Carnegie Mellon University
16-681 2020 Fall

Project Test Plan

Ground-Air Collaboration for Future Relay Aerial Mission

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September 22, 2020

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Introduction

This document provides a guideline and schedule for the tasks and milestones to be completed by MRSD Team C during Fall 2020 semester. The Schedule Section outlines the key milestones for different progress reviews, corresponding tests to be completed, and system requirements to be satisfied. The details of the tests to be completed are listed in the Tests Section. The tests were divided into four subsections: Test series 1 contains the tests for UAV software development; test series 2 contains the tests for UGV software development; test series 3 focuses on hardware subsystem and integration; test series 4 includes the overall system integration tests. Team C will follow the listed tests and schedule to conduct validation and verification for the Fall 2020 semester.

Schedule

Date	PR	Milestones	Tests	System Requirements
Oct 1	8	1. Demonstrate results of the UAV GPS waypoint following and obstacle avoidance 2. Demonstrate results of the UAV autonomous landing on an Apriltag 3. Validate integrated system in simulation 4. Verify UGV sensor proper functioning	1.1 1.2 3.1 4.1	M.P.1-M.P.3
Oct 9	9	1. Demonstrate results of the UAV self-navigation and autonomous landing 2. Validate the localization and mapping functionality of the UGV 3. UGV hardware formfactor locked and ready for hardware testing	1.3 2.1 3.2	M.P.2, M.P.3
Oct 23	10	1. Valide the navigation functionality of the UGV 2. Fully functional customized UGV with demonstrated mobility	2.2 3.3	M.P.4
Nov 6	11	1. Validate entire system in field test	4.2	M.P.1-M.P.3 M.P.7
Nov 18	FVD	1. Demonstrate the planning, navigation and landing functionality of the system	4.2	M.P.1-M.P.3 M.P.7

Tests

Test 1.1 - UAV Obstacle Avoidance

Objective: To demonstrate that the UAV subsystem is capable of self-navigating to waypoints while avoiding simple obstacles

Elements: A unit test of the obstacle avoidance and waypoint following feature of the UAV subsystem.

Location: Boyce Park

Equipment: UAV, Cardboard boxes (1~3)

Personnel: Aaron Guan, Yichen Xu

Procedure:

1. UAV is given a destination in GPS coordinates
2. UAV takes off and approach the destination while avoiding obstacles
3. UAV reaches the destination and lands

Verification Criteria:

- UAV avoids all obstacles
- UAV reaches the destination

Test 1.2 - UAV Apriltag Tracking and Landing

Objective: To demonstrate the UAV's autonomous landing feature using vision based approach and PID controller based outer loop

Elements: A unit test of the visual odometry (with Apriltag) and velocity control loop of the UAV subsystem.

Location: Boyce Park

Equipment: UAV, a 0.5m x 0.5m Apriltag print

Personnel: Aaron Guan, Yichen Xu

Procedure:

1. Place the tag on the ground
2. Have the UAV take off and manually fly it to a random location near the tag while the tag remains within the line of sight of the downward-facing camera
3. Have the landing algorithm takes over which will:
    a. Align the UAV with the center of the tag using a PID controller
    b. Once the position error is below threshold it will start descending
    c. Once the UAV gets too low for tag recognition, perform default landing

Verification Criteria

- UAV lands on the Apriltag with error < 0.25 m

Test 1.3 - UAV self-navigation and autonomous landing

Objective: To demonstrate the ability of the UAV to perform navigation and landing in full autonomous mode

Elements: A subsystem level test of the UAV subsystem's navigation and landing modules

Location: Boyce Park

Equipment: UAV, cardboard boxes a 0.5m x 0.5m Apriltag print

Personnel: Aaron Guan, Yichen Xu

Procedure:

1. UAV is given the GPS coordinates of the Apriltag
2. UAV takes off and approach the Apriltag while avoiding obstacles
3. When the UAV is within 1m radius of the Apriltag, switches to Apriltag tracking and landing
4. UAV lands on the Apriltag

Verification Criteria

- UAV avoids all obstacles
- UAV lands on the Apriltag with error < 0.15 m

Test 2.1 - UGV Mapping and Localization

Objective: To verify that the UGV executes mapping and localization function within required accuracy

Elements: a unit test of the mapping and localization of the UGV subsystem

Location: MRSD Lab or open area near NSH

Equipment: Jackal UGV, IMU, Computer

Personnel: Yi Gu

Procedure:

1. The user records the initial GPS position of the UGV.
2. The user manually drives the UGV away from the initial position.
3. The user sends the initial position to the UGV and the UGV automatically navigates to it.
4. The user records the difference between the final position and the initial position.
5. The user repeats step 1 to 4 for 5 times.

Verification Criteria

- The mean difference between the initial position and final position is less than 0.3 m

Test 2.2 - UGV Navigation

Objective: To verify that the UGV could not only detect the obstacles but also keep a safe distance from obstacles to steer itself toward an efficient path, which achieves the requirement of accuracy and time.

Elements: a unit test of navigation functionality of the UGV subsystem

Location: MRSD Lab

Equipment: Jackal UGV, IMU, Computer

Personnel: Yi Gu

Procedure:

1. The user turns on the UGV.
2. The user selects a location and sends the GPS position of it to the UGV.
3. The UGV plans its path and navigates towards the goal.
4. The user records the time for navigation and also the final destination.
5. The user repeats step 1 to 3 for 5 times
6. The user turns off the UGV.
7. The user records the mean of time and difference between final position and target position.

Verification Criteria:

- The UGV avoids all obstacles
- The UGV reaches the destination with mean difference between the final position and target position less than 0.3 m
- The UGV navigates towards the target position within the 120s averagely

Test 3.1 - UGV Sensors Setup Verification Test

Objective: Verify the proper functioning of UGV sensors (GPS, IMU, LIDAR)

Elements: This is a subsystem level test of the UGV sensors combinations

Location: MRSD Lab + NSH B Level Parking Lot

Equipment: Jackal UGV, Linux Computer

Personnel: Zhaoyuan Huo

Procedure:

1. The user powers on the UGV subsystem
2. The user executes the script on Linux Computer to build up connection between UGV and Linux Computer
3. The user printout the rostopic received, check for GPS, IMU, LIDAR topics
4. The user echo the localization information from GPS and IMU
5. The user visualize the LIDAR PointCloud in RViz
6. Turn off the UGV
7. Terminate the ROS script and close the connection

Verification Criteria:

- Connection between Linux Computer and UGV can be built and remains stable during the test
- LIDAR PointCloud visualization is close to the scene of the test room
- Localization information can be read and interpreted correctly

Test 3.2 - Landing Module Mechanical Retrofit Fit-Check

Objective: Static verification to ensure that the dimensions of the assembled UGV system with landing module are fit and can maintain safety tolerance between key components

Elements: This is a subsystem level test on the mechanical designs of landing module and mounting structure

Location: MRSD Lab

Equipment: Jackal UGV, Landing Module, DJI M100 UAV

Personnel: Zhaoyuan Huo

Procedure:

1. The user assembles the landing module onto the fully loaded UGV platform
2. The user place the fully loaded UAV with propellers onto the landing platform
3. The user measure the closest horizontal distance between the components of UAV and UGV

Verification Criteria:

- The assembly/disassembly process has no mismatch
- The overall assembly is stable in the static condition
- There is at least 20cm horizontal safety distance between different components on UAV and UGV respectively

Test 3.3 - UGV Hardware System Integration Test

Objective: Verify both proper functioning of UGV sensors, signal transmission, retrofit robustness, and vehicle mobility while UGV is travelling

Elements: This tests the integration of the UGV mechanical and sensor hardware subsystems

Location: NSH B Level Parking Lot

Equipment: Jackal UGV, Linux Computer, Routers

Personnel: Zhaoyuan Huo, Aaron Guan

Procedure:

1. The user places UGV with integrated landing module on a flat ground in a open test area
2. The user powers on the UGV
3. The user executes ROS script on the Linux computer and builds connection between the UGV and the computer
4. Echo the GNSS output
5. Visualize the LIDAR PointCloud with RViz
6. The user presses "up" key on the keyboard, to manually control the UGV to go straight
7. The user presses "up" + "left"/"right" keys on the keyboard, to manually control the UGV to take left and right turns
8. Power off the UGV
9. Terminate the ROS script and close the connection

Verification Criteria:

- GNSS output can give correct localization information
- LIDAR PointCloud visualization is close to the scene of the test area
- Hardware assembly remains stable while the UGV is travelling
- UGV demonstrates mobility without disturbance from the mounted landing module and sensors

Test 4.1 - Integration Test

Objective: Verify the planner could work properly in ROS simulation environment

Elements: a integration test of the UGV-UAV system

Location: Home

Equipment: UAV, Linux Computer

Personnel: Wanzhi Zhang, Yichen Xu

Procedure:

1. Construct a simulated environment of 20m × 20m with obstacles
2. Place UAV and UAV at opposite corners
3. Give commands to the system
4. UGV proposes several candidate landing points
5. UGV finds and reaches a valid landing point
6. UAV lands on the UGV at the designated landing point

Verification Criteria:

- UAV and UGV avoid all obstacles
- UGV always finds a valid landing point
- UAV lands on UGV with error < 0.3m
- Process finished in 120s

Test 4.2 - Fall Validation Demonstration

Objective: Demonstrate planning, navigation and landing capability of system

Elements: a system-level test

Location: A 20m × 20m outdoor area near the Cut

Equipment: UAV, Jackal UGV, Linux Computer, cardboard boxes

Personnel: Aaron Guan, Yi Gu, Zhaoyuan Huo, Yichen Xu, Wanzhi Zhang

Procedure:

1. Place UAV and UGV apart in an open area
2. Place piled boxes as obstacles between UAV and UGV
3. Initialize UAV and UGV
4. UAV takes off from UGV landing platform
5. UAV flies off to reach certain predefined waypoints
6. As the UAV completes its goal, it will send a signal to ROS master, and master will dispatch a UGV for landing mission
7. UGV computes potential landing point candidates, and navigates towards the first candidate
8. UGV evaluates the landing feasibility of each candidate until it finds a valid landing point
9. UGV sends a signal to the UAV
10. UAV reaches the landing point and starts tracking Apriltag and plan optimal landing path
11. UAV lands on UGV

Verification Criteria:

- UAV have a safe and steady land on UGV without tipping over
- UAV land on UGV within 60 seconds
- UAV and UGV avoid all obstacles
- Neither UAV or UGV ran out of battery

Appendix

A1. Mandatory Performance Requirements

ID	Requirement	Description
M.P.1	The system will complete landing process on static platform in 60s, with 60% success rate	The landing process should be completed in a limited amount of time in order to be useful for real use cases
M.P.2	UAV and UGV will detect and avoid obstacles with 100% success rate in standard events	The UAV and UGV need to avoid obstacles perfectly for each event, otherwise critical hardware failure would occur
M.P.3	In the test space (area 20×20m, path length > 40m), the UGV will complete mapping within 120s, with (x, y) error less than (0.2m, 0.2m)	The UGV needs to map the environment within time and error limit
M.P.4	In the test space above, the UGV will reach the target point within 120s, with (x, y) error less than (0.3m, 0.3m)	The UGV should be able to navigate towards the goal within time and error limit
M.P.5	UAV will take off with 500g additional weight	The UAV needs to take off with the additional weights of sensors and magnetic force from platform
M.P.6	UAV will continuously fly for 10 min	The UAV should reserve sucient fly time which allows for plan and execution
M.P.7	UAV will be able to communicate with UGV within the range of 1km	Since UAV needs to fly off to do tasks, 1km communication range is needed for testing
M.P.8	Neither UGV or UAV runs out of battery during the task	Both robots need to plan energy consumption ahead to finish the task
M.P.9	The UAV will have a GPS error within 1m	The UGV should be able to sustain the torque generated from the UAV at the instant of landing