Test Plan

Team H

PhoeniX

UAV-AGV Collaborative

Fire-Fighting System

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Submission Date: 18th September 2019

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Introduction

This test plan outlines the requirements and goals to be achieved by team PhoeniX by the Fall Validation Demonstration (FVD) deadline, and the intermediate milestones planned towards reaching those goals. Each intermediate capability milestone details the requirements it will address and the method by which we will address them. Each milestone builds upon the previous towards completing the integrated UAV-AGV fire fighting system. Our Fall Validation Demonstration will consist of a full demo of the UAV and AGV demonstrating fire extinguishing capability. The experiment details the tests step-by-step, and how that step maps to our requirements.

Schedule

P.R.	Date	Capability Milestone	Associated Test	Associated Requirement
8	Sept 26	Capability to fly/drive through the opening	8.1	F.R. 2, F.R. 5
9	Oct 10	Communication across the system with shared database	9.1	F.R.10, M.P.10
		Improved extinguishing material deploying mechanism	9.2	F.R. 9, M.P. 9
10	Oct 24	Driving around the obstacle using local planning	10.1	F.R. 6, M.P. 5
		Fire extinguishing material deployment during flight	10.2	F.R. 9, M.P. 9
11	Nov 7	Global path planning in simulation	11.1	F.R. 2, M.P. 2
		Accurate state estimation for a long mission	11.2	F.R. 4, M.P. 3
12	Nov 19	Joint Global mission capability (Rehearsal)	12.1	F.R. 1-10, M.P. 1, 5, 8, 9
FVD	Nov 25	Joint global mission capability	13	F.R. 1-10 M.P. 1, 5, 8, 9

Logistics

Personnel

The team of 4 members is divided into two sub-teams with 2 members in each working on the UAV and AGV systems hence they will be responsible for testing the primary requirements for their respective systems although other team members may be present depending on the availability. A single team member will present the integrated system for the FVD. The remaining teammates will act in a supporting role.

Equipment

For any experiment, the mandatory equipment required are safety glasses, allen keys, screwdriver set, keyboard, mouse, laptop, VHB, scissors, cutters, zip ties, USB cables (micro USB, USB-C), HDMI & monitor, spike guard. For UAV testing: drone m210, propellers, spare batteries (main), spare batteries (radio), extra propellers (one full set), battery monitors. For the AGV testing, we will need the husky with the computer & 3DM sensor attached.

Off-Campus Testing

Some tests may be carried at Gascola and hence 2 members will be traveling to the site with the other MBZIRC teams in the AirLab ambulance.

Tests

Test 8.1: UAV & AGV autonomously traversing through an opening

<table>
<tr><th colspan="2">Objective</th></tr>
<tr><td colspan="2">Demonstrate that the UAV and AGV are able to detect an opening and navigate through the opening autonomously.</td></tr>
<tr><th>Elements</th><th>Equipment</th></tr>
<tr><td>UAV navigation and control
AGV navigation and control
Local planner for AGV (without obstacle avoidance)
Four-point visual servoing for drone</td><td>Window opening for UAV
Door opening for AGV</td></tr>
<tr><th colspan="2">Procedure</th></tr>
<tr><td colspan="2">UAV Component:
UAV takes off in front of the window (not directly facing the window) up to the height of the window.
Once UAV detects the four corners of the window, it aligns itself in the direction perpendicular to the opening.
Moves straight through the window and lands at a predefined location.
AGV Component:
AGV starts in front of the door.
Once it detects the four corners of the door, it plans a trajectory through the opening, passes through the opening and stops.</td></tr>
<tr><th colspan="2">Validation Criteria</th></tr>
<tr><td colspan="2">UAV and AGV successfully pass through the opening without crashing into the window/door</td></tr>
<tr><th colspan="2">Location</th></tr>
<tr><td colspan="2">Gascola/NSH B Level (shown as a video)</td></tr>
</table>

Test 9.1: Communication subsystem test

Objective	
Demonstrate that the UAV and AGV are able to communicate, pass messages to each other wirelessly and store the fire status in a central database hosted on the husky	
Elements	**Equipment**
1. Collaboration subsystem	1. Husky with a router 2. UAV with the Manifold-2C
Procedure	
1. Husky and the drone are placed 25m apart on the test site 2. The distance will be measured by the operator 3. The systems (husky and UAV) will turn on and try to connect with each other 4. Post successful connection the husky will send some dummy fire coordinates to the UAV 5. The UAV will enter the coordinates in the central database 6. The database will be opened on the husky to verify if the information entered in it	
Validation Criteria	
1. The UAV and AGV connect to each other within 25m radius 2. The agents can exchange messages with each other by entering the information in the database on the husky	
Location	
CMU Mall / Cut (shown as a video)	

Test 9.2: Improvised fire extinguishing mechanism

Objective	
Demonstrate that the water deployment mechanism can throw water at a distance of 1.5m, the extinguishing system weighs less than or equal to 1KG (including water)	
Elements	**Equipment**
1. Fire extinguishing subsystem	1. Power supply 2. Fire extinguishing subsystem
Procedure	
1. The operator will turn on the extinguishing system in an open area 2. The water from the pump will be allowed to flow for some time 3. The distance from the operator/pump to the area where the water projectile falls will be measured and reported	
Validation Criteria	
1. The distance measured has to be greater than 1.5m 2. The system weighs less than or equal to 1kg	
Location	
NSH B Level	

Test 10.1: Obstacle avoidance test

Objective	
Demonstrate that given a waypoint and an obstacle between the AGV and the waypoint, AGV can plan and execute a path that goes around the obstacle	
Elements	**Equipment**
1. Navigation subsystem for AGV	1. AGV (Husky) 2. Intel Stereo Camera 3. Obstacles (boxes)
Procedure	
1. Obstacles will be put at random places between the base station and goal location 2. Operator will turn on the husky and provide the goal location coordinates 3. Husky will create an occupancy grid using Intel stereo camera and will generate safe path keeping minimum 0.75m distance from the occupied grid cells (obstacles) 4. The husky controller will generate control signals to move husky through the planned path 5. Husky will update the occupancy grid and recompute the desired path periodically as it moves along the trajectory 6. Husky will stop after reaching the goal location	
Validation Criteria	
1. AGV should reach within 1m radius circle at the goal location 2. AGV should maintain at least 0.75m distance from the obstacles	
Location	
NSH B Level	

Test 10.2: Extinguishing material deployment (inflight test)

Objective	
Demonstrate that extinguishing deployment mechanism on the UAV can shoot water inflight at a targeted distance of 1.5m	
Elements	**Equipment**
1. Fire Extinguishing Subsystem for UAV	1. UAV platform 2. Water collection vessel 3. Water deploying mechanism
Procedure	
1. Vessels of size 0.5mx0.5m will be put at around targeted distance 2. The operator will start the mission on the UAV 3. UAV will take off and hold in place and will start deploying water after 10 seconds 4. UAV will keep deploying water for 30 seconds 5. UAV will land on the ground	
Validation Criteria	
1. UAV is successfully able to take off, land and handle changes in the weight due to deployment without becoming unstable during flight 2. UAV is able to shoot water programmatically. 3. Water is collected in the vessel situated at a targeted distance of 1.5m	
Location	
Outside NSH B level	

Test 11.1: Global path planning simulation test

Objective	
Demonstrate that global multi-agent path planning algorithm is able to generate high-level paths for UAV-AGV that covers at least 60% of the overall region with as little overlap as possible	
Elements	**Equipment**
1. Path planning subsystem	1. Workstation computer
Procedure	
1. High level abstract 2D map of the test area will be provided as input 2. Path planning algorithm will create occupancy grid and generate paths for both UAV and AGV 3. Planned high-level trajectories will be overlaid on the abstract 2D maps 4. Coverage, overlap and performance metrics for generated trajectories are computed and outputted	
Validation Criteria	
1. Generated paths have at least 60% joint coverage of the targeted map (M.P. 2) 2. Generated paths have less than 20% overlap in the explored region	
Location	
Simulation	

Test 11.2: State Estimation Test

Objective	
Demonstrate that the UAV and AGV is able to localize itself in the environment and traverse the desired trajectory accurately	
Elements	**Equipment**
1. SLAM subsystem 2. Navigation control	1. AGV (Husky) 2. UAV (DJI)
Procedure	
UAV Component: 1. UAV takes off from the base station and reaches up to a height of 2m. 2. Follows a square trajectory of length 3m each side. 3. Lands at the base station (same as the starting point). **AGV Component:** 1. AGV starts from the base station. 2. Follows a square trajectory of length 5m each side. 3. Drives back to the base station (same as the starting point).	
Validation Criteria	
1. Both AGV and UAV should accumulate less than 5m drift for every 100m of distance traveled. 2. The maximum error between the desired and actual trajectory should be less than 1m.	
Location	
NSH B Level (shown as a video)	

Test 12.1: Global Mission

Objective	
Demonstrate that each subsystem has been fully integrated and that the performance complies with requirements.	
Elements	**Equipment**
Entire integrated software and hardware sub systems	UAV, AGV, Water collection vessel, Window opening for UAV, Door opening for AGV
Procedure	
Follow the procedure of SVD	
Validation Criteria	
Full validation criteria of Fall Validation Criteria	
Location	
Gascola (shown as a video) / NSH B Level	

Fall Validation Demonstration

Objective	
Demonstrate that each subsystem has been fully integrated and that the performance complies with the requirements.	
Elements	**Equipment**
Entire integrated software and hardware subsystems	UAV, AGV, Water collection vessel, Window opening for UAV, Door opening for AGV, Heated water bag

Procedure & Requirement Validation	
UAV & AGV Component:	
1. UAV/AGV takes off/drives from the base station and reaches upto the height of 2m. (F.R.1)	☐
2. AGV sends the GPS location of the building (Area of Interest).	
3. Global planner generates high-level desired trajectory for UAV and AGV. (F.R. 2)	☐
4. Respective Local planner commands UAV/AGV controller to avoid intermediate obstacles while following high level trajectory. (F.R. 3, 4, 5, 6)	☐
5. UAV detects the four corners of the opening, aligns itself in the direction perpendicular to the opening and moves straight to pass through the window. (F.R. 2, 5)	☐
6. AGV detects the opening, generates trajectory through it and finally drives through it. (F.R. 2, 5)	☐
7. AGV detects the fire locations in an indoor environment and deploys water at the fire. (F.R. 7, 8, 9 for AGV)	☐
8. UAV also detects the fire locations in the environment, visual servos towards the fire location and deploys water to “extinguish” the fire. (F.R. 7, 8, 9 for UAV)	☐
9. UAV and AGV shares their detected fire locations. AGV goes to the UAVs fire location to deploy additional material. (F.R.10)	☐
10. UAV will land within 5m radius from the center of goal location and AGV reaches its goal location within 1m (M.P.1).	☐
Post Mission Validation	
1. Deposited 40% of the extinguishing material inside the vessel. (M.P. 9)	☐

Appendix

System-level functional and mandatory performance requirements

Requirement ID	Requirement Description	
F.R.1	Take-Off and Land from the base station	
	M.P.1	Land within 5 m radius from the center of base station for UAV and 1 m for AGV
F.R.2	Plan Trajectory	
	M.P.2	Explore 50 m x 60 m x 20 m environment with greater than 60% coverage (robot has seen and identified potential fire) in 10 minutes or less
F.R.3	Create a real-time map	
F.R.4	Localize itself in the environment	
	M.P.3	Accumulate less than 5 m drift for every 100 m of distance traveled
F.R.5	Traverse desired trajectory	
	M.P.4	The maximum error between desired trajectory and actual trajectory should be less than 1 m
F.R.6	Avoid collision with obstacles and other UAVs/AGV	
	M.P.5	Keep 0.75 m minimum distance between system and obstacles
F.R.7	Detect Fire	
	M.P.6	Detect fire from a maximum 1.5 m away - in the line of sight of the UAV and UGV

F.R.8	Localize and Monitor Fire	
	M.P.7	Localize fire with less than 1 m error
F.R.9	Deploy material strategically	
	M.P.8	Carry 1 kg of extinguishing material each
	M.P.9	Deposit 40% deployed extinguishing material on the target area of minimum 0.5 m x 0.5 m at 1.5m distance
F.R.10	Coordinate between different UAVs & AGV	
	M.P.10	Reliable communication within 25 m

Mandatory non-functional requirements

Requirement ID	Requirement Description
M.N.1	Fit in the size of 1.2m x 1.2m x 0.5m (UAV)
M.N.2	Fit in the volume of 1.7m x 1.5 m x 2m (AGV)
M.N.3	Feature kill switch for safety
M.N.4	Maintainable with easily replaceable components like motor, batteries, ESCs, etc
M.N.5	Interoperate with other MBZIRC team's systems by the means of functional modularity