Platform Tracking and Landing on a moving Platform.

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ABSTRACT

This project explores the development of an advanced system for autonomously landing a drone on a moving platform, leveraging image-based path planning constrained by computational limitations that prevent dynamic memory allocation. The solution utilizes a MATLAB script combined with a PID controller and a state flow architecture to manage transitions based on real-time sensor data. The drone, equipped with a camera, ultrasonic sensor, barometer, and IMU, adjusts its flight path by analyzing regions of interest within captured images. This control mechanism ensures the drone aligns its trajectory with the moving platform, adjusting for positional errors and the velocities in the x and y axes. The integration of the state flow system enables seamless state transitions and coordinates various actions driven by feedback from the PID controller and a specific landing protocol, enhancing the precision and reliability of the landing operation on a dynamically changing target.

Keywords:
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## [1] 1. INTRODUCTION

This project extends the capabilities of a Parrot MiniDrone equipped with an IMU, camera, barometer, and ultrasonic sensor to perform precision landings on a moving platform. Tailored modifications to the drone's flight code, initially optimized for static path following and landing, now facilitate dynamic interaction with moving targets. The system integrates enhanced path planning, control algorithms, state estimation, and landing logic, alongside established modules for fault detection and logging. Central to this project is the advanced image detection module, which now plays a crucial role in tracking the moving platform's position and velocity. Using real-time image processing and optical flow analysis, the system continuously adjusts the drone's trajectory in the x and y axes to minimize positional errors relative to the moving platform. This dynamic tracking is managed through a series of carefully calibrated PID controllers that process feedback from the state estimator to refine motion control and ensure precise alignment with the platform.

Once the drone achieves optimal alignment over the platform, the focus shifts to descending control. This phase leverages a proportional control strategy, which adjusts the drone's z-axis position based on the aggregate pixel count in the central region of the captured images. This method ensures a controlled and stable descent, synchronizing the landing process with the real-time motion of the platform below. The regions of interest for image analysis and PID tuning parameters have been meticulously defined to support robust performance, preventing oscillation, and ensuring swift convergence to the target, thus enabling a precise and reliable landing on the dynamically moving platform.

Task 1: Simulate the Drone Landing in Simulation

1. Update the Simulator and make the platform moving by applying sinusoidal motion to the platform

Task 2: Develop the tracking algorithm for the platform =.

Task 3: Develop the landing logic for the drone while the platform is accurately being tracked.

METHOD

The Simulation Block is where we make the changes to the simulation parameters, we apply translational motion to the platform using a sinusoidal wave according to the frequency and amplitude required according to the project requirements.

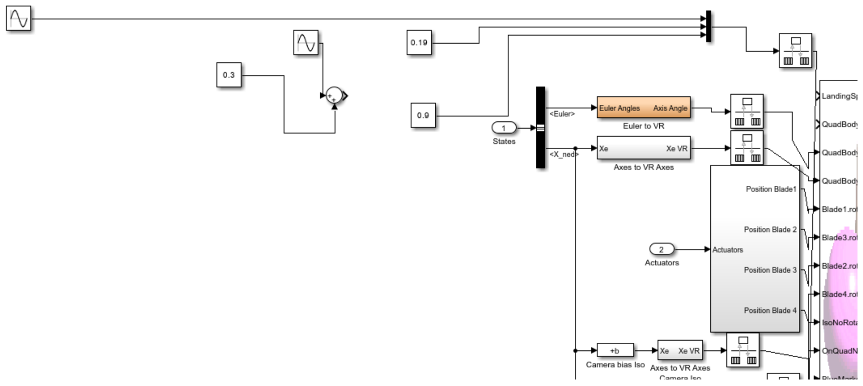

Figure 1. Platform Motion

The MATLAB function calculate_ang processes a binary image to locate and analyze a specific object within that image. It calculates the object's centroid by computing image moments, then determines the object's orientation relative to a predefined point by calculating the angle between them. The function also evaluates pixel density in defined regions of the image, which might be useful for additional analysis or control decisions. Essentially, it's tracking the position and orientation of an object within the image and quantifying certain attributes of the area around the object for further use.

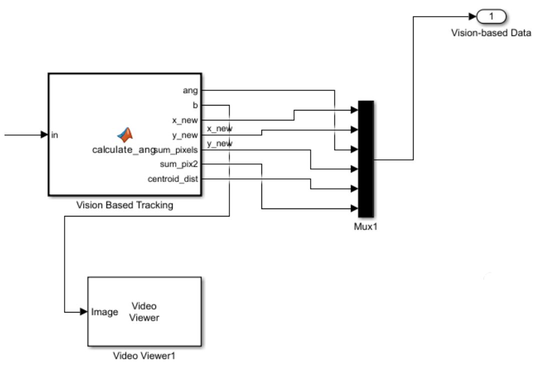

Figure 2. Vision Based Tracking Module

The Path Planning Module utilizes stateflow for the control of the drone in varying scearios, it calculates the centroid and minimizes the error in the position of the drone with respect to the platform based on the position and velocity of the platform, it then initiates the landing sequence to safely land the drone while tracking the platform simultaneously. PID controllers are used to estimate the errors and minimize the position errors while the controller then updates it with position as well as velocity errors so that the tracking is accurate for varying speeds of the platform.

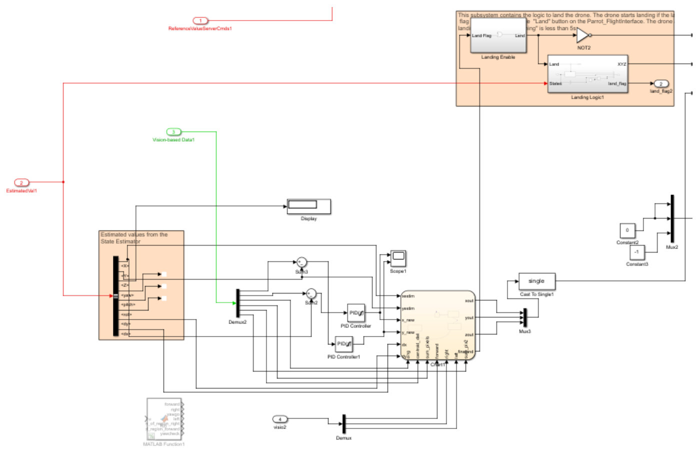
Figure 3. Flight Planning Module

The Figure Below shows the controller outputs from the PID in the controller module, the errors are stably minimized to zero and so the control inputs eventually degrade to zero as the landing is successful. The control inputs show that the x error is the main error as y is just initially there as the position is off in the y , there after the linear x control input keeps increasing until stabilizing along with the integrator to continuously track positions.

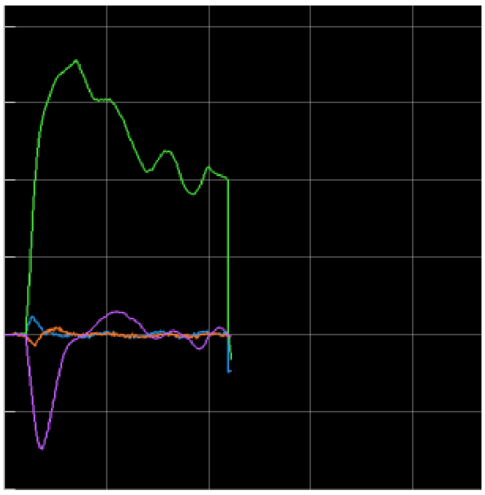
Figure 4. Controller Inputs

Figure 5. Drone Simulation Landing

Figure 5 above shows the simulation where the model is initially tested using different algorithms and planners, once the requirements of the project are met within certain thresholds, then it is deployed and tested on real drone.

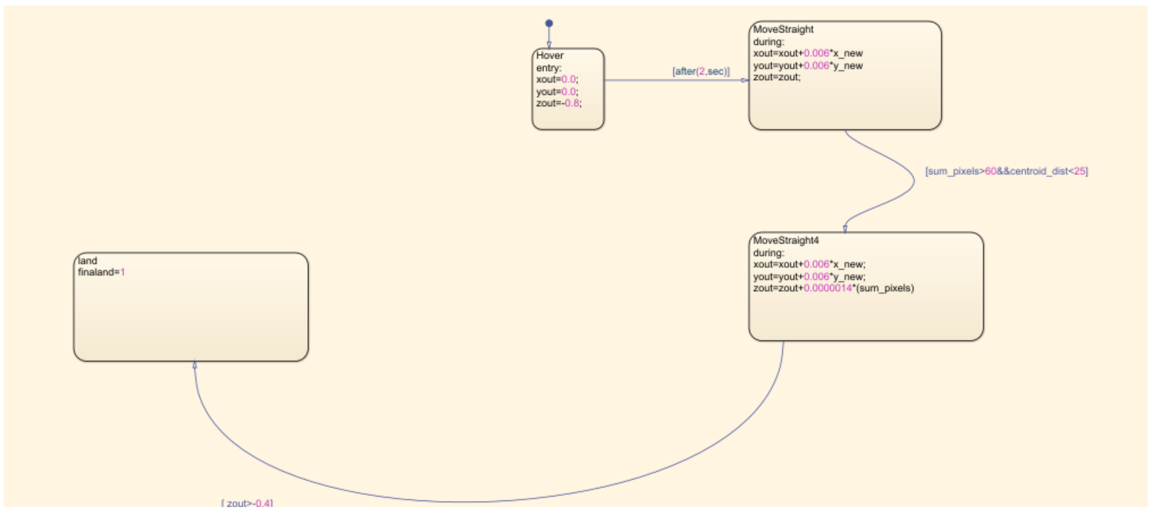

Figure 6. StateFlow Chart

Figure 6 shows the states the drone follows after initialization of the flight, it hovers for 2 seconds, then follow the x_new and y_new to track the position of the platform as well as reduce the altitude error as the distance of the centroid of platform is below a threshold, the drone slowly starts descending, it then initiates a final landing sequence when the drone is below an altitude threshold, as below a certain threshold the optical flow can give false readings. Significant gain tuning is required as PID controller performance largely depends on the gains of the controller, the gains above are calculated after significant tuning which provides optimal performance in terms of performance and stability. We use a discrete controller as our inputs are discrete images.

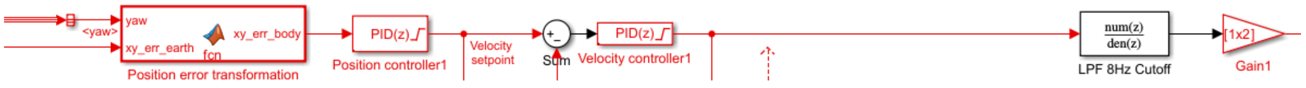

Figure 7. Controllers Module

The PIDs are cascaded the outer controls the positions and the inner controls the velocity, adding an acceleration control added a lot better track in highly nonlinear trajectory and speed of platform, however the real drone cannot handle that level of controller as unstably keeps crashing on launch.

RESULTS AND DISCUSSION

The drone demonstrates accurate performance and stability in both simulation as well as real demonstration, the drone is able to recover in presence of disturbances like inaccurate x and y coordinates of the drone on launch as the stability is impacted by wind, battery and other conditions, the drone is able to maintain stable tracking and landing over the platform and the errors stabilize to maintain the platform coordinates and velocity.

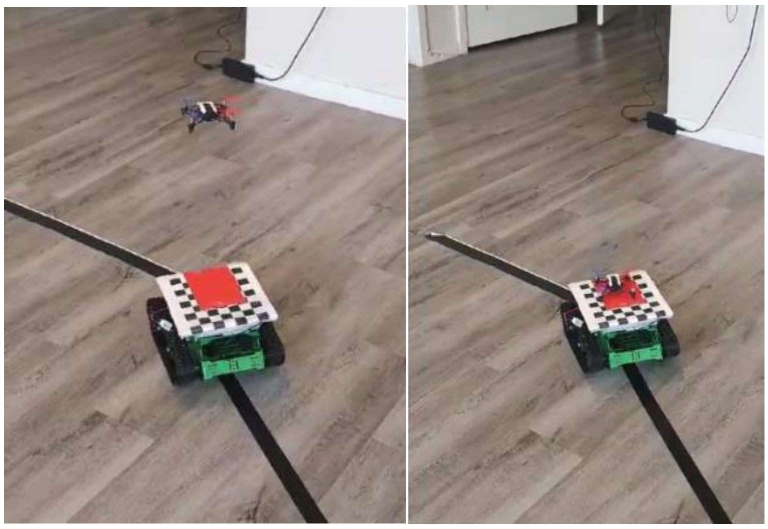

Figure 8. Drone Landing on Moving Platform

CONCLUSION

The autonomous Platform Tracking and landing enables the drone to fly autonomously in a controlled environment which can be quite useful for pick and place in a highly dynamic environment. The robust PID controller and path planner enable the drone to fly in the presence of disturbances and correct the path back with a stable and quick response.

Video link: - https://www.youtube.com/watch?v=BC3rqH2GxHs

https://www.youtube.com/watch?v=hQ6WelZc7Jo (presentation)

https://youtu.be/pKt866nZ3-A (simulation video)

REFERENCES

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