UAV-AGV Collaborative Fire Fighting Robots – MBZIRC 2020

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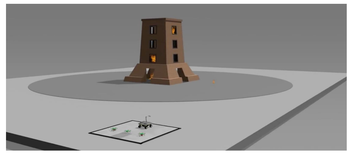
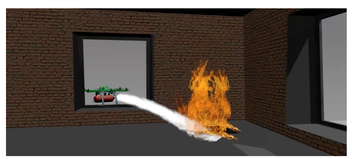
Project Overview

- In the year 2011 in the US alone, there has been around 484,500 structural fire incidents costing around $9.7 Billion and 2,640 civilian deaths.
- Multiagent heterogeneous UAV & AGV fire-fighting system with navigation, perception capabilities and mechanism to deploy fire extinguishing material can act as the first responder to tackle the problem.
- Given a fire alarm signal, the system can autonomously search for fire inside the building as well as surroundings and puts out the fire.

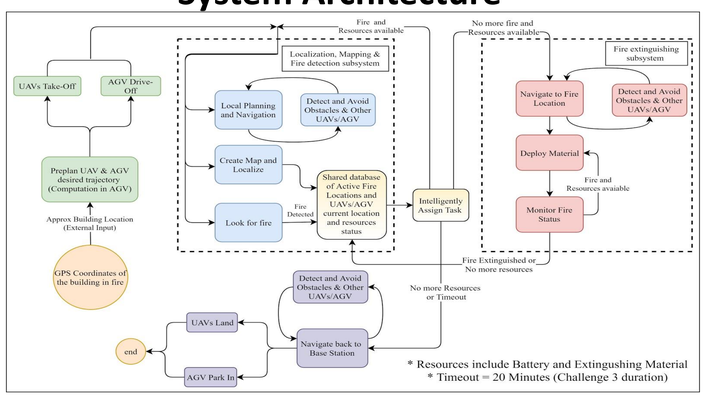
Use Case

How PhoeniX system collaboratively extinguishes fire?

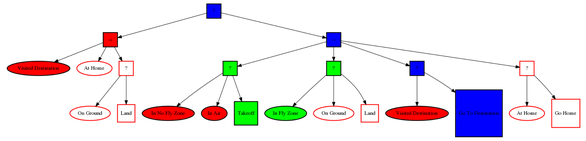




System Architecture



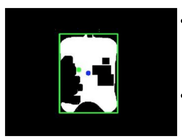
Mission Planner



- Behavior trees define how a set of actions and conditions should be used to accomplish a task.
- The tree is made up of execution nodes, control flow nodes, and decorator nodes.
- An active action node can have a SUCCESS, RUNNING, or FAILURE status.
- For both UAV and AGV, missions are divided into major tasks like takeoff/land, drive off, detect opening, go to the fire, extinguish the fire, etc.

Fire Detection

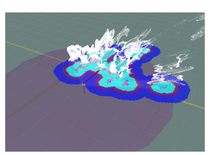
- On UGV, the base joint on the UR5 arm is rotated from 0° to 180° to search for the fire around the environment.
- Since there is no manipulator on UAV, it yaws around the environment from -90° to 90° to search for the fire.

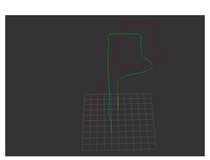


- Segment out high-temperature regions from the thermal images obtained using FLIR BOSON 320 camera.
- Morphological operations are used to remove the noise and increase the reliability of fire detection.

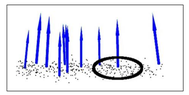
Localization, Mapping and Navigation

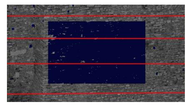
- Wheel odometry output is fused with multiple sensors (T265 tracking camera & 3DM-GX5-45 GNSS) using robot localization to get filtered odometry.
- 3 RealSense Depth cameras are mounted on the front of the Husky for pointcloud with nearly 180° field of view.
- Combined point-cloud data from all the three cameras are converted into the laser scan from 0° to 180° in a resolution of 0.5°
- The laser scan is used with GMapping ROS package to generate a 2D occupancy-grid cost-map and move_base planner is used to generate collision-free path to the goal location.

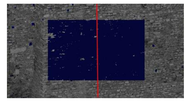




Door/Window Detection



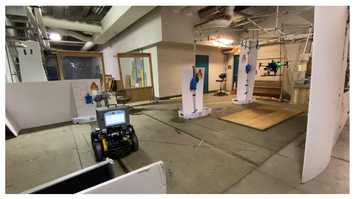




- Detect the dominant plane to identify the wall in the scene using the ICP method.
- Once the wall's plane is identified, the desired yaw change is computed for the UAV based on the orientation of the detected wall.
- Line scanning method: In the point cloud, x-axis & y-axis are scanned using a sliding window mechanism to find the horizontal & vertical edges of the window.
- Rising and falling edge laser scan values (r,θ) pair is converted into (x, y) coordinates to get the centroid of the opening.

Validation Experiment

- Demonstrated a joint UAV and UGV mission at NSH B-Level within an arena specifically designed to mimic a real-life scenario.
- A total of 3 fires were at unknown locations in the arena. UAV and UGV were given rough coordinates of the building to go inside and search for fire.
- UAV extinguishes one fire and sends the location of the other fire to the UGV.
- UGV extinguishes 1 fire on its own and extinguishes the other fire with the help of UAV.



Conclusions

- We successfully demonstrated a fully autonomous collaborative robotics system that shows the system's capabilities at a much-reduced scale.
- We went through multiple iterations of hardware for the drone starting from a custom tilted hexacopter to a DJI Matrice M210 V2.
- Designed our own very powerful extinguishing system for the UAV which throws water at a distance more than 2m even in the presence of downward thrust from the motors.
- The behavior tree-based mission framework makes our system compatible with other AirLab projects and with also other MBZIRC teams.