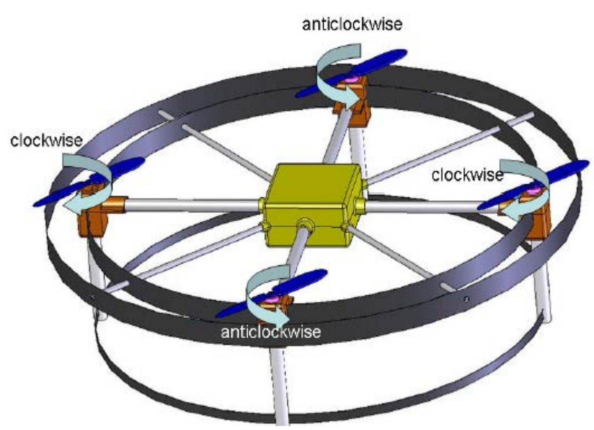

Figure 1. Quad-rotor configuration.

The design of the quadrotor is engineered to be structurally sound and easy to assemble. Its unique layout minimizes vibrations and increases stiffness, making it less susceptible to bending. The materials used in the structure were chosen for their strength and durability, while also being lightweight to ensure easy portability. The central hub is designed to ensure proper alignment and orientation of the rotors during assembly, and can be easily disassembled for maintenance. The prototype uses commercial RC equipment for the electric motors and rotors for its cost-effectiveness and ease of use. The use of rigid rotors simplifies the aerodynamic modeling, but may increase external disturbances. To enhance safety, the quadrotor features an external carbon fiber shield around the propellers. The overall specifications of the aircraft can be found in the **Table 1**.

Table 1. Drone specification.

Dimension	650 × 650 mm
Propeller size	254 × 120 mm
Structural weight	800 gr
Total weight	1300 gr
Payload weight	600/750 gr
Brushless engine	
Size	30 × 37 mm
Weight	55 gr
Speed controller	
Maximum	20 A
Weight	14 gr

The weight of the proposed Drone is estimated using $T = 2 \times W$; where T is the thrust force and W is the weight of the Drone or quadrotor. The power required by the brushless motor is calculated using $P = K \times N^3 \times D^4 \times \partial \times \eta$; where K is the propeller constant whose value is 5.3×10^{-15}, N is the speed of the rotor in rpm, D is the diameter, ∂ is the pitch of the propeller, and η is the efficiency.

The thrust generated by the rotors is calculated using $T = [(\eta P)^2 \times 2\pi \mathrm{R}^2 \times \rho]^{1/3}$. The velocity of air accelerated downward is calculated using $V_d = 2P\eta/T$.

To control the direction and movement of a quadrotor, the rotation speed of each of its four propellers must be carefully manipulated. By adjusting the thrust produced by each rotor, the aircraft can be made to hover, move forward, or change direction. To achieve a stable hover, all rotors must rotate at the same speed. This creates equal thrust in all directions and cancels out any torque. To move forward, the thrust on one motor is decreased while the other motor thrust is increased, creating a rotation around the pitch axis. Similarly, lateral movement is achieved by adjusting the thrust on two opposite rotors and rotation around the roll axis. Lastly, to change the yaw, the thrust on alternate motors is increased and decreased and constant altitude is maintained during the operation.

2.2. Components

The main components of the delivery Drone are frame, motors, propellers, battery, flight controller and sensors. The frame of the Drone enhances the structural integrity. It provides support to all the other components associated with it. The motor helps the propeller to take off the entire body. The propellers lift off the Drone from the ground and helps to fly. The battery is the power source for motors and other loads such as LEDs, sensors and so on. The flight controller is the brain of the Drone that controls and manages the entire operation with the help of humans. Various sensors used in the device are gyroscope, compass, position sensor, velocity sensor, and altitude sensors. The camera module acts as the eye of the Drone.

The design of this system centers around the use of a multi-rotor Drone, specifically chosen for its capabilities in delivering lightweight packages. These Drones are controlled by adjusting the speed of multiple motor-propeller units, making them aerodynamically unstable and requiring an on-board computer for stable flight. The computer uses data from gyroscopes and accelerometers to maintain an accurate estimate of the Drone's orientation and position. The quadcopter configuration is the simplest type of multi-rotor Drone, with each motor-propeller spinning in the opposite direction of the ones on either side of it. The Drone can control its roll and pitch by adjusting the speed of certain motors, and can turn left or right by adjusting the speed of diagonally opposite motors. Horizontal motion is achieved by leaning the Drone in the desired direction of travel and increasing overall thrust. The altitude of the Drone is controlled by adjusting the motor speed.

In this work, we are utilizing the technology of GPS to track the location of the consumer and ensure accurate delivery of the package. The specifications of GPS Module are shown in **Table 2**. The GPS system is a widely used in navigation technology that provides information on location and time. The GTPA010 module is integrated into the Drone, making it easy to use and able to interface with microcontrollers with a voltage range of 3.2 V to 5 V. The GPS data output of the module makes it simple to parse and extract the necessary information for guiding the Drone to the correct destination. This is a crucial component in ensuring that the package is delivered to the correct location and the right person.

Table 2. Specifications of GPS module.

Specifications	
Size of the printed circuit board	46 mm × 18 mm
Total No. of channels	60
Relative humidity (RH)	10% to 90%
Rate of data transfer	4800/9600/38400/57600/115200 BPS
Frequency	L1, 1575.42 MHz, C/A Code-1.023 MHz
Communication protocol	UART
Current and voltage (operation)	<30 mA at 3.0 V
Power rating	100 mW
Accuracy range	3 m
Sampling rate	10 Hz
Power supply voltage	3.2 V to 5.0 V (typical: 3.3 V)

3. Proposed methodology

The package delivery process utilizing Drones is a unique and efficient method that uses GPS location technology to navigate the Drone to the designated destination. The schematic diagram of the proposed system and the flow diagram of facial pattern are shown in the **Figures 2** and **3** respectively. The Drone is equipped with advanced sensors, such as a facial recognition sensor, to ensure accurate and secure delivery. Prior to placing an order, customers are prompted to provide their facial features which are then stored in the server's database. When the Drone reaches the delivery location, it captures an image of the recipient and sends it to the server for comparison. Once the server verifies the recipient's identity, it sends a message to the customer to retrieve the package. If the facial recognition sensor is unable to verify the recipient's identity, the Drone returns to the hub.

The server is connected to the Drone and the Drone signal is captured to the Global Positioning System (GPS). The GPS signal have control over camera through which user can have control over it. All the signal is returned back to the server. Then the signal is generated to check the facial pattern of the person. If the facial pattern maps with the recorded pattern then the package shall be delivered as per the command. If the facial pattern doesn't maps then the package will be holded.

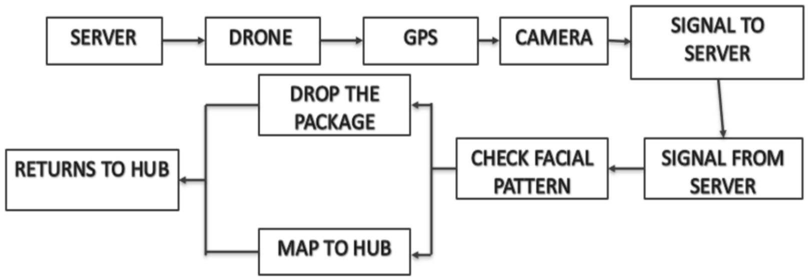

Figure 2. Schematic diagram of the proposed system.

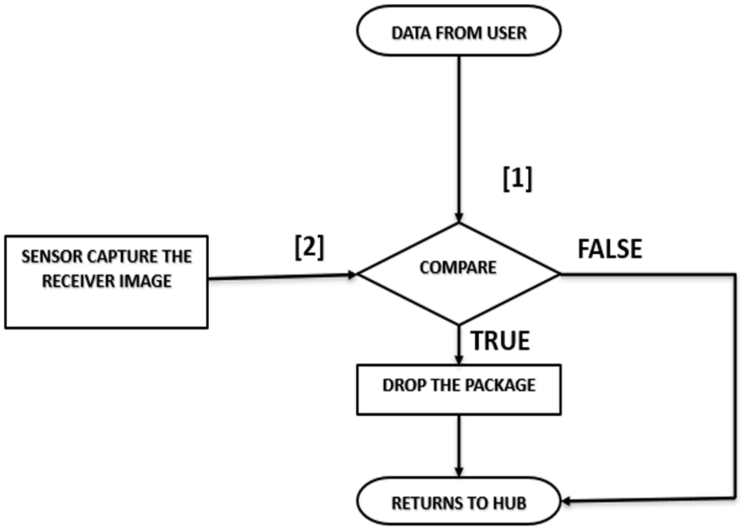

Figure 3. Flow diagram of facial pattern.

The package delivery process begins with a consumer placing an order through a specially designed app created by the host. As part of the registration process, the consumer provides their personal information such as their address, contact number, and a facial scan to be used for verification purposes. Upon receiving the order, the host prepares the package and loads it onto a Drone, along with the consumer's address and facial scan. The Drone then utilizes GPS to navigate to the consumer's location, mapping the shortest distance and making its way to the exact destination. Upon arrival, the Drone sends a signal to the host, and a message is sent to the consumer to come and collect the package. The Drone captures the consumer's facial pattern and compares it to the one provided by the host at the time of loading. If there is a match, the Drone releases the package and returns to the hub. If there is no match, the Drone displays an "incorrect match" message and returns to the hub.

The signaling between Drone and server working is done using Robocraze GPS module and backup radio link (RDS2) will be enabled when the GPS system fails and send alert signal. When both technology fails, the Drone wait for 10 min and with the help of optical sensor, it lands to a near safe place. The package will be dropped from 12 to 15 feet in the air.

4. Results and discussion

The comparison table presented below highlights the distinctions between the current model and the proposed model. It primarily delves into the design, performance, and key components of both models, as well as how the proposed model has improved upon the previous model in terms of weight and advanced features.

This comparison shown in **Table 3** illustrates the advancements made in the proposed model to ensure a more efficient Drone for delivery services.

Figure 4 illustrates a weight comparison between a traditional single wing Drone and a rotor Drone utilizing the hover control model.

Table 3. Tabular column of existing and proposed model.

Description	Delivery service with OTP (existing)	Delivery service with facial pattern (proposed)
Explanation	The Drone is used for the delivery service with the help of GPS and GSM module for location tracking and verification process.	The Drone is used for the delivery service with the help of GPS and face recognition module for location tracking and verification process.
Key component	GSM network	Facial recognition
Out come	The Drone will deliver the package when the consumer enters the correct OTP. Else it will return to base.	The Drone will deliver the package when the consumer facial pattern matches with the data provided by the host. Else it will return to base.
Weight of the Drone	1.7 kg	1.3 kg
Weight of the payload	300/350 Gms	600/750 Gms
Flight time in minutes (maximum)	30 min	31 min
Speed in KPH (maximum)	72 kph (S-mode)	72 kph (S-mode) 50 kph (P-mode)
Angular velocity in degree per second (maximum)	200°/s (S-mode)	250°/s (S-mode) 150°/s (P-mode)
Take-off weight	907 g	1375 g
Flight distance in KM (maximum)	14 km	18 km

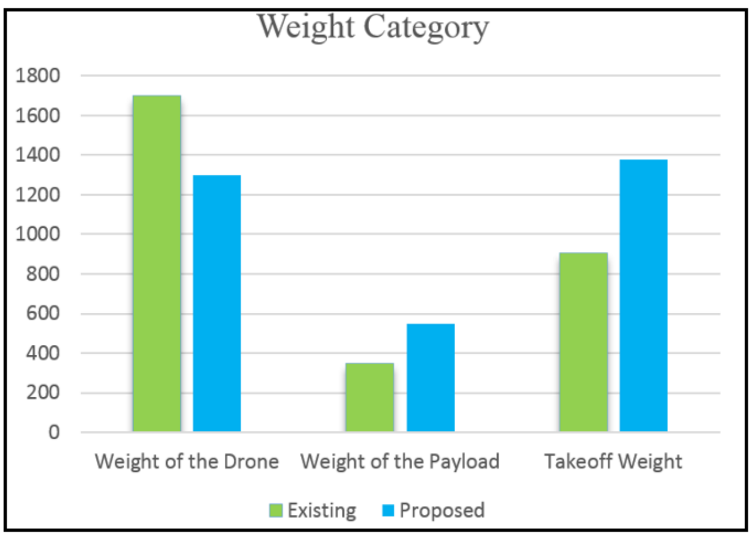

Figure 4. Graph of weight category of existing and proposed model.

The graphic displays a clear distinction between the two, with the rotor Drone being significantly lighter in weight. This is due to the rotor Drone's design, which utilizes multiple rotors for lift and propulsion rather than a single wing. This allows for a more efficient distribution of weight and a reduction in overall aircraft weight. **Figure 5**, on the other hand, compares certain features of the single wing Drone and rotor Drone using the hover control model. The graphic displays a side-by-side comparison of various parameters such as power consumption, flight duration, and control stability. The rotor Drone is seen to have superior performance in all of these areas, highlighting the advantages of its design over the traditional single wing Drone. This includes the rotor Drone's ability to maintain stable flight through the use of multiple rotors, which allows for greater control and efficiency. Additionally, the rotor Drone's power consumption is lower, resulting in a longer flight duration. These comparisons provide a clear advantage of the rotor Drone over the traditional single wing Drone in terms of design, performance, and weight efficiency.

The whole flow from take-off to delivery shall be configured using Mission planner 1.3.76 as shown in **Figure 6**. It is an open source firmware used to configure the route with the help of google map or other related map.

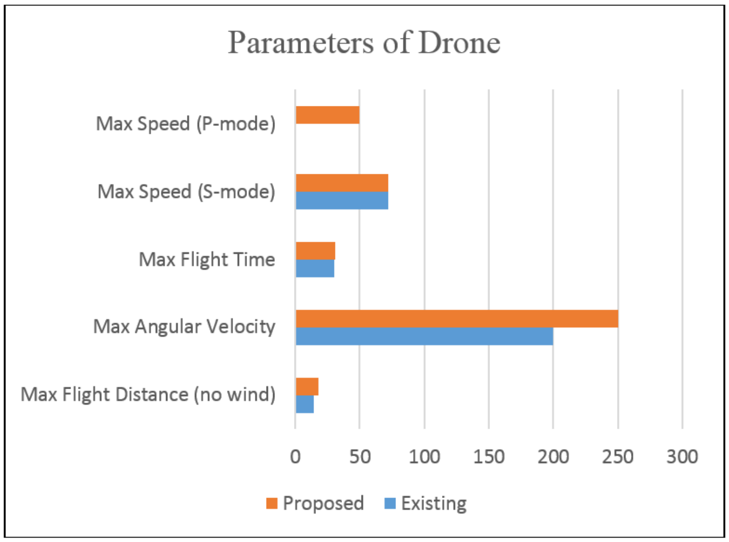

Figure 5. Graph of parameters of Drone.

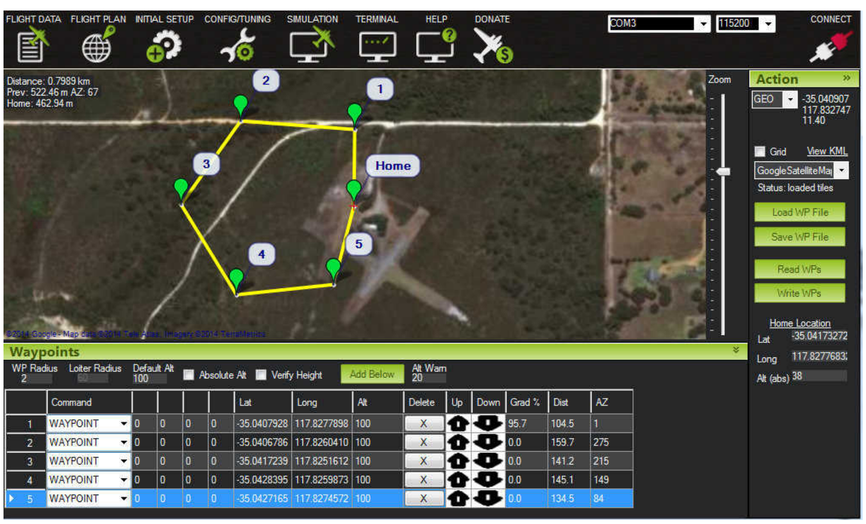

Figure 6. Sample flow path of Drone delivery.

Mission planner 1.3.76 is a firmware application used to monitor the Drone delivery process and system. The mission planner is also used as the configuration utility for the proposed Drone system. This uses google map for setup or configure the route. The algorithm of facial recognition is embedded in the server at the remote place and its communicated through the Drone. The Drone captures the image of the target person and matches with the registered details. Once it matches, it proceeds with the next stage. If it fails, OTP option helps for the successful delivery.

The theoretical modelling and the simulated analysis of the proposed system shall be updated with longitudinal approach with a dashboard and analyze the delivery experience over time and patters. The facial recognition by varying the camera angle shall be analyzed, since the efficiency shall be improved by varying the camera angle. Various AI technics shall be incorporated and compared for better facial recognition. The 3D modelling techniques may also improve the performance of face recognition. There is a risk of morphs, hence suitable techniques shall be followed to reduce the risk of morphs. Hybrid power source techniques shall be focused to improve the available energy source for uninterruptible service. Accuracy, network communication, power consumption and hybrid power source are the part of future plans to enhance the system.

5. Conclusion

The use of Drones for package delivery is a growing trend, particularly for small, lightweight items such as drugs, food, and electronics. Drones with Nano technology offer the advantage of faster delivery times compared to traditional transportation methods, due to their ability to bypass traffic and travel directly to the destination. Nano engineered motors creates wide possibility in the development of Drone technology. To improve the efficiency and performance of these Drones, various techniques such as hover control model have been employed to minimize the overall weight of the Drone, allowing for increased payload capacity and higher fleet height. The results illustrate the weight and feature comparison between the single wing Drone and the rotor Drone using hover control model, it can be observed that the hover control model has significantly reduced the gross weight and increased the payload weight of the Drone, resulting in improved performance and efficiency. The Drone Delivery Service can be enhanced by incorporating a feature that allows consumers to accept or decline orders. Users can opt-in to receive their package by confirming the delivery, or they can choose to decline the order, prompting the Drone to return to the hub. Additionally, the service can be expanded to accommodate the delivery of larger packages. The Drones can be equipped with advanced sensors to accurately capture the user’s facial patterns for identification and verification. Currently, packages are only delivered to the doorstep, but in the future, the service can be advanced to include the capability of delivering packages to specific floors within a building. This will require further development of the Drone’s navigation and delivery capabilities. Drone motion control may be revolutionized with the adoption of Nano technology in Drone development.

Author contributions

Conceptualization, KSP and SR; methodology, KSP; software, KSP; validation, NK; investigation, SK; writing—original draft preparation, KSP; writing—review and editing, SR, SK and NK. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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