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Rice Seed Sowing Drone for Agriculture

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Abstract: This paper discussed about the design, development and test of a quadrotor drone in the rice seed sowing process of the wet seeded rice farming. A seed sowing mechanism was designed to be attached to a quadrotor which allows the process of rice seed sowing to be more precise and uniformly distributed. The rice seed in this experiment is planted inside a capsule filled with peat moss to prevent seedling damage as well as to provide more effective seed sowing. The seed sowing mechanism is designed based on a spiral spinner which can provide sufficient amount of release force that can overcome any disturbances and can propel the seed toward the desired target position.

Keywords: Quadrotor Drone, Precision Agriculture, Capsule, Rice Seed

1. INTRODUCTION

One of the critical issues in agriculture is lack of workers. Rice is one of the most important economic crops in Thailand and contributes to the most export income (180,270 million baht and 11 million metric tons at 2018) [1]. Nowadays farmer (1,984 farmer group) and farming area are gradually decreasing (71.2 million rai at 2018) [2] due to the economic circumstance. Hence, there should be a new rice farming method that is more efficient. One of the methods that can solve both technical and labour problems is to use drone for rice farming. At present, farmers have used various types of drone in rice farming process, for example spraying fertilizer and taking photo of the crop for data analysis. However, this technique has not been applied in in rice sowing process. Most rice fields in Thailand can be categorized into two types: the transplanted rice field and the broadcast rice field. The rice seed sowing technique in this research aims to bring advantages from both types of rice field together. Normally in the transplated rice field, when rice sapling is transplanted, a controlled and uniformly distributed distance between each rice sapling will promote higher yield than the broadcasting method. On the other hand, the broadcasting of seed (i.e. seed sowing) allows quick planting process which can reduce time and save labour cost in rice farming. This research focuses on the method of wet seeded broadcast rice farming as show in Fig. 1. In this method, the seed is normally pre-germinated prior to sowing onto the pre-standing water in the fields. This process is easier and requires less amount of labour work. By using a drone to sowing or broadcasting seed instead of human, the seed sowing process can be controlled with higher precision and the seed can be dispersed more uniformly. Thus, this proposed method should result in higher yield of rice than the normal broadcasting method and requires less time and labour than the transplanting method.

Fig. 1 Wet seeded broadcast rice field.

Sunil Karbharee Diwate from DY Patil School of Engineering Academy, Ambi (DYPSOEA) has applied a drone into the seed sowing process [3]. This project is mainly based on minimizing manpower and cost of the equipment so that it can be affordable to most farmers. They proposed to use an agricultural drone instead of a conventional fuel-based IC engines and heavy machineries. He compare parameter that related to seed sowing process between man, tractor and drone as show in Table 1.

Table 1 Compare parameter manual, tractor and drone.

No.	Parameter	Man	Tractor	Drone
1	Manpower	More	Moderate	Less
2	Time Required	More	Moderate	Less
3	Sowing	Manually	Automatic	Automatic
4	Adjustable seed Distance	No	No	Yes
5	Seed Wastage	Moderate	More	Less
6	Pollution	No	More	No
7	Energy Need	High	Very High	Less
8	Alarm and Display	No	No	Yes

Erico Pinheiro Fortes from Bridgewater State University used a drone for planting seed in reforestation purpose [4]. The purpose of this project is to dispersing seeds into the field that has potential for reforestation. The seed dispersal mechanism comprises of a container for storing seeds and a motor-controlled mechanism for releasing them as show in Fig. 2. This motorized device is designed to precisely regulate the flow at which the seeds are released. The seed dispersing software running on the Arduino microcontroller drives the motor proportionally to the velocity of the aircraft so that the seeds are precisely released at the desired location.

Fig. 2 Seed dispersal mechanism for reforestation by Fortes [4].

CFR Innovation is a company from Canada that developed an optimized spreading tool for drones called UAV Granule Spreader (UGS) [5]. This tool can adjust spreading width and rate. The attachment system is designed to minimize its impact on the flight stability of drone. Joyance Tech [6] from china also developed a spreader drone for seed and fertilizer. This technology is designed for reducing time and labour for farmers. Both use horizontal spinner concept for seed spreading. This design is useful for a quick seed spreading operation in large area but it is not suitable for a precisely control position of the seeds as show in Fig. 3.

Fig. 3 The UGS tool from CFR Innovation [5], The seed and fertilizer spreading device from Joyance Tech [6].

2. SYSTEM OVERVIEW

The purpose of this research is to use a quadrotor drone in the rice wet seed sowing process. The proposed design of the seed sowing mechanism focuses on requirement that the drop position and the distance between the planted rice seed can be precisely control. The quadrotor drone contains an automated flight features specified by a Mission Planner program with the GPS navigation system. User can make flight plan and set waypoint for rice seed sowing in the specified area.

2.1 Concept

The concept of a rice seed sowing drone is to combine different advantages of the transplanting and the broadcasting rice sowing techniques. The rice seed sowing mechanism installed on a drone allows the process of rice sowing to be as quick as the broadcasting technique while the seed planting position can be precisely controlled and spread uniformly as well as the transplanting technique. In the wet seed sowing process, rice seeds have to be germinated before dispersing. In our innovative design, a capsule which contains a germinated rice seed is used instead. Each capsule is filled with peat moss and rice seeds as show in Fig. 4. Peat moss is a growing medium which increases the weight of the rice capsule to make sure that each capsule is firmly planted into the ground even when the surface water level is high and also help protecting the seed during the germination period. Each capsule has 3 rice seeds for ensuring the chance of growth at each planted position. Since the shape and dimension of all capsules are the same, therefore the seed sowing mechanism can be designed such that the smooth operation of a seed feeder and spreader can be easily achieved. In our experiment, a yellow capsule is chosen so that each seed capsule can be easily observed when dropped and dispersed into the test field.

Fig. 4 The prepared rice capsule for the seed sowing experiment.

2.2 Mechanism Design

In order to design the seed sowing mechanism that can provide sufficient force for dispersing a seed capsule into the ground from a quadrotor, the relationship between different forces that affect the seed capsule should be analyzed. The forces that affect a falling object from a drone comprise of a drag force, a gravitational force and a release force from the seed sowing mechanism. The lift force from the drone propeller can be analyzed by CFD (Computational Fluid Dynamics) which shows the air flow field under a quadrotor. These forces affect to the position of a rice capsule as shown in Fig. 5.

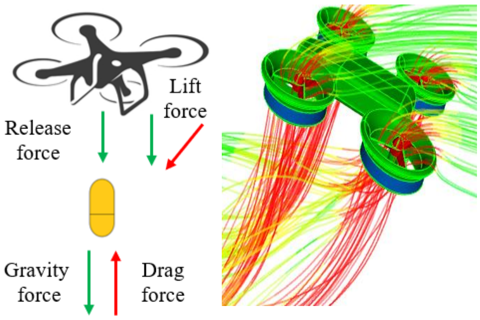

Fig. 5 Different forces that affect a falling rice capsule from a quadrotor.

Drag force acts in the opposite direction of the relative velocity between air and the object. This force depends on shape, size and velocity of the object, as in Eq. (1)

$$F_d = \frac{1}{2}\rho V^2 C_d A \qquad (1)$$

Where:

- ρ is the air density (kg/m)
- V is the velocity of object (m/s)
- C_d is the drag coefficient (N/m²)
- A is the cross sectional area of object (m²)

The seed sowing mechanism is designed based on a spiral vertical spinner concept in order to increase the release force of capsule from the drone. This mechanism can be separated into multiple components as show in Fig. 6. A hopper can be filled with rice capsules from the top. The hopper is connected with the feed tube. At the center of feed tube, a servo motor rotates a gate mechanism. This gate can block a capsule from feeding into a spiral spinner. The servo motor can be controlled to open and close by a user via a remote transmitter during flight. A spiral spinner connects to a DC motor with rotating in clockwise direction. The spiral spinner is designed so that its CM (Center of Mass) is at the center to reduce vibration during its operation. When a capsule is fed to the center of the spiral spinner, it will be propelled with a centrifugal force and released at the shoot tube. Most components of the proposed seed sowing mechanism were made with PLA material using a 3D printer for its lightweight property as show in Fig. 6.

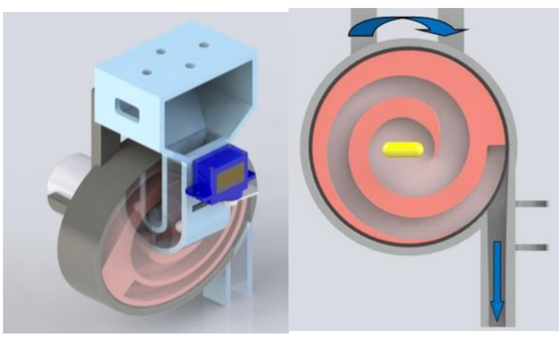

Fig. 6 The design of a seed sowing mechanism.

The release force from a sowing mechanism can be calculated from the centrifugal force caused by the spiral spinner, as in Eq. (2)

$$F = m\omega^2 r \qquad (2)$$

Where:

- m is the mass of object (kg)
- r is the radius of spinner (m)
- ω is the angular velocity of spinner (rad/s)

In order to successfully release and propel the seed capsule into the planting field, the combination of the release force and the gravitational force has to be larger than the summation for the drag force and the lift force. The required release force was used for selecting a dc motor for this sowing mechanism. The DC motor control circuit is designed with an adjustable rotational speed as show in Fig. 7. This circuit consists of 12V DC motor, a driver board (L298N), an Arduino NANO microcontroller and a 14.8V Lithium Polymer battery. The rotational speed of a spiral spinner can be adjusted by sending different PWM (Pulse Width Modulation) signal from an Arduino NANO microcontroller. The rotational speed directly affects the release force of this seed sowing mechanism. The technical specifications of the seed sowing mechanism are show in Table 2.

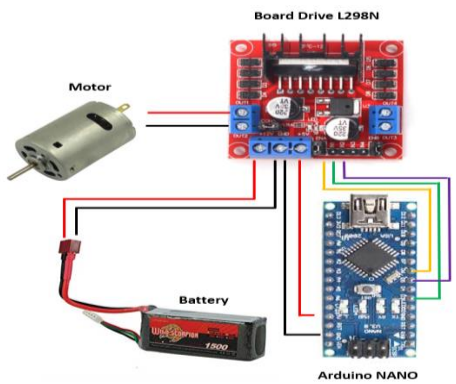

Fig. 7 DC motor circuit.

Table 2 Specifications of the seed sowing mechanism.

DC Motor	12V, 1A, 9500RPM
Servo Motor	SG 90, 5V
Battery	3 cells 11.1 V
Weight	320 grams

2.3 Quadrotor Equipment

A quadrotor which is used in this experiment is the X-frame type with a DJI 450frame wheel as shown in Fig. 8. The specifications of the experimental quadrotor are shown in Table 3 and its components are show in Fig. 9.

Fig. 8 Quadrotor

Table 3 The specifications of an experimental quadrotor

Number of rotors	4
Frame wheel	363 mm
Propeller	10" x 4.5"
Motor	Brushless 935 rpm/V
Battery	Li-Po 14.8 V
Stabilization control module	Pixhawk PX4
Total weight	1.7 kgs

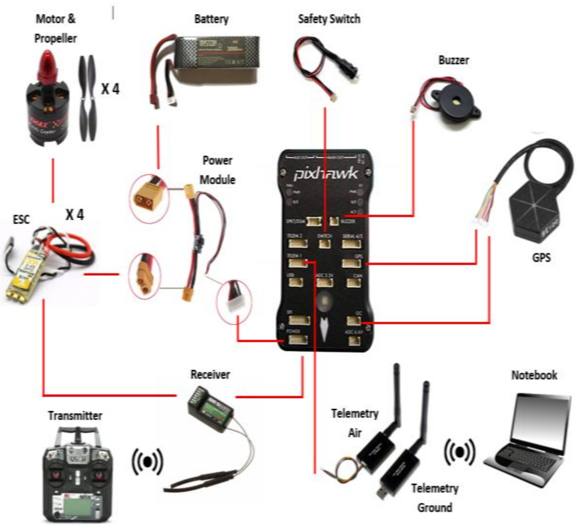

Fig. 9 Components of an experimental quadrotor

2.4 Flight Control System

Mission Planer Program is use for automated flight control quad rotor drone. This program is open source develop by ardupilot. It has many features ground station application that can help for experiment such as examine flight data (Altitude, Speed, GPS Status), Flight Plan, PID tuning and Data log as show in Fig. 10

Installation mechanism to drone is affect to the flight stability because drone gain more weight and mechanism is asymmetric. PID tuning feature in Mission planner can help this problem by adjust response sensitivity of roll, pitch and yaw.

Fig. 10 Mission planner program.

Data log feature is used to record altitude, longitude, latitude. Transfer data by telemetry between drone and computer. Data longitude and latitude will convert to X Y positioning for easy to plot graph in experiment. Calculated by Eqs. (3) ~ (4).

$$Y_t = (lat_t - lat_1) \times 60 \times 1852 \quad (3)$$

$$X_t = (lon_t - lon_1) \times 60 \times 1852 \times \cos(lat_t \times \frac{\pi}{180}) \quad (4)$$

Where:

- lat_1 is the first latitude data, home position
- lon_1 is the first longitude data, home position

3. EXPERIMENT AND RESULT

3.1 Germination of rice seedling in a capsule

The first experiment was performed to validate the possibility to rice seed germination in a rice capsule. In this experiment, the planting testbed replicated the wet seed rice field environment which comprises of clay and water. The rice capsules were prepared by filling a capsule with peat moss and 3 rice seeds. The prepared rice capsules were planted into wet clay soil for 3 days. The moisture in the wet clay soil would dissolve the shell of a capsule entirely. All rice seeds inside a capsule successfully germinated into rice saplings as shown in Fig. 11.

Fig. 11 Rice seedling from capsule.

3.2 Vibration impact on the flight stability

The objective of the second experiment is to test the impact of vibration caused by the seed sowing mechanism on flight stability. When the spiral spinner motor is ON, an additional vibration is created from the spinner movement. This experiment started by creating a flight plan for an automated flight in the mission planner program. Then the drone position in XY was logged in two flight conditions; the spinner motor ON and the spinner motor OFF. The results can be compared as shown in Fig. 12. From this graph, it shows that the vibration which caused by the spinner mechanism didn't affect flight stability.

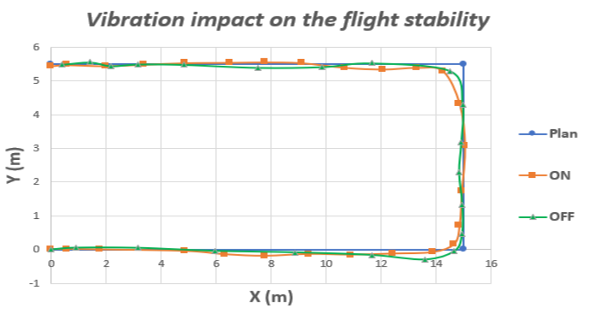

Fig. 12 Flight paths under two conditions: spinner motor ON and spinner motor OFF.

3.3 Precision of the seed sowing mechanism

In the third experiment, the precision of the seed sowing mechanism when installed and operated onboard the quadrotor is tested. In this experiment, the quadrotor used a loiter-flight mode in order to maintain the position at 2m altitude. 15 capsules were released from the seed sowing mechanism to the ground continuously. The position of each rice capsules on the ground was recorded and plotted on a scatter plot in Fig. 13. These rice capsules formed a <2 cm cluster around (0,0) position. Therefore, the precision of this seed sowing mechanism is within 2 cm which should be sufficient for planting rice seeds at target distance of 30 cm apart (i.e. the planting distance with the maximum yield for a transplanted method).

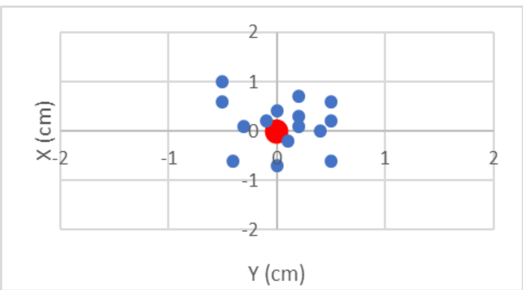

Fig. 13 Graph show precision of mechanism.

3.4 Automatic seed sowing process

The objective of the 4th experiment is to validate the effectiveness of the proposed rice seed sowing process using a quadrotor. In this experiment, the quadrotor will fly under an automated flight plan. The seed sowing mechanism will be tested with various spinner speeds which directly affects the planting distance. Parameters that affect the planning position of the rice capsule are drone altitude, drone speed and the spinner motor speed. Experimental parameters for this experiment are shown in table IV. This test varies 3 drone speeds and 3 spinner motor speeds which resulted in 9 test conditions as show in Table 4. The drone speed can be adjusted in the mission planer program and the spinner motor speed can be adjusted by changing the PWM signal. The feasible range of the spinner motor speed is between 4650 to 5400 rpm because when the spinner motor is operated at the speed lower than 4650 rpm,it will not provide sufficient torque for the spinning mechanism. On the other hand, when the spinner motor speed is greater than 5400 rpm, the spinning mechanism will create large amount of vibration that could affect the stability of the flight. In each trial, 20 rice capsules were released in a straight-line flight plan with an altitude of 2 m for 5.5 m distance.

Table 4 Experiment parameter

Drone Speed (m/s)	**Mechanism motor speed (rpm)**		
2	4650	5030	5400
3	4650	5030	5400
4	4650	5030	5400

A graph in Fig. 14 shows the comparison between the flight plan waypoints, the actual position of the drone and the position of capsule on ground of the test flight with the best results. In this test flight, the drone speed is 4 m/s and the spinner motor speed is 5030 rpm. This graph is shown at scale 1:1 at the distance of 5.5 m. The rice capsule position on the ground correlates with the straight-line path specified by the flight plan. The rice capsules were successfully deposited on the ground at about 30 cm apart along the straight line on the X axis.

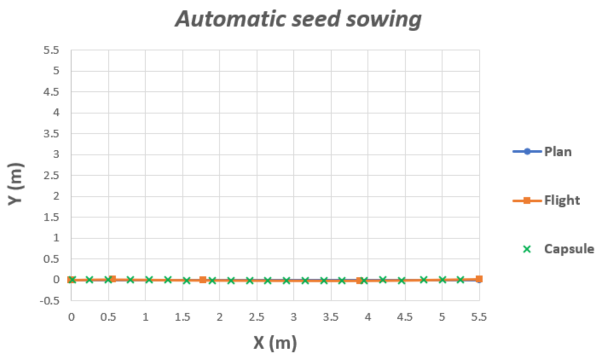

Fig. 14 Automatic seed sowing graph.

Fig. 15 shows the zoomed in graph of the position comparison between the flight plan, the actual position of the drone and the position of the rice capsules. At the closer look, this graph shows that the rice capsules were deposited on the ground with the deviation of 1-2 cm in the Y axis which is within the target planting precision specification. Table V and VI summarize the results of the rice capsules planting position when the drone speed and the spinner motor speed were varied. When the drone speed is lower than 4 m/s, the drone could not withstand an external wind speed, thus it failed to maintain the straight-line flight path and could not deposit the rice capsule at the specified location. The only cases that the seed sowing drone successfully performed is when the flight speed was set to 4 m/s. At 3 spinner motor speed variations, the rice capsules were deposited on the ground at less than 30 cm interval. However, when the spinner speed is at 5030 rpm, the rice capsules were deposited in a straight line with only 0.8 cm deviation along the Y axis. Therefore, the best parameters for the drone speed and the spinner motor speed for rice seed sowing operation in this experiment is 4 m/s and 5030 rpm.

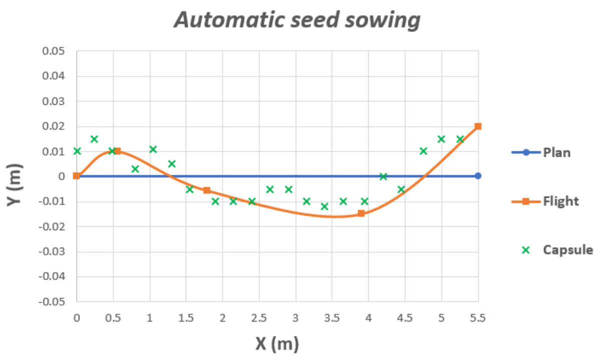

Fig. 15 Zoomed in automatic seed sowing graph.

4. CONCLUSIONS

In this paper, we proposed an innovative design of the wet-seed rice sowing mechanism to be installed on a quadrotor for a high precision rice planting process. The seed sowing tools has a spiral spinner mechanism which can release a seed capsule at the specified interval. By installing the seed sowing mechanism on the drone, the process of rice planting can be done automatically with higher precision and speed. The proposed mechanism is designed to be used with a rice capsule which protects rice seed during the germination period and during the sowing process. The rice seed sowing automatic process were tested with different parameters including various drone speeds and spinner motor speeds. The best results show that this process can be performed automatically, the rice seed capsules were planted in a straight line at 24 – 28 cm interval with the deviation from the target line in Y axis of 0.8 cm.

In the future, we plan to increase the size of a quadrotor for better positioning, less flight time and higher payload.

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