CS Capstone Requirements Document

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American Helicopter Society Micro Air Vehicle Competition

Prepared for

Potentially Columbia Helicopters

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Abstract

Oregon State University (OSU) is participating in this year's Mirco Air Vehicle Challenge hosted by the Vertical Flight Society (AHS). The OSU team is large and interdisciplinary. This document covers the basic structure of the team's software and its expected functionality.

Contents

List of Figures

1 Introduction

1.1 Purpose

This document establishes definite project requirements of the CS team's portion of the Vertical Flight Society's (VFS) micro air vehicle (MAV) obstacle course challenge. Each requirement is described in detail.

1.2 Scope

This document is constrained to the CS team's work on the MAV. These top-level features are the focus:

- Display of onboard cameras and sensors
- Obstacle detection and avoidance
- Helipad target recognition
- Digital flight controls

1.3 Product Overview

This document covers the interactions between: the different features, how users are supposed to interact with the team's MAV, assumptions made by the team, and the constraints faced by the team.

1.3.1 Product Perspective

The MAV will transmit sensor data, which the CS team's software will capture and process. The software will use the data to make flight control decisions and then transmit the orders to the MAV. The software will provide a level of semi-autonomous control, but fall short of a fully autonomous system. The software exists to help the pilot, not to fly the craft.

1.3.2 Product Functions

The MAV will have a dedicated computer that handles data processing and flight controls. Computer software will process incoming camera and sensory information and provide the pilot with visual, and potentially auditory, feedback. Feedback includes coordination of helipad targets and obstacle warning detection. Particular information, regarding collision avoidance in particular, will be transmitted back to the MAV for flight control override.

1.3.3 User Characteristics

The MAV is controlled remotely by an experienced pilot. Visual display, pickup assist, and obstacle warning system will provide the pilot with additional information to navigate the MAV.

1.3.4 Limitations

The competition and the MAV should conform to the rules established by the Vertical Flight Society, which enforce safety considerations, inclusion of remote control functionality, a 500 gram weight limit, a 45 centimeter dimension limit in any direction, and inclusion of an onboard camera. The 500 gram weight limit and budget limitations prevent the use of desired hardware, including Intel RealSense camera, laser scanner, laser range finders, high bandwidth broadcasting equipment, and powerful onboard processing units.

1.4 Apportioning of Requirements

This gantt chart describes our estimated timeline of completing tasks. Each phase needs to be completed by the end of it's width. Documents for the grade portion of this project are due by the end of each term, denoted by the green bars. In terms of the CS team, code for the various helicopter components should be feature complete by the end of winter term.

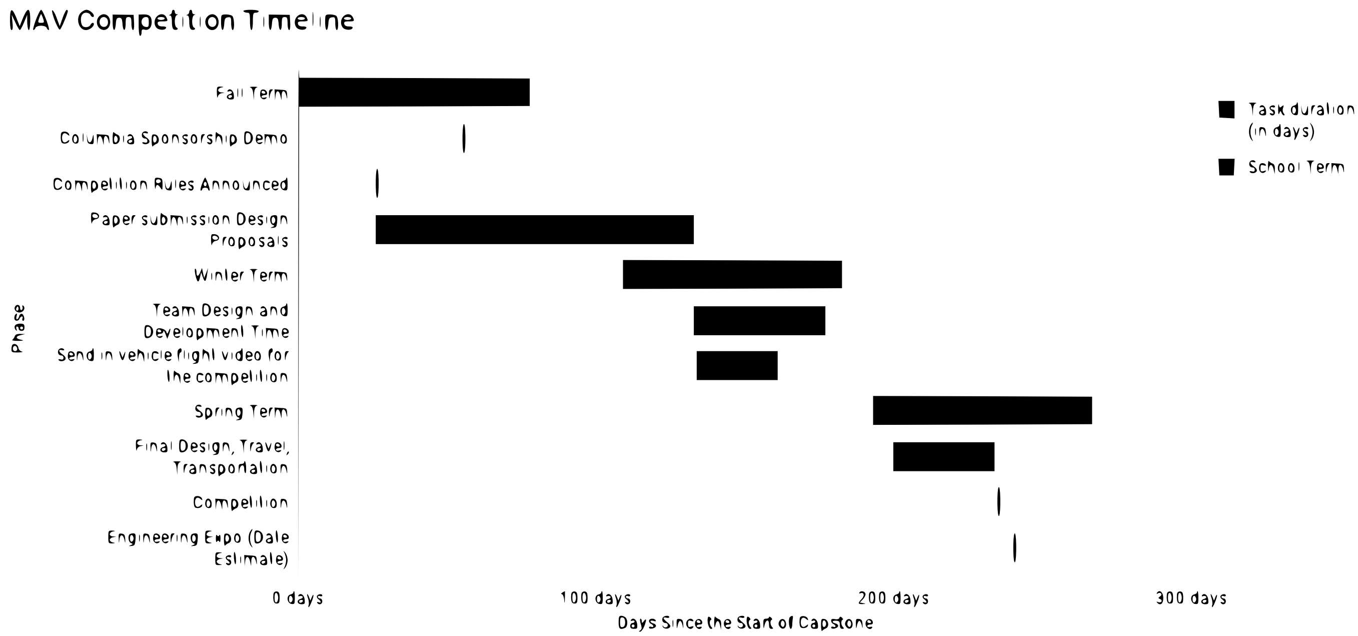

Figure 1: Completion Timeline

1.5 Definitions

- **Computer Vision**: A subset of artificial intelligence that deals with providing information through visual and image data.
- **Convolutional Neural Network (CNN)**: A type of Neural Network that has learnable weights and biases that help to inference the data better. A CNN learns from each raw pixel from an image and assigns new weights to the convolution layer.
- **Convolutional Layer**: A layer of a CNN that performs the computations.
- **Dropout Layer**: A layer of the CNN that prevents overfitting of data.
- **Micro Air Vehicle (MAV)**: A remotely controlled, semi-autonomous, coaxial helicopter.
- **Package**: A sealed paper lunch bag, containing a pamphlet. A braided wire loop is attached at the top of the bag for acquirement.
- **Package A**: A package weighing between 20 and 25 grams.
- **Package B**: A package weighing between 25 and 30 grams.
- **GUI**: Graphical user interface.

1.6 References

[1] Vertical Flight Society. (2018). *7th Annual VFS Micro Air Vehicle (MAV) Student Challenge* [PDF file]. Retrieved from https://vtol.org/files/dmfile/7th-annual-mav-student-challenge_v7_oct182018.pdf?fbclid=IwAR3-J_yJIKUKoGPBfsdJFAbjMUzXo

2 Specific Requirements

This section contains all the input and functional requirements of the MAV's software.

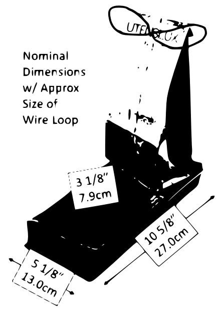

Figure 2: Package

2.1 External Interfaces

The following section composes hardware components required for the software.

Tool ID: FC

Name: Flight Controls

Description: Controls for adjusting cyclic, collective, anti-torque, and throttle.

Inputs: GRYO, ACCL, MRTRAN

Output: MRTRAN

Tool ID: GYRO

Name: Gyroscope

Description: A gyroscope is needed to stabilize all three axes of alignment of the coaxial helicopter. The device will prevent the aircraft from flipping over and provide orientation data for flight controls.

Output destination: MRTRAN

Tool ID: ACCL

Name: Accelerometer

Description: To keep the helicopter stable, there is a need for small reading changes in the motion of the helicopter. The addition of the accelerometer data will significantly improve the helicopter's ability to maintain a stable position.

Output destination: MRTRAN

Tool ID: IRL

Name: Infrared Laser

Description: Infrared lasers will point towards the front of the MAV, coming to a point in front of the craft. These lasers will interact with obstacles in front of the MAV. The infrared camera will monitor the interactions between obstacles and the lasers.

Output destination: MRTRAN

Tool ID: IRCAM

Name: Infrared Camera

Description: The infrared camera will see where the front facing infrared lasers hit objects in front of the MAV. The software will process the data to provide the pilot with information regarding the viability of the current flight path.

Output destination: MRTRAN

Tool ID: NCAM

Name: Nose Camera

Description: Front facing color camera to provide the pilot with flight visuals.

Output destination: MRTRAN

Tool ID: ACAM

Name: Acquire Camera

Description: Downward facing color camera to provide the pilot with flight visuals.

Output destination: MRTRAN

Tool ID: IRRANG

Name: Infrared Rangefinders

Description: The infrared rangefinders will detect objects close to the MAV. They have a limited range of 30 cm. The infrared rangefinders will be positioned around the craft to provide the best possible coverage of the plane perpendicular to the floor.

Output destination: MRTRAN

Tool ID: URANG

Name: Ultrasonic Rangefinders

Description: The ultrasonic rangefinders will detect objects at medium range from the MAV. They have a range of six meters. The ultrasonic rangefinders will be positioned around the craft to provide the best possible coverage of the plane perpendicular to the floor.

Output destination: MRTRAN

Tool ID: MRTRAN

Name: MAV's Radio Transmitter/Receiver

Description: The onboard transmitter will broadcast the MAV sensor data to the receiver connected to the team's dedicated computer and receive flight control data.

Inputs: GRYO, ACCL, IRL, IRCAM, NCAM, ACAM, IRRANG, URANG, CRTRAN, FC

Output destination: CRTRAN, FC

Tool ID: CRTRAN

Name: Computer Radio Transmitter/Receiver

Description: The radio transmitter/receiver connect to the pilot's computer for communication with the MAV.

Input: MRTRAN

Output: MRTRAN, DPROC

Tool ID: DPROC

Name: Processing Unit

Description: A dedicated, standalone computer for processing incoming camera and sensor data. Also responsible for processing commands for the MAV. Includes display, keyboard, joystick, and throttle.

Input: CRTRAN

Output: CRTRAN

2.2 Functions

The following section composes hardware software functionalities.

Feature ID: VDISP

Name: Visual Display

Description: Outputs a user interface that displays sensor data.

Dependencies: None

Input: DPROC

Output: DPROC

Feature ID: DFC

Name: Digital Flight Controls

Description: Commands for controlling flight of MAV. Includes stability control and automatic hover.

Dependencies: None

Input: DPROC

Output: DPROC

Feature ID: COLWA

Name: Collision Warning

Description: Warn pilot of incoming obstacle.

Dependencies: None

Input: DPROC

Outputs: DPROC, COLAV

Feature ID: COLAV

Name: Collision Avoidance

Description: Override MAV controls whenever an obstacle is detected.

Dependencies: COLWA, DFC

Input: DPROC, COLWA

Output: DRPOC

Feature ID: IREC

Name: Image Recognition

Description: Process camera and range sensor data for locating and recognizing helipad targets. Aligns MAV over target.

Dependencies: DFC

Input: DPROC

Output: DPROC

2.3 Competition Walkthrough

The MAV must complete a mission that is themed as Washington's Flight for Liberty. The MAV's mission performance is the standard to which the OSU team's software will be held. Objectives of the mission are described below (please refer to Figure 1 for the visual):

1) The mission begins with the MAV parked at Thomas Paine's helipad. Upon the start of a ten minute timer, the MAV must do the following:
   a) Take off from the helipad.
   b) Hover for ten seconds.
   c) Acquire Package A.
   d) Hover for ten seconds.
   e) Fly North until reached the net barrier.
2) Upon reaching the the barrier, the pilot must:
   a) Climb MAV 1.83 meters, plus a safe height, above the barrier.
   b) Spot and verbally express visual contact with McKonkey's Ferry.
   c) Fly north, descending to a safe height, until reached and passed the center line of McKonkey's Ferry, by approximately 0.5 meters.
3) Once within 0.91 meters from the northern side of McKonkey's Ferry, the MAV must head east, until crossed Delaware River and reached Pamphlet Delivery helipad.
4) At Pamphlet Delivery helipad, the MAV must release the package, as close to the bullseye as possible.
5) After releasing the package, the pilot must maneuver MAV south, to Camp Washington Pickup Zone. On its way, the MAV must:
   a) Fly over a 1.22 meter high barrier.
   b) Fly under a 0.61 meter obstacle.
6) At the Camp Washington Pickup Zone, the MAV must:
   a) Acquire Package B.
   b) Hover for ten seconds.
   c) Head back to Thomas Paine's helipad, reversing the route.
7) Upon reaching Thomas Paine's helipad, the pilot must:
   a) Verbally express visual contact with Thomas Paine's helipad.
   b) Have the MAV release the package as close to the bullseye as possible.
   c) Land the MAV within 0.91 meters of the helipad.

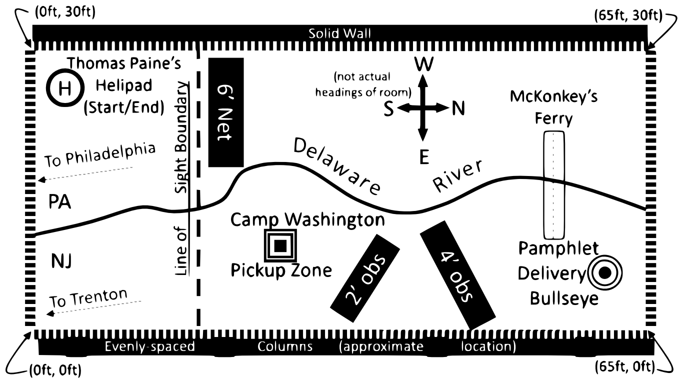

Figure 3: Course Map

2.4 Verification

Measurement is done by the qualitative assessment of mission phases described below:

Take off and Hover The MAV must perform a stable hover, above base, at a height of two meters.

En Route to Delivery/Pickup Area The MAV must have a clearly-announced, timed, and smooth transition to the package delivery and package pick up sites.

Obstacle Avoidance The MAV must avoid obstacles between the home base the target search area. Metrics include successful avoidance and smoothness of flight around obstacles.

Target Acquisition The MAV must establish a stable hover for at least five seconds over each delivery/pickup location target and smoothly transition between searching, hover, and drop-off/pickup phases. Metrics include lateral target tracking error and stable roll/pitch performance.

En Route Return to Base The MAV must return to base with a user signal. Remote operator can use LOS. "Base" can use homing beacons for autonomous return to base. Metrics include qualitative smoothness of transitions and time to acquire stable hover over base.

Hover and Landing The MAV must acquire a stable hover, two meters above base, before landing. Metrics include hover and landing performance, as well as, distance from the center of the helipad.