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Research Article

Development of 650mm Unmanned Drone for Greenhouse

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Abstract

A unmanned drone was developed with a length of 650 mm and a height of 300 mm for the purpose of preventing pesticide poisoning in the greenhouse. A Flight Controller (FC) was used to control the drone and an Electronic Speed Controller (ESC) was used for stable motor control. Thrust and discharge tests showed a thrust of 1,331 at 90% of Pulse Width Modulation (PWM) capable of a combined flight. The drone could fly for more than 5 minutes. As a result of measuring the flight time of the drone, it took 5 minutes and 5 seconds to fly with a control liquid and 7 minutes and 15 seconds without a control liquid. Since it is expected that it will take about 100 seconds to control each greenhouse, the 650mm unmanned drone is expected to be used effectively in greenhouses to prevent pesticide poisoning.

Keywords

Unmanned drone, Flight controller, Greenhouse, Pesticide control, Flight time

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Introduction

The agricultural sector has steadily developed recently through the White Revolution and the Green Revolution. In particular, smart farms and greenhouses that apply information and communication technology have become the driving force that guides the agricultural industry (Choi, 2020; Kim et al., 2020; Min et al., 2020; Shin & Jeon, 2020) . Smart farms are being researched in a variety of ways because they can improve work speed and efficiency. However, as smart farm facilities require a lot of investment, the number of farms using greenhouses such as vinyl greenhouses is increasing. To increase agricultural production, pests that occur in crops must be controlled. However, pesticides used to control pests often cause poisoning accidents among farmers. The use of drones is increasing as an alternative way to reduce the control time and prevent pesticide poisoning accidents. Drone is one core field of the Fourth Industrial Revolution. Drones are being studied not only in agriculture, but also in other industries because they have the advantage of being able to be remotely controlled by radio waves while performing missions (Kim et al., 2021; Kim, Lim, & Jung, 2019; Lim, 2019, 2020; Son et al., 2021; Yoo et al., 2020) .

Recently, research using drones for smart safety city platform construction and particular matter measurement is being conducted (Cho, 2020; Park & Ko, 2020) . In addition, research is underway to apply LoRa technology and drone technology to live broadcasting systems (Mfitumukiza et al., 2016). Also, attempts are being made to use drones for systematic information management of forest resources (Oh, 2019). In the agricultural field, drones are already being used, and recently, a monitoring system that can check battery data in real time so that drones can fly safely is also being studied (Lee, Yang, & You, 2017). However, drones used for pest control are very large in size. When they are used in greenhouses with outer walls made of vinyl or glass, there is a great risk of damaging not only drone, but also greenhouse. For this reason, farmers who operate facility houses often use pesticides directly to control the facility to prevent damage to the facility. To control pests using drones in greenhouses, drones need to be miniaturized and lightweight to make them smaller and easier to move. In this study, a small and lightweight drone that could be used for pest control in greenhouses was developed and its characteristics were analyzed.

Design and Development

Greenhouses used in the agricultural sector vary in size depending on characteristics of the cultivated crop. The most popular greenhouse is made with a width of 8 m, a length of 100 m, and a height of 3 m. Since the maximum height of a greenhouse is 3 m, considering the height of a cultivated crop, there is a margin of about 1 to 2 m left. In addition, if there are more than four grooves in a 8 m wide greenhouse, the width of the drone must be very narrow. Therefore, a drone with a width of 650 mm and a height of 300 mm was designed and developed. Figure 1 shows a 3D design of the unmanned drone for greenhouses.

Fig. 1. 3D design of the 650 mm unmanned drone for greenhouse: A, Size of the 650 mm unmanned drone; B, Isometric of the 650 mm unmanned drone

The drone for greenhouse has a battery that supplies power, a fuselage part for flight, and a spray part for pesticide control. Figure 2 shows a block diagram of the 650 mm unmanned drone for greenhouse.

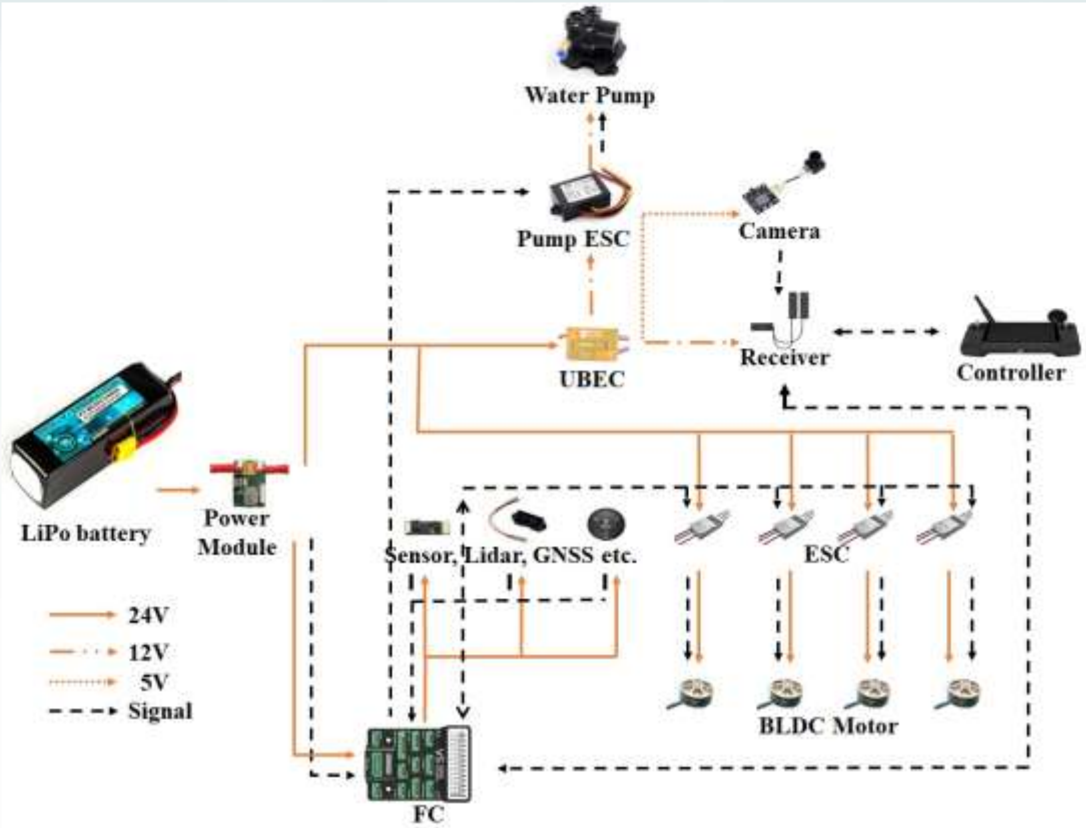

Fig. 2. Block diagram of the unmanned drone for greenhouse

To power unmaned drone, 22.2 V, 6,300 mAh, and 6-cell Li-Polymer Batteries (PT-B6, 300mAh POLY-TRONICS Co., Ltd, China) were used. The applied power is dropped to 5V via a Power Module (HV Power Module, CUAV Co., Ltd., China), a supply to Flight Controller (FC), and a supply power of 25.2–22.2V via the Power Distribution.The FC was used for drone fuselage control and automatic flight control. The FC (Pixhawk v5 nano, CUAV Co., Ltd, China) had a built-in FMU V5 and a STM32F765 high-performance processor with three accelerometers and three gyro sensors to help maintain speed, direction, and horizontality. In addition, 5V power required for operating Global Navigation Satellite System (GNSS), Light Detection And Ranging (Lidar), air flow sensor, and front sensor to be stably supplied was set.

Since the unmanned drone should be used in tight spaces such as greenhouses, if accurate location information is not reflected, they can cause serious damage to vinyl greenhouses and crops. Therefore, the drone was set up to be able to receive location information in centimeters using GNSS. The GNSS (Here+ RTK, HEX Co., Ltd, China) used in this study could receive up to three location information at the same time from GPS, Galileo, GLONASS, and BeiDou to calculate the precise latitude and longitude and check the drone's real-time flight location and route, allowing the drone to fly automatically. Considering the maximum takeoff weight, an efficient Brushless DC motor (BLDC, Antigravity MN4006 KV380, Tmotor Co., Ltd, China) was used to rotate the propeller to generate lift and thrust. An Electronic Speed Control (ESC, Alpha 40aesc, T-motor Co., Ltd., China) was used to control current and motor speed by PWM signals received through the FC. To avoid outer walls and obstacles, a front sensor (Tf Mini, Benewake Co., Ltd., China) was equipped to recognize distances of up to 12 m and measure up to a range of 2.3°. The front sensor used in this study was suitable to be mounted on the drone that was miniaturized and lightweight with a size of 42 mm x 15 mm x 16 mm, a weight of s 0.3 g, and an automatic avoidance function to enhance safety.

In addition, even if crop growth rate was not uniform, the lower part of the drone was equipped with a Lidar (Here flow, HEX Co., Ltd, China) sensor to maintain a certain distance from the crop. Using a controller (Herelink Airunit, HEX Co., Ltd, China) to which the transceiver integrated module was applied, the video transmitted from the camera could be viewed in real time via a Qground program. The controller used a 2.4 GHz frequency band to control the drone and received the video. It could control the drone up to 20 km and transmit flight data and real-time. Figure 3 shows the developed unmanned drone

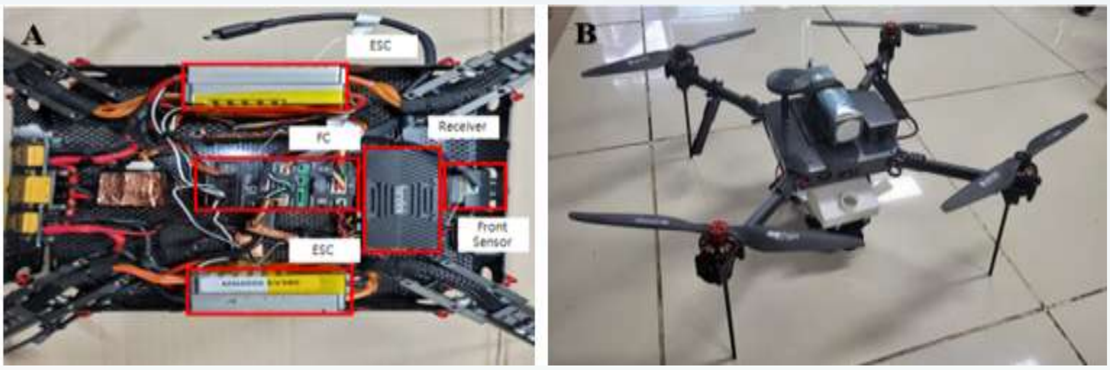

Fig. 3. The developed unmanned drone for greenhouse: A, Main parts inside the drone; B, Fabricated of the drone

Results and Discussion

Drone need more thrust than gravity and drag to fly. Therefore, the thrust of the drone was measured using a thrust tester (Series 1580 Thrust Stand, Rcbenchmark, Canada). In the experiment, the motor, ESC, battery and propeller used in the drone were connected to a computer to measure the amount of thrust generated. System of the thrust test are shown in Figure 4.

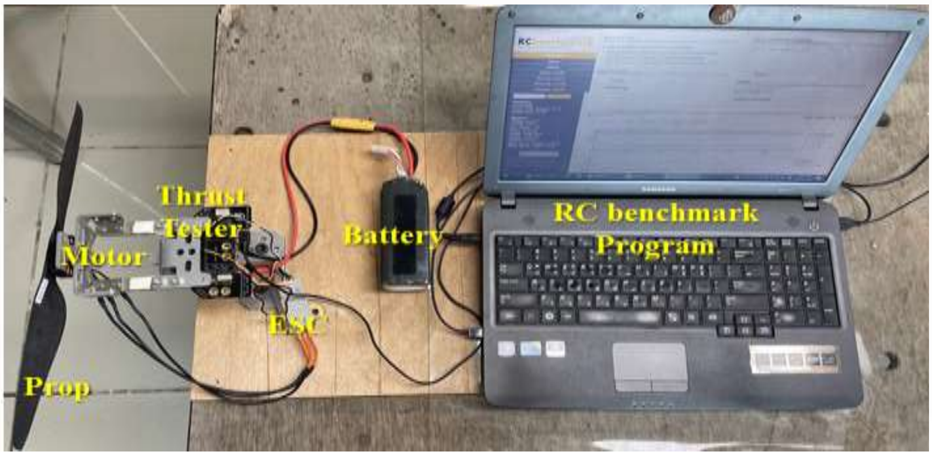

Fig. 4. System of the thrust test

The developed drone is used under conditions of temperature and humidity higher than room temperature. Therefore, the motor output was limited to a maximum of 90% for safe operation. A RCbenchmark GUI program (RCbenchmark, Tyto Robotics Inc. Canada) was used to analyze thrust characteristics. Revolution Per Minute (RPM), thrust, and current consumption were measured while varying the Pulse Width Modulation (PWM) throttle range of the motor from 0% to 90%. Results are shown in Figures 5 and 6.

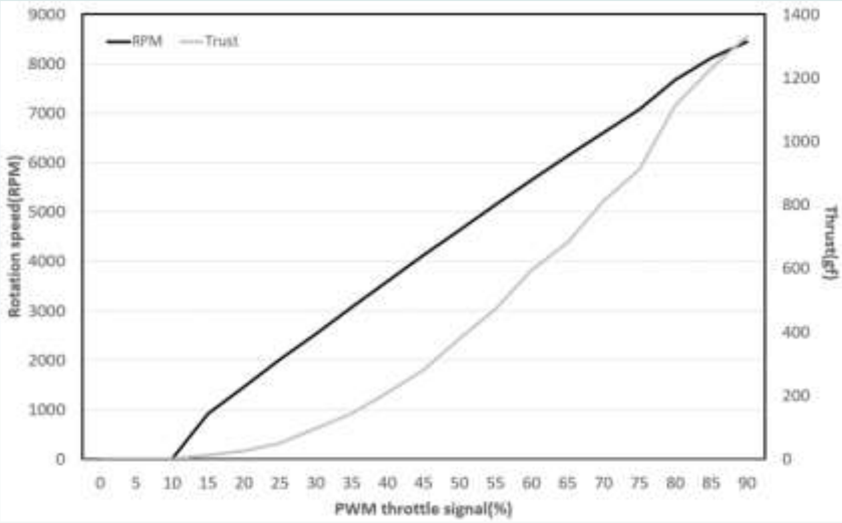

Fig. 5. Thrust and RPM measurement results according to PWM throttle change

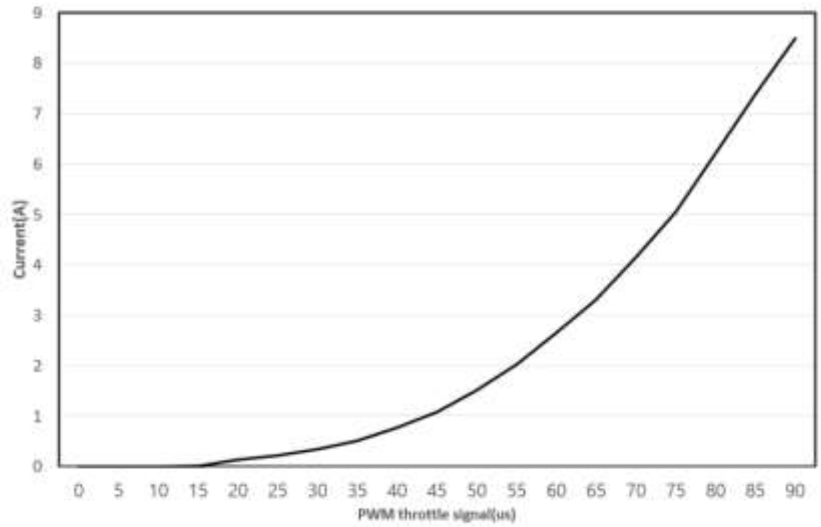

Fig. 6. Current consumption measurement result according to PWM throttle change

As a result of measurement, the motor did not rotate until 10% of PWM throttle. This was because it did not exceed the threshold voltage required to drive the motor. The actual operation started from 15% of PWM throttle. At 90% of PWM throttle, a thrust of about 844 RPM and 1,331 gf was generated. Now that the result was a measured value of one motor, the actual thrust generated by the drone would be 5,324 gf. Considering the weight of the drone, the drone was expected to be able to hover at a thrust of 4,640 gf and to fly and hover at 80% of PWM throttle. Considering that the general height of a greenhouse is 3 m, it is judged that sufficient thrust can be secured for the drone to operate. The current consumption showed a linear increase as the motor and propeller were driven faster. A lower current was consumed compared to the simulation result. To calculate the flight time of the drone, batteries used in the discharge tester (BD200 Dischager, Sky Rc, China) were connected and the discharge was tested. Figure 7 shows the system of the discharge test.

Fig. 7. System of the discharge test

At the time of the experiment, the full charge voltage was set to be 25.2 V and the maximum discharge voltage was set at 22.2 V. The consumption current used to operate a propeller in the range of 50% to 90% of PWM throttle was entered with reference to Figure 6. Table 1 shows results of the discharge test.As a result of the discharge test, one propeller was driven at 50% of PWM throttle for about 157 minutes. It means that a drone with four propellers can use the battery for about 39 minutes at 50% of PWM throttle. In addition, it was measured that the drone could use the battery for more than 7 minutes at 80% of the PWM throttle where hovering was possible. It could use the battery for more than 5 minutes at 90% of PWM throttle, which was the maximum output. Assuming that a drone is flying at a speed of 2 m/s in a working environment such as a small greenhouse, it is expected that it will take 100 s to control one greenhouse. Therefore, the drone made in this study can secure sufficient control time.

Table 1.
Results of the discharge test

PWM throttle (%)	Current (A)	Time (s)
50	1.8	9,450
55	2.0	7,140
60	2.6	5,460
65	3.23	4,200
70	4.1	2,940
75	4.9	2,430
80	6.23	1,740
85	7.4	1,500
90	8.55	1,260

However, in an actual flight, drones require more thrust due to external environmental factors such as wind in addition to the weight of the fuselage. Inside the greenhouse, drones are less affected by wind. However, their own vortex may cause them to depart from the path and reduce flight safety. In this study, the drone was designed to be operated stably by controlling the thrust generated from each motor via FC. Table 2 shows measured flight time of the unmanned drone developed in this study.

Table 2.

Flight time of the unmanned drone

Flight classification	Hoverling		Mixed flight	
Contains pesticides	With pesticides	Without pesticides	With pesticides	Without pesticides
Flight time	5min 11sec	7min 30sec	5min 5sec	7min 15sec

In the discharge test with 80% of PWM throttle, which could allow the drone to hover, it was predicted that the drone could hover for about 7 minutes and 15 seconds. However, the actual hovering time with the control liquid was about 5 minutes and 11 seconds. Thus, there was a difference in flight time due to increased power use and weights of sensors and cameras, including the FC used for the drone. In addition, in the discharge test when the PWM throttle was set to be 90%, the flight time was measured to be about 5 minutes and 15 seconds. The actual flight time was measured to be about 5 minutes and 5 seconds. Considering that the maximum estimated time required to control one greenhouse is less than 2 minutes, it is judged that the drone can be fully utilized in a greenhouse.

Conclusion

The unmanned drone was designed and developed to prevent poisoning accidents during pest control in greenhouses. Considering the size of a greenhouse, a drone with a width of 650 mm and a height of 300 mm was designed and developed and its characteristics were evaluated. For safe characteristic evaluation, the motor output was limited to up to 90%. As a result of the thrust test, the motor was driven from 15% of PWM throttle. A thrust of about 844 RPM and 1.331 gf was generated at 90% of PWM throttle. The discharge test was expected to allow a combined flight of 5 minutes or more at 90% of PWM. As a result of measuring the combined flight of the unmanned drone designed and developed in this study, the drone was able to fly for 5 minutes and 5 seconds with a control liquid and 7 minutes and 15 seconds without a control liquid. It was judged that the difference between the discharge test result and the actual flight time was caused by the power consumption and weight increase due to various sensors and cameras. It is expected that about 100 seconds are needed to control a greenhouse using a drone. Therefore, the unmanned drone developed in this study is considered to be useful controlling a greenhouse. It is expected to be able to reduc pesticide poisoning incidents in farmers.

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