RoboSAR Test Plan

Team F

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Introduction

This test plan outlines the detailed steps that will be taken by RoboSAR (Multi Robot Search and Rescue) in the Fall semester to validate the mandatory requirements outlined in Appendix A. The tests will be distributed across the upcoming progress reviews and will culminate in the Fall Validation Demonstration this November. The document will also serve as a guide for the remaining development work over the course of the semester.

Our tests are divided based on all our subsystems of SLAM, Perception, Task Allocation, Fleet Management System and Navigation.

Logistics

Personnel

RoboSAR Team members are sufficient to perform all the tests. In most of our tests one team member operates the Mission Control GUI which in turn interacts with the rest of the system. One team member can help set up the robots. Another can help scatter the victims dummied by apriltags in the environment. One can help document the test results while the last member can present and describe the operation of the system to the judges, stakeholders and the audience.

Location

All subsystem tests will be performed in NSH 1604 while the full system tests need robots to navigate an indoor environment and due to constraints on the mobility of the robots, we can do those tests in select environments with favorable flooring in Wean Hall, Scott Hall or Tepper. The final FVD location is tentatively planned in the Scott Hall but that is subject to change.

Equipment

The following items are typically required to perform our tests:
1. Laptop : To run the centralized server of the system
2. Monitors or large screen: Screens can be used to show the Mission control GUI and also to show visualization of the system in rviz
3. Khepera robots : N number of khepera robot to conduct multi robot search and rescue

4. Wifi routers and repeaters : Wifi router is used to create a local wireless network so that all robots can talk to the server.
6. Victim mockups w/ apriltags: Bunch of apriltags which will be scattered around the environment

Schedule

Our test schedule is largely governed by PR dates. The following are the tests that we plan to conduct.

Date	PR	Milestones	Tests	Requirements
09/27	8	➔ Working of GUI. ➔ Detect victims within 0.02m accuracy. ➔ Test Velocity Obstacles in simulation ➔ Research / Prototype of MrSLAM	SLAM Perception Module Testing Local Collision Avoidance Test	**M.F.0**. **M.P.0.** **M.P.4.** **M.N.0.** **M.N.2.**
10/12	9	➔ Velocity obstacles Integration with system + Testing ➔ Frontier exploration in simulation ➔ MrSLAM prototype + Testing ➔ Swarm Control Research / Prototype in simulation	Local Collision Avoidance Test Frontier Exploration Test Mapping & Victim Localization Test	**D.F.1**. **M.P.1.**
11/02	10	➔ Integrate frontier exploration with system ➔ Heterogeneous task allocation with “search” and “rescue” robots. ➔ Fully functional MrSLAM	Frontier Exploration Test Local Collision Avoidance Test Mapping & Victim Localization Test	**D.F.0.**
11/15	11	➔ Integrate swarm control with the system. ➔ Integrate MrSLAM with Navigation, Perception and Task Allocation subsystems.	Perception Integration Testing Mapping & Victim Localization Test	**D.F.1**.

11/21	FVD & FVD Encore	➔ Heterogeneous task allocation on physical or simulated agents. ➔ Collision free navigation. ➔ Agents' ability to successfully navigate to allocated tasks without collision.	Fall Validation Demo	**D.F.3**. **M.N.3**.

Subsystem Tests

The tests to be carried out by us are categorized with respect to the subsystems for ease and convenience.

SLAM

Name	**Multi-Robot SLAM Test**
Objective	To ensure that generated map and location of agents are accurate
Elements	Autonomy stack: SLAM system
Location	Simulation
Equipment	3 Khepera robots with LRF modules, laptop
Personnel	1 person to operate the laptop and run test
Procedure	1. In simulation, set up agents at starting position so they can see world origin AprilTag 2. Teleoperate agents to explore environment
Verification Criteria	● Generated map is accurate and stable (D.F.0) ● Position estimates of agents are within 30 cm of true position after loop closures

Mapping and Victim Localization

Name	**Mapping & Victim Localization Test**
Objective	To ensure that generated map and location of victims are accurate
Elements	Autonomy stack: SLAM system, perception system
Location	Scott Hall
Equipment	3 Khepera robots with LRF modules, WiFi router, laptop
Personnel	1 person to operate the laptop and run test
Procedure	1. Place AprilTags (victims) in environment 2. Determine ground-truth positions of victims Set up world origin AprilTag Set up agents at starting position so they can see AprilTag Teleoperate agents to explore environment and locate victims
Verification Criteria	● Generated map is accurate and stable (D.F.0) ● Found victims are reported and localized (M.F.0) ● Position estimates of victims are accurate (M.P.1)

Perception

Name	**Perception Module Testing**
Objective	To ensure precise victim detection and communication to server
Elements	Autonomy stack: Perception, FMS, Communication systems
Location	Vicon Area
Equipment	1 Khepera robot with Cameras, AprilTags, WiFi router, laptop
Personnel	1 person to operate the laptop and run test
Procedure	1. Place the robot on the table. 2. Place the AprilTag in a detectable position and mark points on the testing area with known distances from the robot as ground truth. Example: A. x = 0.05, y= 0.05, z = 1. B. x = 0.06, y= 0.08, z = 1.2 etc. 3. Mark the readings given by the perception module in each case and compare with ground truth recorded above. 4. Remove the AprilTag and suddenly introduce it back to check the communication and latency.
Verification Criteria	● The recorded values are accurate within 0.02m. ● The communication is lossless with ignorable latency

Name	**Perception Integration Testing**
Objective	To ensure precise victim detection for a multi-robot fleet
Elements	Perception, FMS, MrSLAM
Location	Scott Hall
Equipment	3 Khepera robots with Cameras, LRFs, AprilTags, WiFi router, laptop
Personnel	2 persons to operate the laptop and run test
Procedure	1. Place AprilTags at 9 known locations on the testing area 2. Start Mission Control and give tasks to the 3 agents such that all the AprilTags can be detected by the agents . 3. Once an AprilTag is detected as a ‘delta-pose’ value from a particular agent, compute the pose of the AprilTag with respect to world frame and compare it with the above ground truth. 4. Repeat the experiment until all AprilTags are spotted.
Verification Criteria	● The pose values with respect to the world frame computed from the pose given by the perception module on the agents are accurate within 0.02m. ● All 9 AprilTags are detected within 0.02 m ● The communication is lossless with ignorable latency.

Frontier Exploration

Name	**Frontier Exploration Test**
Objective	Ensure robots are exploring an unknown environment in minimal time.
Elements	Navigation
Location	Simulation / Scott Hall near TechSpark
Equipment	Laptop, Khepera Robots, WiFi network
Personnel	Whole team
Procedure	Procedure: 1. Set up agents in the test area. 2. Ensure frontiers are accurately generated for the said area. 3. Observe that agents are being assigned to the correct frontiers that minimize cost and maximize utility. 4. Agents stop when there are no more frontiers to expand.
Verification Criteria	● System shall map and search in unknown environment simultaneously during operation

Navigation

Name	**Local Collision Avoidance Test**
Objective	To ensure that the path planned avoids collision with obstacles known in the map and other agents
Elements	Autonomy stack
Location	Vicon area
Equipment	Khepera robots, server, obstacles
Personnel	1 person to operate the laptop and run test
Procedure	1. Set up the static environment with obstacles. 2. Start the agent bringup software, along with the autonomy stack. 3. Send different goal points to multiple robots with paths in collision. 4. Observe the path being followed by the robots to go from its source point to the goal point. 5. Repeat this by giving multiple goal points. 6. Observe any collisions.
Verification Criteria	The robot does not collide with any obstacle or agent while traversing to the goal point.

Fall Validation Demonstration

Name	**Fall Validation Demo**
Objective	➔ Task allocation on physical or simulated agents. ➔ Collision free navigation. ➔ Agents' ability to successfully navigate to allocated tasks without collision.
Elements	Localization, task allocation, path planning, trajectory tracking, agent health monitoring
Location	Scott Hall near TechSpark
Equipment	Khepera robots with LRF modules, computer, WiFi router
Personnel	Whole team
Procedure	1. Agents will be placed at their initial starting positions within the operating area. 2. Robot will figure out their initial position based on a home apriltag. 3. The agents will explore and map an unknown environment. 4. "Search" agents are able to explore the environment, while "Rescue" agents are also able to search the environment for victims. 5. Agents will move in a coordinated formation. 6. Agents will detect victims/fiducial markers and report their location to the user. A count will be maintained for the number of victims identified by each robot. 7. The map, agent status, and victim locations will be visualized on a GUI. 8. Once an agent completes a task, it is reassigned to a new one. Steps 3-7 are then repeated until the whole area is searched.

	9. Once the area is searched, the agents return to base, and the mission is terminated.
Verification Criteria	● System shall identify and localize victims in environment using fiducial markers within desired rescue time ● System shall adapt to changes in the fleet size like addition of agents by the users or loss of robots during operation. ● System will detect 75% of victims in the environment. ● System will localize victim position within 20cm.

Appendix A

Mandatory Requirements

M.F.0. System shall identify and localize victims in environment using fiducial markers within desired rescue time

M.F.1. System shall localize robots with a known map of the environment

M.F.2. System shall dynamically allocate tasks to agents in the fleet for optimizing time required for the search

M.F.3. System shall ensure simultaneous navigation of agents which have been allocated a task

M.F.4. System shall adapt to changes in the fleet size like addition of agents by the users or loss of robots during operation.

Performance Requirements

M.P.0. System will detect 75% of victims in the environment.

M.P.1. System will localize victim position within 20cm.

M.P.2. System will finish searching environment 20% faster than the naive algorithm for a typical indoor environment.

M.P.3. System will have downtime of less than 5s for busy agents.

M.P.4. System will update agent status for user at 1Hz frequency.

M.P.5. System will handle at least 3 agents in the fleet.

M.P.6. System will search 70m^2 within 3 minutes

Appendix B

Non Functional Requirements

M.N.0. System shall visualize the environment, locations of victims, and robot agents during operation

M.N.1. System shall home agents on emergency stops, and after completion of search

M.N.2. System shall have user interface to add/subtract robots during operation

M.N.3. System shall be well documented and have reusable software framework for swarm robotics

Desirable Requirements

D.F.0. System shall map and search in unknown environment simultaneously during operation

D.F.1. System shall support flocking/formation control of multiple robots executing similar trajectories

D.F.2. System shall account for victims needing simultaneous detection by multiple robots

D.F.3. System shall account for victims needing detection by specific types of robots