24-774 ACSI: Individual Project Proposal

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1 Design Problem Definition

I would like to develop a controller that can land a Crazyflie on a moving target. The target landing area should have a sufficiently small surface area and be moving at a sufficiently high speed to make this a challenging task. (For additional difficulty the target could be moving in a non-linear or unknown trajectory.) I was inspired by two real-world situations: landing fighter planes on an aircraft carrier, and the current DARPA Subterranean challenge which requires landing a drone on top of a ground robot in an underground environment in order to recharge during a search and rescue operation.

I would like to focus on building three key capabilities: (1) exploring a space and finding the target object, (2) identifying the trajectory of a target object and (3) matching the Crazyflie trajectory to be able to land on the target object. This is closely related to [1] which has used an advanced collection of onboard sensors to accomplish these three tasks without additional computing or sensing capabilities. I would like to accomplish these goals using only the optics board supplied with the Crazyflie if possible - I am curious to figure out if it is possible to use a low flight path to scan the ground for an object above the ground plane using the range finder and thus find the moving target.

I am considering using the following algorithms to meet each capability: (1) a regularized search pattern at low height to find the target object, (2) a Kalman filter (or some version thereof) to perform state estimation of the target object and to predict its next position and (3) either fuzzy logic or model predictive control to match the Crazyflie's trajectory to the target object's trajectory.

2 Existing Approaches

I have reviewed several examples of landing a drone on a moving target in the literature. The most compelling example is demonstrated by Falanga et al. in this Youtube video https://www.youtube.com/watch?v=Tz5ubwoAfNE and in their associated conference paper [1]. Falanga et al. use more advanced image processing techniques to identify the target landing site and use the camera data to extract its velocity data [1]. They use an Extended Kalman filter to predict its trajectory [1]. They use a combined higher level controller to decide the next position of the drone and a lower level controller to move to that position [1]. The details of these controllers are given in another paper and are said to be based on the dynamical model of the drone [1]. Falanga et al. also review other work, indicating that motion capture systems, computer vision and GPS are the most prevalent methods of performing state estimation [1]. Visual servoing, a method that requires less precise image processing, has also been used to perform state estimation, as described by Serra et al. in [1],[2].

In a review article by Wickramanayake et al., they describe various tracking systems that use QR codes or black and white marked zones to identify the landing area using vision systems [3]. They state the most common tool for identifying the landing zone is image processing using data from an onboard camera. [3] Researchers have performed object detection via an external computer with wireless connection, but this is slow [3]. Others have used powerful onboard computers to perform image analysis in real time, pulling data from the onboard IMU and implementing control using PID controllers on each rotor, and fuzzy logic for high-level control [3]. Another example of high-level control with fuzzy logic was demonstrated by Stockton et al. in [4], although they also used OpenCV in Python for image processing, with low-level control provided by PID controllers. An additional article about their work is presented in [5].

3 Feasibility

I think the main challenge for this project will be getting sufficiently accurate data from the optics deck (camera, range finder) to be able to find and follow the moving target object. I also am not sure how much work this will be and I'm concerned that it will be too large a scope for this class.

4 Team Composition

I am happy to continue working with my existing team (Pranav Narahari, Keitaro Nishimura, and Zongwen Mu).

5 References

(1) Davide Falanga, Alessio Zanchettin, Alessandro Simovic, Jeffrey Delmerico, Davide Scaramuzza, "Vision-based Autonomous Quadrotor Landing on a Moving Platform", IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), Shanghai, 2017.

(2) P. Serra, R. Cunha, T. Hamel, D. Cabecinhas and C. Silvestre, "Landing of a Quadrotor on a Moving Target Using Dynamic Image-Based Visual Servo Control," in IEEE Transactions on Robotics, vol. 32, no. 6, pp. 1524-1535, Dec. 2016.

(3) Wickramanayake, Dimuthu Rajasooriya, Rajitha Ranawella, Kavin Karunarathne, Namal. (2018). Landing on to a moving target using quad-copter : a comprehensive survey. 10.13140/RG.2.2.10167.98725.

(4) Stockton, Nicklas Kumar, Manish Cohen, Kelly. (2017). A Fuzzy-Logic-Based Solution to Dynamic Target Interception and Landing with a Small Multi-rotor Aircraft. 10.2514/6.2017-1752.

(5) Cole, Sally. "Landing drones on moving targets." Military Embedded Systems. http://mil-embedded.com/articles/landing drones-moving-targets/ Visited 10/14/2019.