2023 ASEE Midwest Section Conference

Facilitating Investigation of Drone Precision Landing for Education

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Abstract

Precision landing for drones uses a combination of hardware and software programming to land a drone as close as possible to a target location. With the increasing popularity of mini drone usage in education, we leverage the off-the-shelf (OTS) educational drones to facilitate an open-source platform for students and researchers to work on an on-going challenging precision landing problem. In this paper, we discuss the educational Tello-EDU drone that uses vision based infrared sensor to perform precision landing maneuver on the target landing pads. The experimental results of varying altitude in combination with the landing trigger events through software programming demonstrates the ability of mini drones help to improve the landing guidance.

Keywords

Precision landing, drone education, IR camera image processing, altitude variation, and software trigger landing.

I. INTRODUCTION

Precision landing uses several features of drone hardware coupled with programming concepts to fine-tune the accuracy of the landing. This is important because a drone can only get so close to a precision point using global positioning system (GPS) satellites. GPS is generally accurate to within 5 meters. The accuracy of the position using these GPS satellites can be marginal. Hence, we need to use other techniques for precision landing, to help students and researchers to quick start on this interesting and challenging precision landing problem, we use the drone's real-time bottom camera to see identify the area of landing. This will enable the drone at a precise point instead of relying solely on the GPS to get it close enough to the target.

The Tello-EDU drone used for this research has a forward-facing camera, a bottom-facing infrared sensor (IR sensor), and a software development kit (SDK) that enables the user to write code for the drone's performance. The drone comes with mission pads that work with the software as triggers for specific code to run when recognized. In this paper, we will explore the implications of altitude on the detection and code enhancements of the Tello-EDU. We demonstrate that with increased altitude, the vision system of the drone would be less accurate due to the field of vision being greater at increased altitudes.

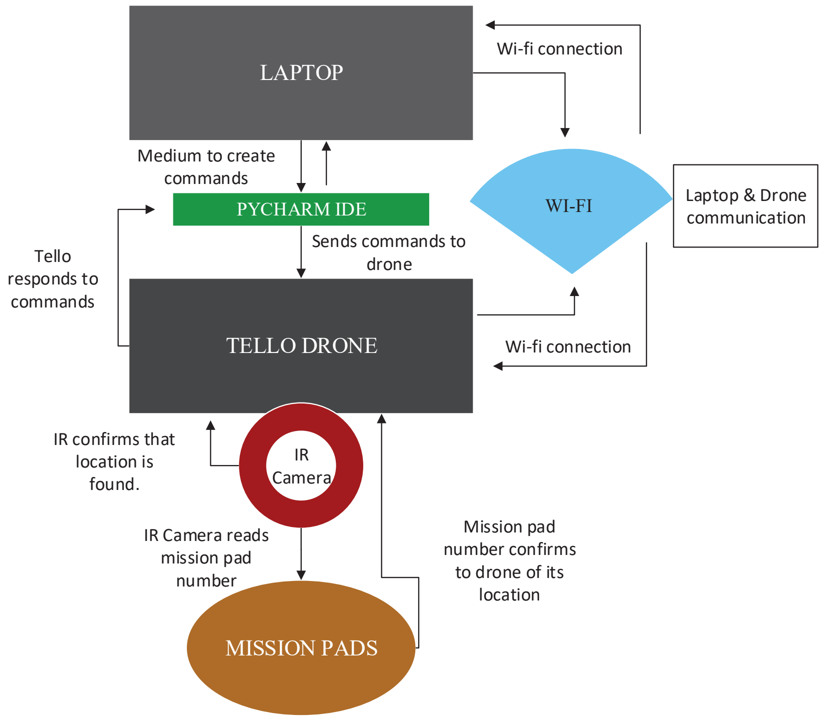

Figure 1: Overview of precision landing

In recent years, there is a rapid growth of drone technology and their capabilities. Many commercial off-the-shelf drones have options that need to be more utilized and understood. This paper will cover the concept of precision landing using consumer-off-the-shelf (COTS) [1] software and devices. This research can be planned, executed, and replicated easily for other researchers wanting to try or expand on.

The rest of the paper is organized as follows: Section II details the automation methodology of precision landing using educational drone, section III discusses our findings before and after software modification, section IV presents the challenges and threats to validity, section V reviews existing literature while section VI presents conclusion and future work.

II. METHODOLOGY OF PRECISION LANDING

Figure 1 provides the overview of our experimental setup. In figure 2, we illustrate the methodology using a flowchart. The experiment requires the drone to fly forward within a specified range, locate the mission pad, come to a stop, and decrease in altitude in intervals (to allow for a more precise landing). As a precaution, if the drone does not read the mission pad, it will land on its own once it reaches the specified boundary while sending a message to the console log that it's reached its boundary and that it needs to land.

A. Setup

To avoid human error of manual flight, we automate the testing of the precision of Tello-EDU landings using a software program. Python [2] was the language chosen for this program. The DJITelloPy [3] SDK library was used for software functionality and operability with the drone. Once the program is launched the program, it will have total control of the drones' actions. The program authored provides all data back to the user through the system console log. To easily replicate our setup for educational purpose, measurement from the landing target center was taken by tester using steel rule.

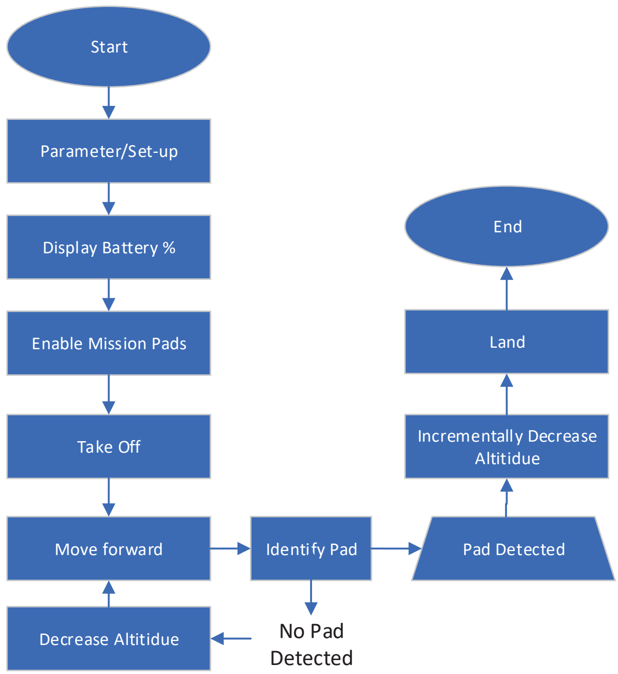

Figure 2: Process flowchart

B. Python Program Requirements

The Python Program has full control of the Tello-EDU from takeoff through landing. Upon program launch the battery level is checked and reported. The landing zone is denoted by the mission pads and it must be enabled. Mission pad sensing must be set to the bottom facing infrared sensor. After the takeoff, based on the predefined height parameter, height adjustment (if required) takes place. Once completed, the Tello-EDU will then sense if a pad is under the unit. If no pad is detected the Tello-EDU will move forward and sense again. This loop continues until 10 loops have been made or it senses a pad. If a pad is detected the Tello-EDU lands and exits the program. To replicate, the python program will be shared and made available on GitHub [4].

C. Testing method

Testing consisted of a 1-meter straight-line flight from takeoff to landing. All flights occurred in the same environment with a minimum of two meters clear of obstructions. The time-of-flight data and code execution come from the PyCharm [5] console log. The precision measurement was measured with steel rule from the center of the target mission pad and the center of the drone body upon landing, as shown in figure 3. The Tello-EDU was programmed to takeoff, adjust altitude, proceed forward sensing for mission pad, when mission pad is detected the Tello-EDU lands. While no mission pad is detected the Tello-EDU will proceed forward again in a loop until a pad is detected. Once it reaches a specified boundary with no mission pad detection, it will be landed.

Figure 3: Drone landing pictures. From left to right, the drone gets closer to the target landing mission pad.

III. FINDINGS

The findings displayed in figure 4 show the distance from the center of the mission pad to the center of the drone body. The data gathered shows that with increased altitude the drone lands farther from the center of the target. The software loop cycles through code decreased by one cycle when the altitude was at 1.5 meters. The field of view of the IR sensor was increased in size with increased altitude, thus creating a detection of the mission pad sooner. Early detection farther from the center of the pad led to premature landing.

Figure 5 shows the relationship between detection range and altitude. Figure 7 shows the bottom facing camera. Testing was conducted at 0.5m, 1.0m and 1.5m. A gain in altitude directly affects the detection range of the infrared sensors. The Tello-EDU did not detect mission pads consistently when the altitude was set above 1.5 meters.

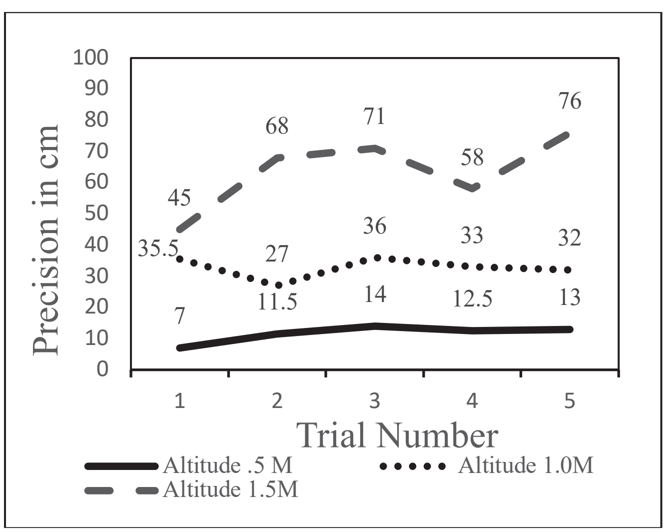

Figure 4: Experimental results without software modification.

Given the results of initial testing, modification was made to the program. The modified programming allows the Tello-EDU to fly at an altitude of 1.5 meters. When a mission pad is detected, instead of landing, the Tello-EDU decreases altitude to .5 meters and cycles through the loop an additional two iterations. The resulting precision landing was greatly improved.

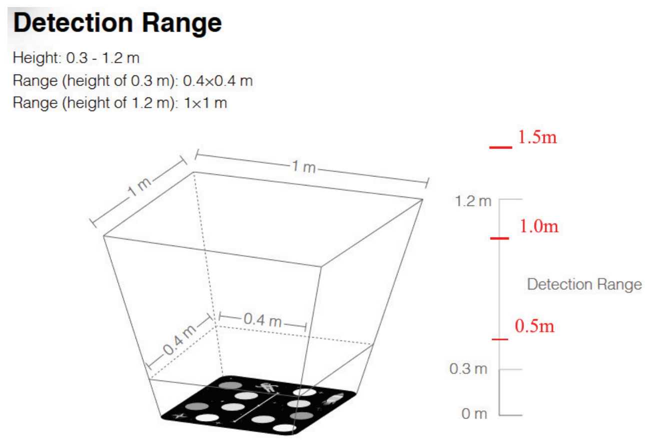

Figure 5: Highlightening the land trigger altitude in red colour text for the Tello-EDU detection range [6]

Figure 6 displays the significant difference in results between the original programming and the modified programming. Both data sets were obtained from flights initially starting at 1.5 meters. With the modified program, a pattern emerged by adjusting altitude and reassessing mission pad information. This demonstrated an increase in precision on the drone target mission pad landing.

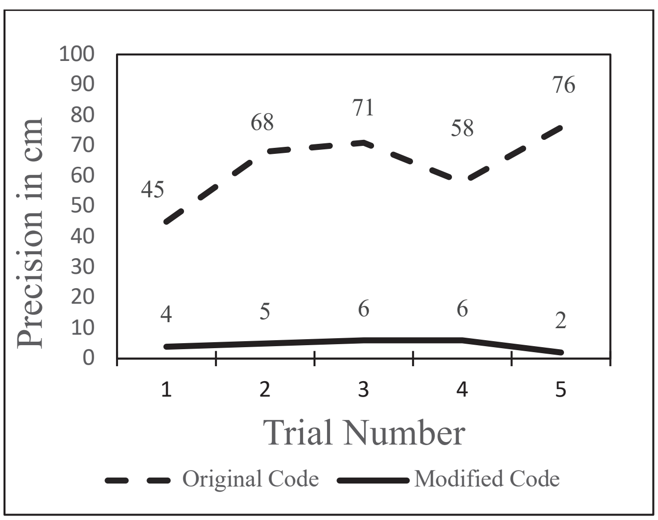

Figure 6: Experimental results with software modification

Figure 7: Bottom facing InfraRed camera highlighted in red rectangular box

IV. CHALLENGES AND LIMITATION OF STUDY

One of the challenges that were encountered while setting up and testing the Tello Drone precision landing in python was the commands not being received from the Tello Drone, or the drone may give an initial response to a command but would abort tasks after that response. Another issue was the wi-fi connectivity between the laptop and the Tello Drone. Occasionally, the wi-fi would disconnect from the Tello Drone while running the program. The biggest challenge was finding a way to live stream from the drone's bottom camera during its landing through python.

There are certain limitations as well. Occasionally the Tello-EDU unit would respond erratically. The inconsistencies in performance of the drone when this occurred nullified any possible data retrieved from the test. The results from these tests were not retained for publication. Errors encountered during testing included:

- Tello-EDU stopped responding
- Tello-EDU poor IMU
- Tello-EDU instability in flight due to bent propellers

V. LITERATURE REVIEW

Tello Drone is used as a Platform for Research and Education [7] with Robot Operating System. However, in this paper, we investigate precision landing as it is uniquely challenging due to the lack of corresponding data between the drones IMU and its vision system as the DJI does not allow this to happen and there's little information on the product on drone sensors.

This lack of corresponding data leads the drone to drift as it lands. The downside of this kind of drone is the unstable holding position due to strong wind and low light [8], creating a particular problem when attempting to land precisely. Still, decreasing the drone's altitude incrementally can allow for a more precise landing while minimizing any drift. However, other solutions may use more complex algorithms to deal with this problem. It involves using the Cartesian plane coordinate system because the Cartesian coordinates of the drone, through simple trigonometric formulation, given the drone's current angle and the desired flight distance relative to the point of launch [9], can substitute for a GPS. Other unique challenges include the drone overheating.

In [10], the authors discuss the Tello overheating. The drone became unresponsive once the temperature reached 35°C (95°F). In our work, to mitigate overheating and preserve drone health, create a function that checks for drone temperature and battery percentage and has it land immediately once it reaches a specified threshold.

The smallest possible variance of deviations in high-precision landing procedures is discussed by Janousek et al. [11]. This emphasizes the need to consider the slight variations that may affect the drone's precision while landing. In our paper, it is the drift and the altitude threshold of the drone's IR camera to read mission pads, QR codes, or objects accurately.

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented an open-source platform leveraging OTS drone to work on a challenging precision landing research problem. We demonstrated how a simple code modification could improve the precision landing in a controlled environment. The experimental results demonstrate the effectiveness of the proposed method with easy-to-follow approach.

In the future, we will include battery charge status and how it effects on precision. We will also explore methods to use OpenCV software to adjust landing automatically while in flight using the IR sensor display.

VII. ABOUT AUTHORS

Gabriel Guillen

He has an associate degree and currently pursuing bachelor's degree in engineering technology at Kansas State University Salina, Aerospace & Technology campus. He is a member of the National Society of Leadership and Success and is currently a work-study student under the supervision of Professor Balasubramaniam. He has worked on sever other technologies such as Leap Motion hand tracking device and has a passion in cyber systems.

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