Utilizing Unmanned Aerial Vehicle (UAV) Technology for Automated Dispensal of Farming Resources

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Abstract

With the increase in population, farmers may start to struggle to farm adequate crops for consumers. The potential of affordable unmanned aerial vehicles (UAVs) to address pressing hunger problems exacerbated by factors such as population growth and the COVID-19 pandemic. With over 815 million people suffering from chronic hunger, particularly in Asia, and agriculture's significant economic role, finding innovative solutions is imperative. The integration of UAVs in precision agriculture, leveraging vegetation indices and sensors for crop health assessment, presents a cost-effective approach to optimize farming practices. However, UAVs face limitations such as battery life constraints and airspace congestion. To mitigate these challenges, this research aims to develop an autonomous drone for pesticide distribution, equipped with technology to autonomously detect and manage recharging needs, ensuring uninterrupted operations. Statistical analysis reveals significant differences in battery life at various motor powers, impacting the drone's speed and range. With an estimated cost of $858.73, this drone system offers an affordable alternative to commercial agricultural drones, which can exceed $16,000. As the global population is projected to reach 10 billion by 2050, the study emphasizes the importance of UAV technology and smart agriculture to meet the growing food demand while addressing hunger problems, making it a vital contribution to sustainable agriculture in the future.

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Introduction

Hunger Problems

With an increase in the world population, a large problem has started to circulate. In order to sustain this growth, the hunger issues here on earth must be conquered. According to the Food and Agriculture Organization (FAO), more than 815 million people are chronically hungry and many of them reside in Asia. (Hafeez et al., 23). This issue was largely amplified by the negative effects of COVID-19. The virus prevented many farmers from planting enough seeds, using enough fertilizers, and obtaining enough pesticides to grow the crops needed to eat. This lower amount of production led many developing Asian countries to issues with maintaining the amount of food for each person in the country. Other countries, such as India, have looked to shift their philosophy to unmanned aerial methods of farming. This can be done with an unmanned aerial vehicle (UAV).

Due to the lockdown, over 107 million tons of harvest was at risk of going to waste. When comparing that figure to last year, this year, there were 103.6 million more crops at risk this time. With 60% of India's agricultural sector accounting for its economy, this is a huge economic problem. While COVID-19 is in the past, it is important to have ways to prepare for another situation like the pandemic. At the time in India, it was only a 1% drop in the wheat market, however for a developing nation where this figure could be more apparent this is an issue (Varshney et al., 2020). Furthermore, hunger problems remain an issue in countries within Africa including Kenya, Nigeria, and Ethiopia. While there is an emphasis on farming, farmers aren't able to produce sufficient surplus to survive through drought cycles. Along with that, it is difficult to manage all of the fields that the people work in. In order to combat these issues, drones can be used to man the farms and crops.

Use of Drones in Farming

Using aerial methods is not a foreign concept to agriculture. Smart farming with Precision Agriculture (PA) is currently being used to measure the wavelengths and vegetation indices to see the condition of each crop. The vegetation index is a value added to the crop to maximize the sensitivity to characteristics while trying to reduce confounding factors in the environment. Using a UAV, one can do crop scouting—a process by which using a UAV, would detect the colors of each crop and using that information along with the PA sensor would determine the true health of the crop (Marinello et al., 2016).

For developing countries, many of the aerial vehicles to test can be expensive. UAVs offer a lower cost due to them being able to man at a lower height and have less complexity while still obtaining precise information. This technology has started its implementation in Japan. About 35% of its rice fields are pest control. Areas of Forestry and Fisheries are using drones in the area of planting, weed management, and fertilization (JP Sinha, 2019).

Drone Functionality

Unmanned Aerial Vehicles (UAVs) typically have high mobility and customization and are commonly known as remote-piloted aircraft and drones. UAVs have been through a wide range of applications in the past decades, including military and farming use. With increasing cost and size reductions of these devices, typically not exceeding 25kg, they have become more accessible to the public for increased usage in all sorts of tasks (Zeng et al., 2016). Major UAV Companies including Parrot, DJI, PrecisionHawk, AGEagle, and Trimble Navigation have developed and commercialized drones for a variety of uses, yet agricultural drones are a lot more specific (Kim et al., 2019).

As the world continually makes new breakthroughs in technology, it advances just as much in its population. According to the ‘Agriculture in 2050 Project,’ by 2050, the world’s population will reach 10 billion. This demands a 70% boost in food production worldwide (Hunter et al., 2017). Smart Agriculture is one of the proposed solutions to this issue and is an active field that continually produces new opportunities for improved farming. The main smart agriculture expansion is agricultural robots, including UAVs (Kim et al., 2019).

UAV’s main uses in smart agriculture involve low-altitude photography of crop fields, through the utilization of various sensors and controllers. These are widely used for visualizing large-scale rice paddies as well as other crop fields. Although UAVs are used primarily for photography, their utilization in planting, involving the distribution of seeds and plant nutrients, is still in development and requires many changes in technology. (Kim et al., 2019).

Limitations of Drones

With new avenues of farming being explored now, and new technology, limitations arise from UAV usage. First off, the technology can be conducive to swarming with multiple drones in the area. Another large limitation of this technology is the battery. The battery life of a drone is one the limitations of it since it has to power all of the motors along with the sensors which can quickly drain the battery. A method of wireless charging with battery packs could be used here in order to sustain the battery health autonomously (Kim et al., 2019).

Purpose

The purpose of this study is to create an affordable drone to autonomously spread pesticides over a plot of land. The components of the drone will allow it to sense when it needs to recharge and make auto-rechargeable technology to make sure the drone can be basically unmanned. The drone will have the ability to sense when its supplies are low and come back to the docking station automatically.

Methodology

Engineering Goals

- Create a low-cost alternative to drone application of pesticides and fertilizers
- Autonomously navigate and dispense pesticides
- Autonomously return to base station, charge and refill tank
- Have a battery life long enough to dispense all of the product at the recommended levels

Materials

Base Drone

- KK2.1.5 Multi-rotor LCD Flight Control Board
- F60PROV 2020KV Motor
- GF 51466 HURRICANE DURABLE 3 BLADE GRAY Propellor
- Lithium Ion Battery - 3.7V 2000mAh Battery
- Aluminum Tubing
- GPS Module

Pesticide Dispensing

- 3L Tank
- 12v DC Pump
- Flat Nozzle
- Tubing

Base Station

- Chargers
- Pump
- Arduino

Procedure

Design

1. Create a CAD Diagram to show the building of the drone station
    a. This CAD Diagram should provide adequate spacing for each propellor, ensuring no overlap
2. Create the wiring diagram for the Drone, this is in order to properly plan out where each motor should be connected in order to fly the drone.
    a. Detail the wiring to show the terminals for which each motor should be connected with its corresponding motor controller
3. Create the wiring diagram for the base station to show how the battery will charge on the station.
    a. The base station needs to be created in such a way that the surface is large enough for battery-to-battery contact and allows for proper charging of the drone.

Building

4. The frame should be constructed according to the CAD
    a. In order to create the proper structure, CAD the drone in different chunks
    b. Each chunk should be enough to fit on the 3D Printed bench.
        i. Each chunk of the drone was printed on a 210mm x 210mm bench, so each piece had to fit within that frame.

c. Connect each piece using designed brackets and holes in the CAD diagram
d. M5 bolts were used in order to connect each piece and combine each drone piece
e. Attach the motors on each wing of the drone using the bolts provided by the motors
f. Attach the propellers to each motor using the locking nut provided by the motors

5. The motors, speed controllers, and flight controller will be soldered together according to the wiring diagram
    a. Ensure that all the motors are connected to each controller without any excess overlap between wires
    b. Each motor should be connected to a single motor controller
    c. Each motor controller will be separately connected to the battery according to the wiring diagram
    d. Follow all safety precautions when following the wiring guide
6. Connect the tank, pump, and nozzle for spraying the liquid
    a. Connect the tubing directly to the pump
    b. From the pump, connect the tubing down to the nozzles to properly allow the flow of fluid
7. Create the base station according to the CAD
    a. This station should provide ample space for the drone to land on
    b. The building should follow a similar process to creating brackets for each piece and connecting using M5 bolts
8. Connect the chargers and the pumps for refilling the drone.

   a. Do this by following the wiring diagram laid out earlier, and put the refilling at the top for easy access to refill the liquid

9. Upload code

Testing

10. Test Autonomous Application
    a. Using the Ardupilot software, test to see the drone's flying capabilities and reach it can travel
11. Test Battery Life
    a. Test the power draw from the motors for adequate flight
12. Test Recharge/Refill time
    a. On the docking station, test to see how long it takes to charge the battery and refill the tank.
    b. The test should be semi-automatic

CAD Diagrams

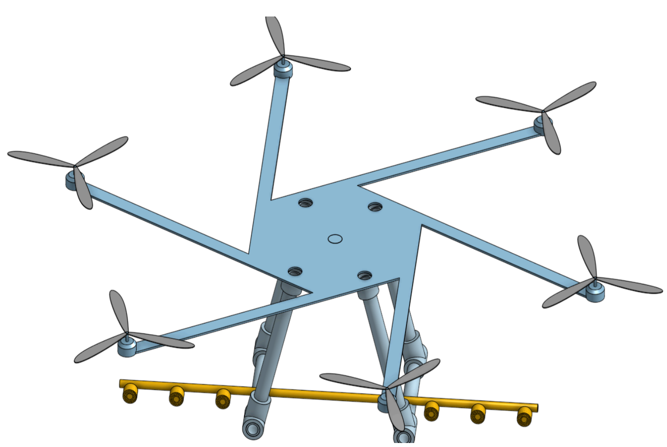

Figure 1: Shows original drone CAD with hexacopter design

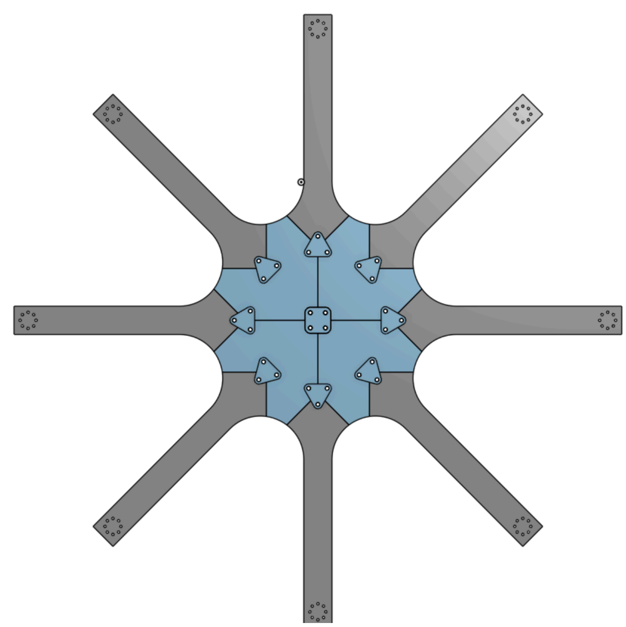

Figure 2: Shows updated printable drone CAD

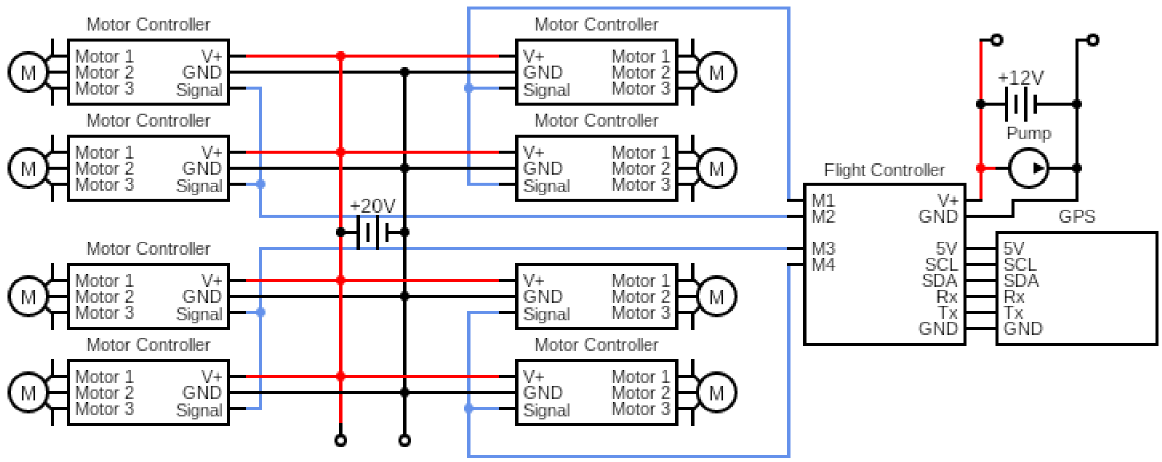

Figure 3: Wiring Diagram for the drone

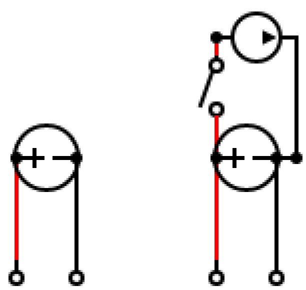

Figure 4: Wiring Diagram for the drone base station

Safety Protocol

The appropriate measures were taken when handling each part of the drone, motor controllers, and propellers. When handling each motor, there was no power drawn to each motor to ensure they were off when handling the drone. Hands were kept away from each propeller when the drone was turned on. Safety goggles were worn during the process of soldering and connection of each drone piece when using a drill. The soldering iron tip was cleaned before and after every use. Each wire was properly insulated to avoid any burns. No disposal methods were necessary as a result of using the soldering iron and solder, as there was no solder waste.

No pesticides or fertilizers were handled, and testing occurred with water to show proper use of the fertilizer.

Results

Figure 5: Completed drone picture

Figure 6: Completed drone picture

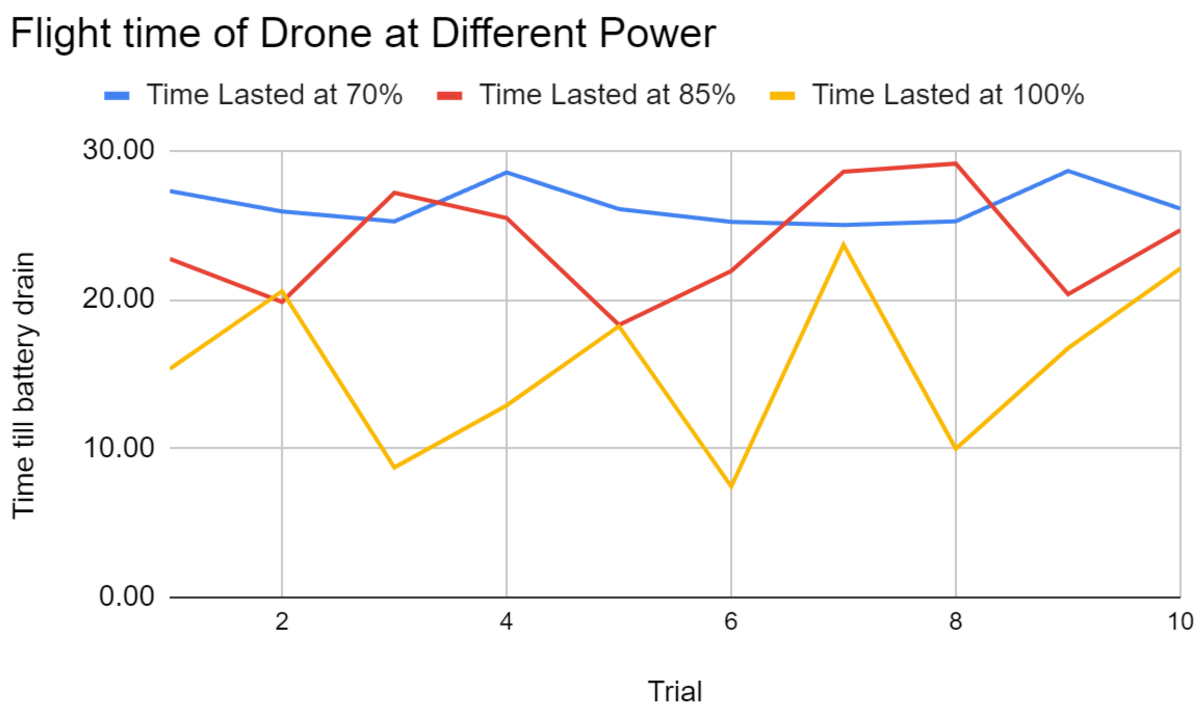

Figure 7: Drone flight time per trial

The battery used to obtain the data in Figure 7 shows the time shows limited flight time with a maximum of 30 seconds for the total flight time. However, this battery would not be the final battery used in the drone creation. Due to financial limitations, the original battery was not able to be used for this experiment.

The dataset reveals several key trends. Firstly, there is a general decrease in completion time as the process advances from 70% to 100% completion. This suggests that the process becomes more efficient as it nears its final stages. However, it's important to note that not all trials follow this trend, with some taking longer to reach 100% compared to 85%. This indicates potential complexities or delays in certain situations.

Secondly, there is significant variation in completion times across the trials, which implies that external factors or random variations play a role. Addressing and controlling these factors is crucial for achieving more consistent and efficient results.

Lastly, there is a spread in completion times at each threshold, with some trials completing faster than others. This unpredictability highlights the need for further investigation to understand and potentially optimize the process. Overall, analyzing these trends and their underlying factors can provide valuable insights for scientific research and process improvement.

After conducting a statistical analysis test, a p-value of 0.00003363975 was obtained which is less than the alpha of 0.05. This means that there is a statistical difference when testing the drone's battery life at different motor powers. In turn, this changes the maximum speed and distance the farmer could have the drone fly.

Discussion

The focus was on establishing the minimum motor power necessary for stable flight, identified as at least 70% capacity for each motor. This threshold was critical in assessing the proper power draw for maintaining stable flight conditions.

Each motor at 70% power consumption should draw 20.64 A of current. Given that the drone was equipped with eight motors, the total motor power consumption was calculated to be 165.12 A. However, this was not the sole factor contributing to the total power consumption. Additional components, such as the pump and controller, added a further 0.125 A to the overall power requirements.

The power consumption of the drone was thus determined to be 165.245 A. This measurement was pivotal in calculating the drone's battery life, a key factor in its operational efficiency. The drone utilized a battery with a capacity of 22 Ah. The battery life was calculated by dividing the battery capacity by the total power consumption, yielding a result of approximately 0.133 hours, or about 8 minutes of flight time. These calculations are done with an alternative battery, not the one used in testing. However, for optimal performance, the battery should be used in farm settings.

Drone Charging

As the drone requires frequent charging, the docking station created would help semi-autonomic this process (Martinez-Guanter, Jorge, et al, 2020). The docking station has sections for the drone to land on to recharge. With an approximate 8" radius, the drone has ample space to roam fields and spread any fertilizers or pesticides needed. This is needed as massive farms have trouble tending to when meaning it on one's own (Martinez-Guanter, Jorge, et al). The importance of the drone is the multi-purpose of the use. With autonomous tracking, the drone could be used as a spot treatment. This could be done through using the vegetation index, and tracking which crops need help (Inoue, Y. 2020). Farmers could use the index to direct the drone to cater to a specific spot, allowing there to be care without the farmer being at risk of toxins due to pesticides or fertilizers.

Cost Analysis

Table 1 - Cost of Parts

Part	Name of Part	Unit Price	Quantity	Total Cost
Flight Controller	KK2.1.5 Multi-rotor LCD Flight Control Board	$19.00	1	$19.00
Motor	F90 KV1300	$29.90	8	$239.20
Propellor	GF 51466 HURRICANE DURABLE 3 BLADE GRAY	$3.29	2	$6.58
Battery*	Tattu 22.2V 30C 6S 22000mAh Lipo Battery With XT90-S Plug For UAV	$475.99	1	$475.99
GPS Module	Ultimate GPS Module PA1616D	$19.95	1	$19.95

	- 99 channel w/10 Hz updates - MTK3333 Chipset			
Nozzles	Agriculture Drone Spraying Nozzle High Pressure Agricultural Uav Sprayer Tip 5pcs Green, Mini Drone Accessories	$5.29	2	$10.58
Tank	3 Quart Natural Multi-Purpose Tank with Mounting Tabs - 8.63" L x 4.25" W x 7.63" Hgt. (2.25" Neck)	$9.85	1	$9.85
Pump	2.5 Lpm 12v Low Voltage Mini Dc Pump	$15.00	1	$15.00
Electronic Speed Controller	4Pcs 20A ESC Brushless Electronic Speed Controller DSHOT BLHeli_S 2-4S Lipo for FPV QAV Drone Multirotor Quadcopter	$31.29	2	$62.58
Total Cost				$858.73

* Alternative battery was used for this experiment

The drone itself would cost a farmer $858.73 to make and would require a laptop for programming. All software is free for the use. With other agricultural drones on the market costing over $16,000, this drone would allow for a more cost-effective way for proper agricultural treatment. The drone has a 1-gallon tank, which allows for ample fertilizer, especially during spot treatment use. For example, the Agricultural Spraying Drone 8 Axis 22kg Payload UAV Drone Agriculture Sprayer costs over $16,600 for commercial use and offers a similar purpose to the drone design that was created. Likewise, the XAG P100 13.5 gal (51L) Agriculture Spraying Drone offers similar pesticide and fertilizer distribution purposes, however costing over $17,000. The drone created can perform actions similarly to the ones on the market currently, however at a lower cost than the ones on the market.

Conclusion

Most of the engineering goals for this project were met. The drone was successfully constructed in a relatively cost-effective manner when compared to other drones on the market. The build used simple materials, and 3D printing which allowed for the quick creation of the drone while maintaining a solid structure and lower weight. This drone was able to autonomously navigate a path and distribute a liquid to represent the pesticide or fertilizer that would be used on a farm. The large radius of the drone allows it to cover a wide spread of land, while also allowing it to travel to specific areas for spot treatment. Farmers may use this treatment The tank provided allows for about 1-gallon worth of liquid, and this can be substituted for any sized tank to the preference of the user. Furthermore, the device is extremely cost-efficient when compared to others on the market. The device is around 20 times cheaper than the ones available on the market. This would allow the drone to be accessible to a wider market of consumers. The docking station would provide easier maintenance for the drone, ensuring that the drone would not need 100% monitoring at all times. It would allow a user to complete other tasks, and leave maintaining the lawn to the drone itself. Along with that, the smaller cost would allow a user to have multiple drones maintaining a larger area of land. The use is relatively simple, however, creating the path for the user may be a little more difficult for the user to use.

One of the major limitations of the drone's battery, and the testing of drones is shorter battery life. When calculated, the drone with the proper battery would last over 8 minutes, which is enough to cover a large area of land. However, the testing drone came with a major issue of only lasting for 30 seconds, which would not allow for a great distribution of resources. Along with this, the difficulty that comes with the docking station would be the extra accuracy required to land on the station and charge. There is a little less room for error when the drone lands itself. Along with this, a little bit of extra technical knowledge would be needed to operate the Ardupilot software, which is helpful when flying drones.

As the drone is still a prototype, there are areas to improve upon when using it. To address the issue of the technical aspect, a map software could be created and have it where the drone is told where to go via a single tap or click. Additionally, exploring alternative battery options with higher capacities and optimized energy-to-weight ratios could significantly extend the drone's flight duration, enabling longer missions and improved overall performance. Furthermore, altering the number and arrangement of propellers warrants consideration as a potential avenue for enhancement, as it could lead to improved flight stability, payload capacity, and maneuverability, ultimately tailoring the drone's design to specific agricultural needs. Moreover, integrating autonomous vegetation farming techniques, guided by data from the vegetation index, holds significant promise. This advanced feature could enable precise spot treatments, allowing the drone to target specific areas in need of intervention while sparing unaffected regions. By harnessing this technology, our drone system could offer an innovative solution for precision agriculture, minimizing resource wastage and optimizing crop management practices. These proposed improvements represent the ongoing evolution of our drone and docking station, aiming to meet the ever-changing demands of modern agriculture and further solidifying its position as a valuable tool for farmers seeking efficient, cost-effective, and environmentally responsible solutions.

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