

Assistive Robot in Low-Visibility Conditions to Support First Responders



Final Project Progress Report

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Project Goal

A *sensing robot* that can:

- Enhance Situational Awareness
 - Map unknown building environments in real-time
- Accelerate Rescue Operations
 - Locate trapped victims efficiently



Challenges in Fire Building



Smoke

Transparent Glass Debris



Debris

Potential Impacts



Know building structures



Increase rescue speed



Minimizing risk safety of first responders



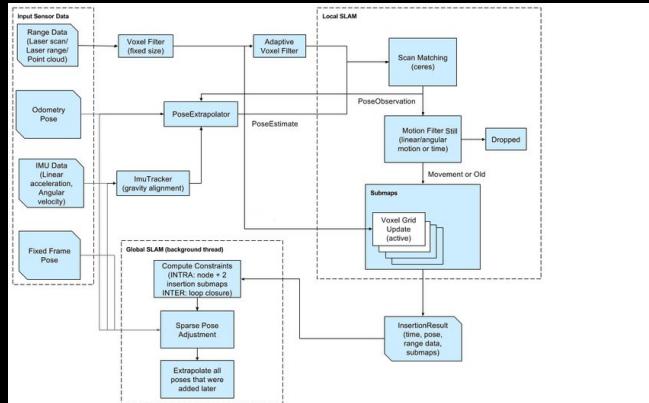
Reduce evacuation time

Existing Solutions

Google Cartographer

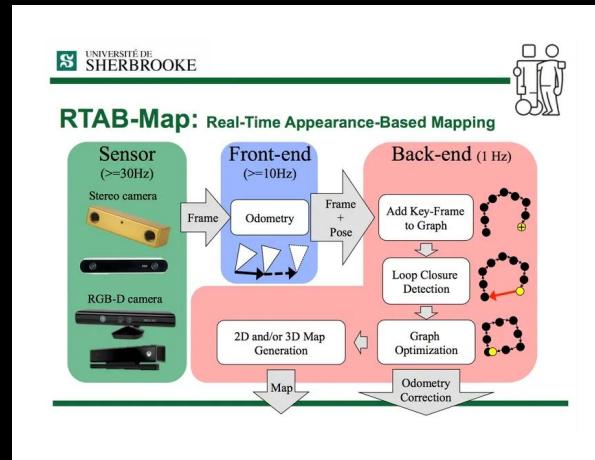
Open-source SLAM framework developed by Google.

Combines LiDAR, IMU, and depth data to create real-time 2D/3D maps of environments.



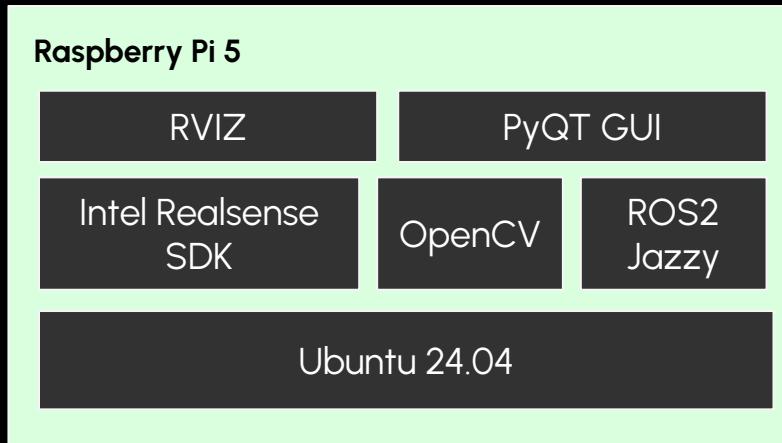
RTAB-Map (Real-Time Appearance-Based Mapping)

RGB-D SLAM system that uses visual features from cameras like Intel RealSense to produce dense 3D maps



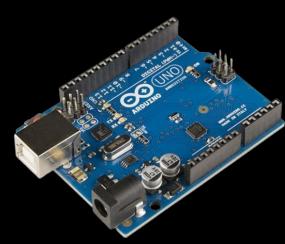
Our Solutions

System Architecture



Raspberry Pi 5, 8GB RAM

UART
Serial



2 x 6V DC motor



Ultrasonic sensor

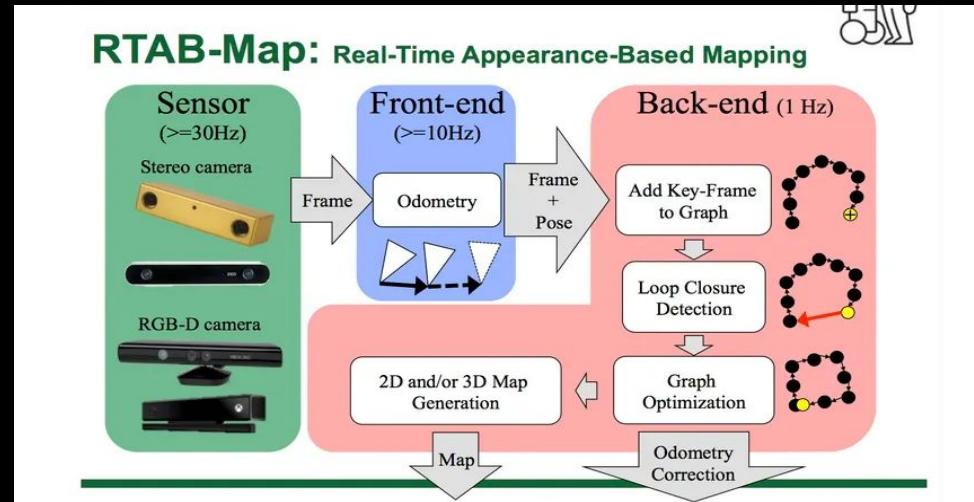
RTAB-MAP (Real-Time Appearance-Based Mapping)

What is RTAB-MAP?

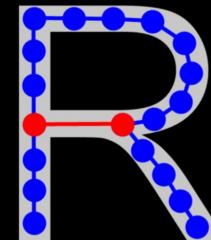
- Graph-Based SLAM (Simultaneous Localization and Mapping) approach
- Works with RGB-D, Stereo, and Lidar sensors

How it works:

- **Loop Closure:** constantly checks if the current image matches a location visited previously
- **Bag-of-Words:** uses a specific visual technique to determine the likelihood of a location match
- **Correction:** If a match is found, it updates the map graph and runs an optimizer

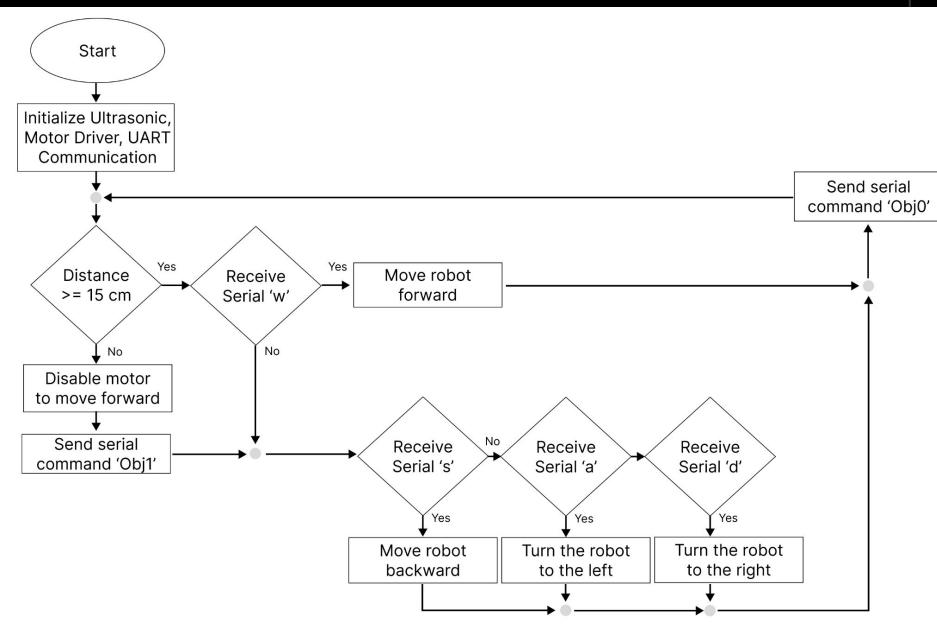


Source: [Labbe2015ULaval.pdf](#)



Collision Avoidance

Supporting robot navigation while in smoke condition and also transparent objects (i.e. glass)





Conducted Experiments (*No look operation*)



Dry Ice for Simulating smoke environment

Results

2D Mapping



Stereo

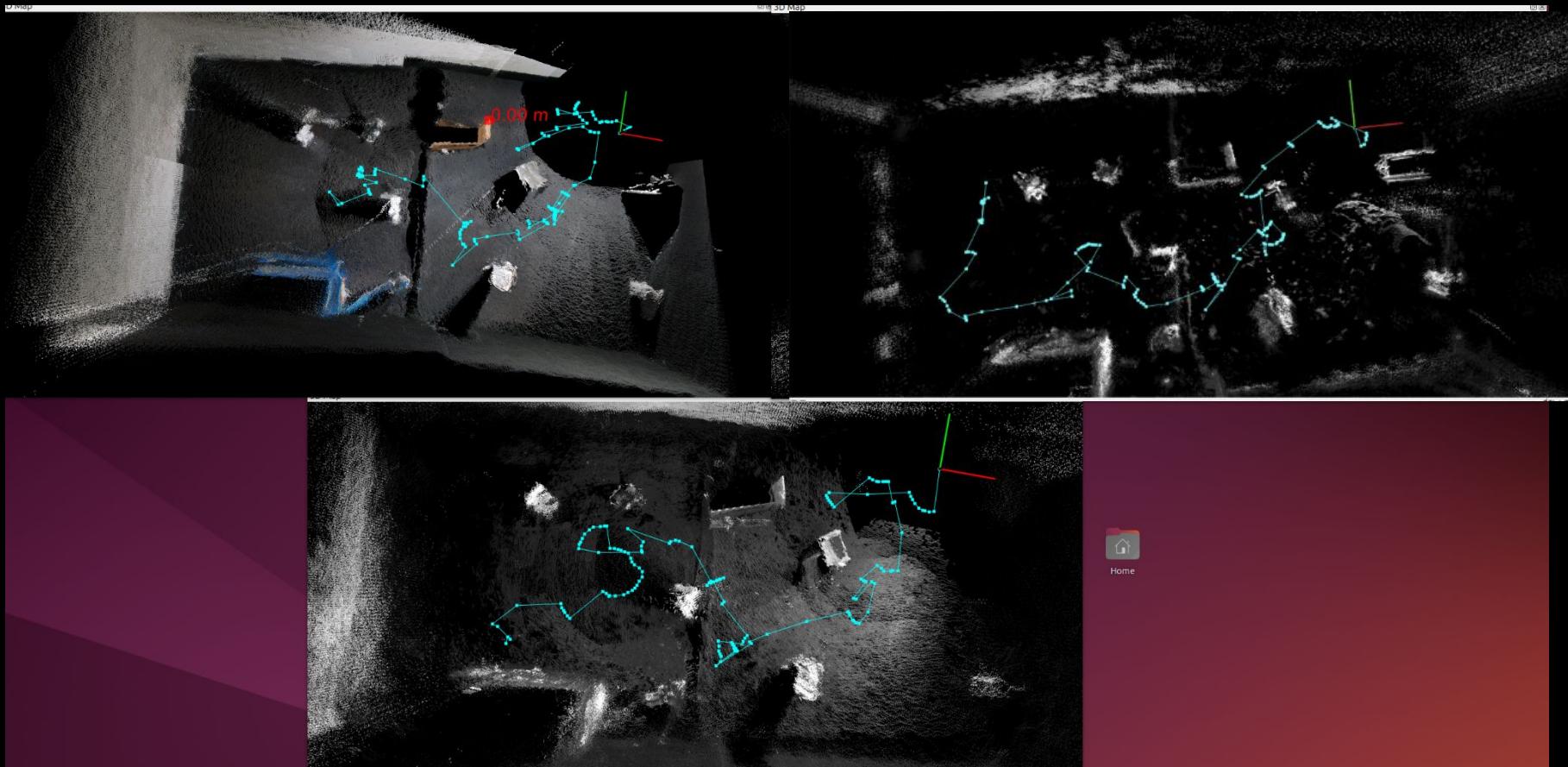


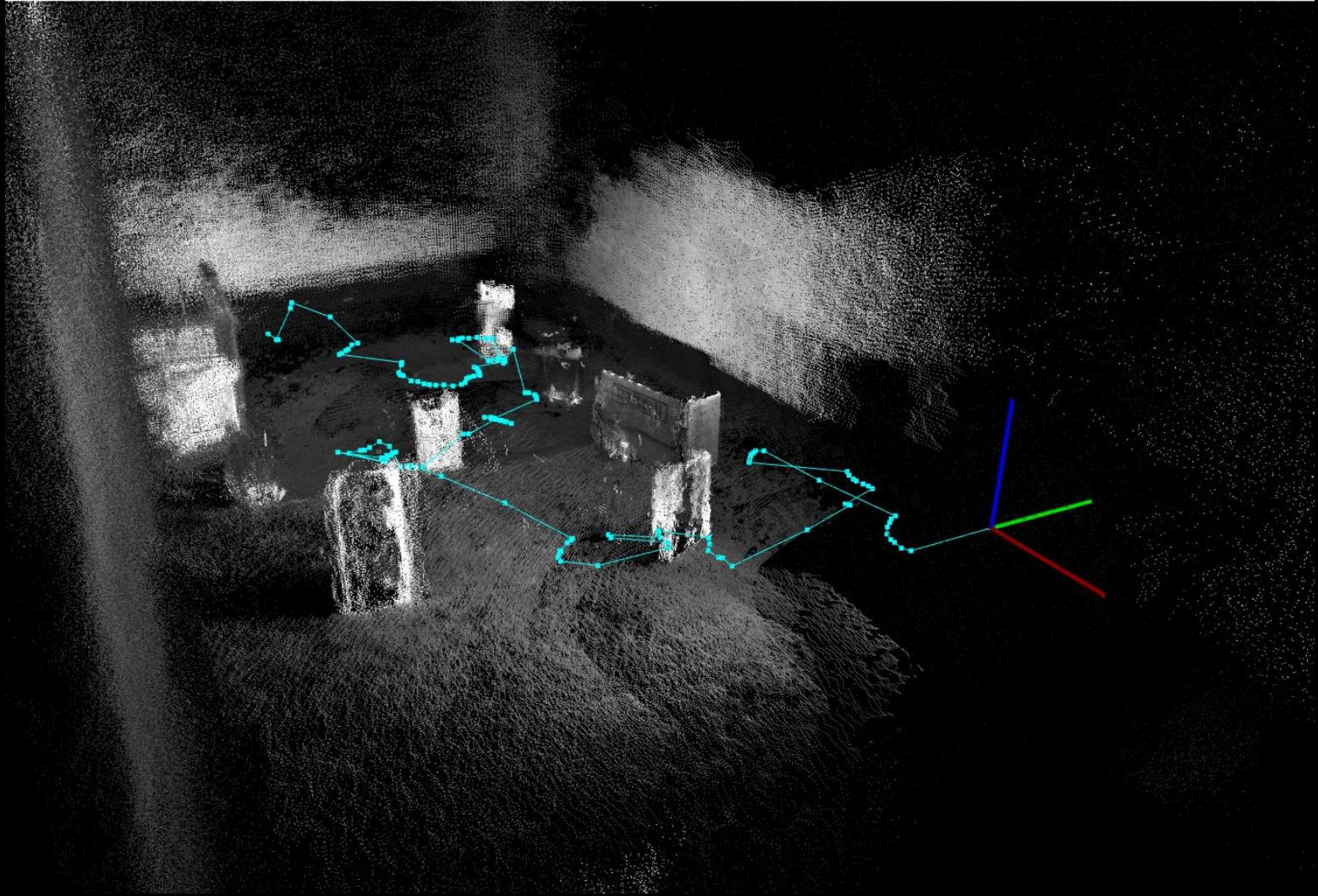
RGB-D

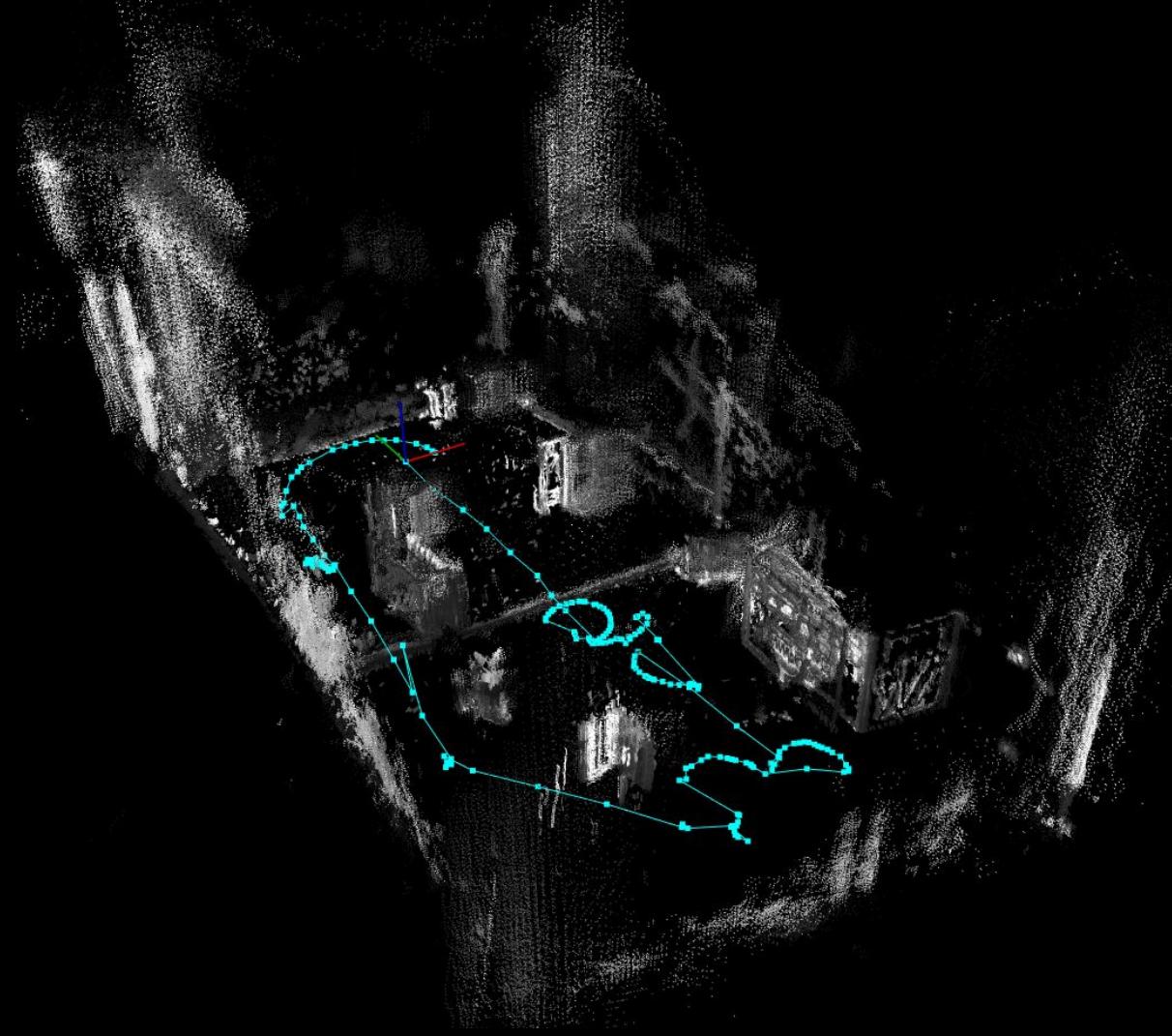


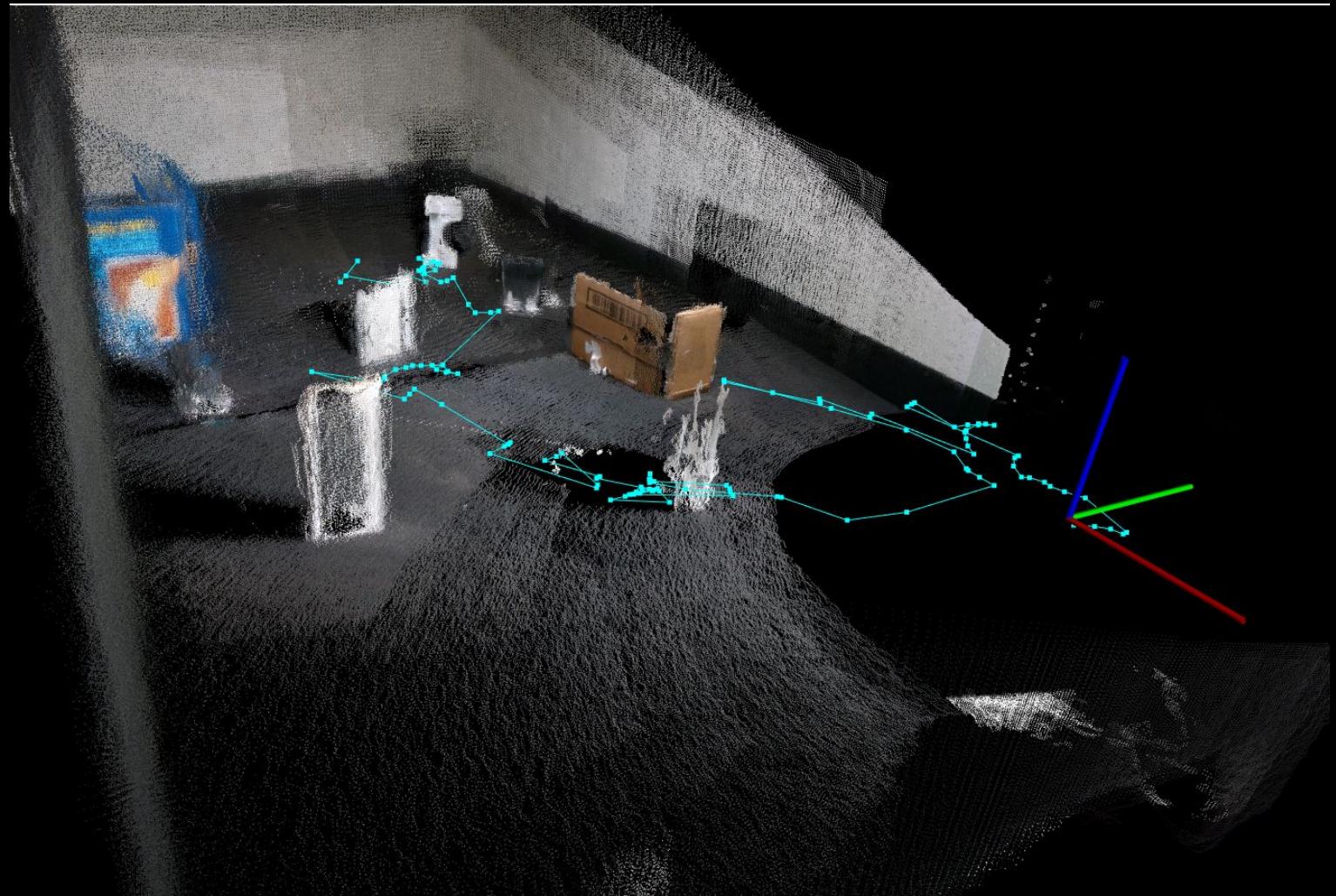
Infrared

Comparison Top Down









Difficulties and Challenges

- Depth Estimation Issues on Plain or Textureless Surfaces
- Jerk and Drift in the Robot Car
- Difficulty in Recognizing Small Text or Printed Patterns

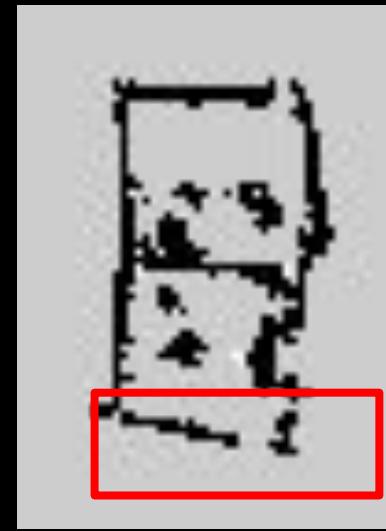
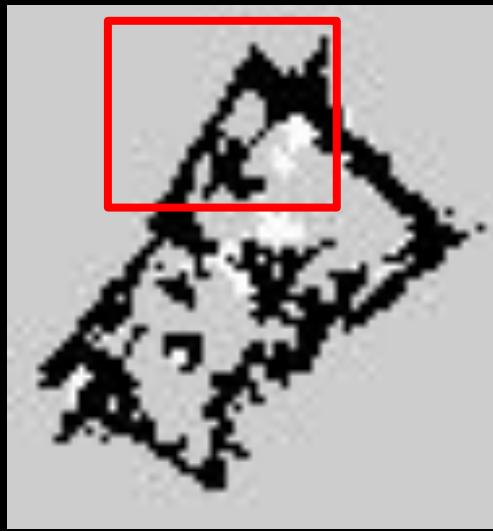
Plain wall with no textures,
depth camera not able to get
the details



Small details in printed pattern,
odometry confused with too
many details, and gave the error

Difficulties and Challenges

- Odometry error (needs graph optimization)



Future Works

Implement localization in the created map and path planning

Build more solid car chassis & feasible for harsh condition

Experiment with more harsh condition

Measure the mapping accuracy

Implement odometry correction by applying graph optimization (g2o, GTSAM)

Conclusion

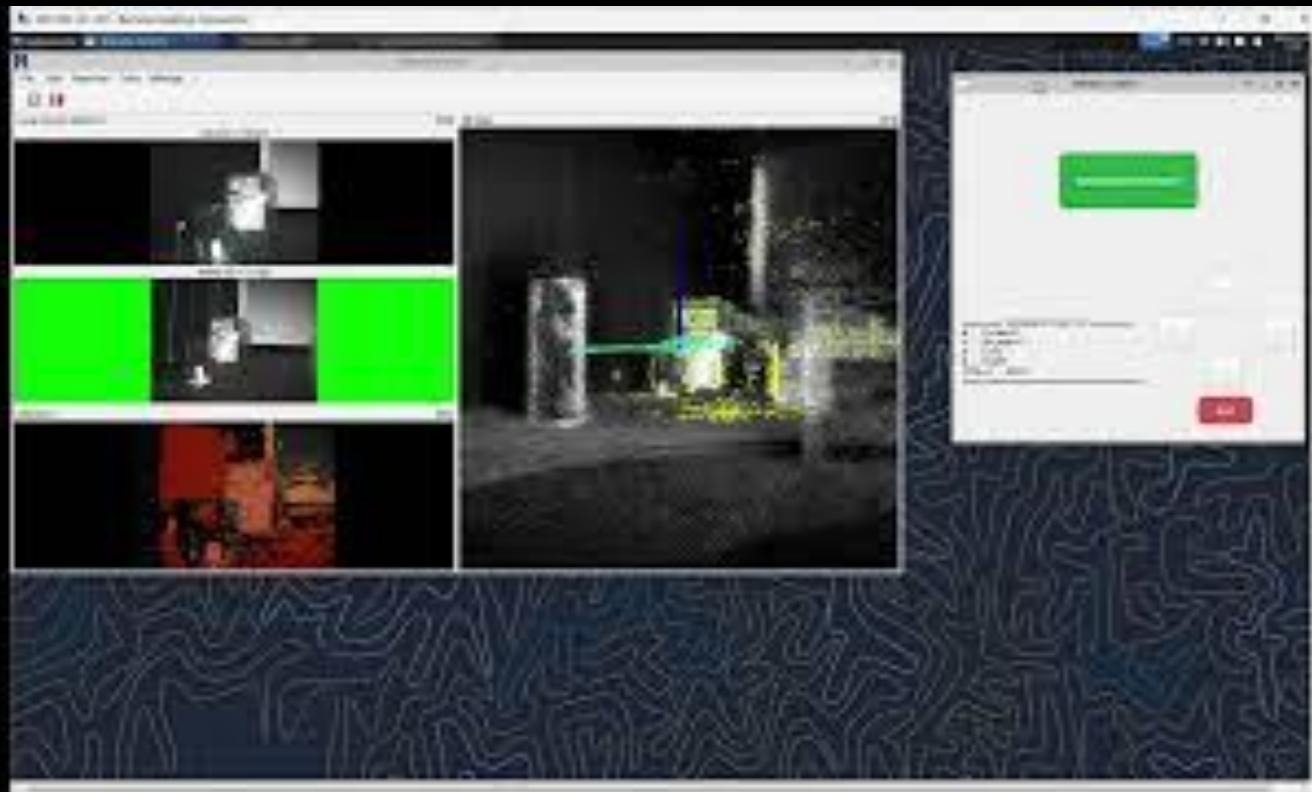
- Successfully demonstrated multi-modal sensing to improve reliability in low-visibility environments
- Achieved reliable mapping and obstacle detection in normal and degraded visibility
- Demonstrated that acoustic + visual data improves safety and robustness

References

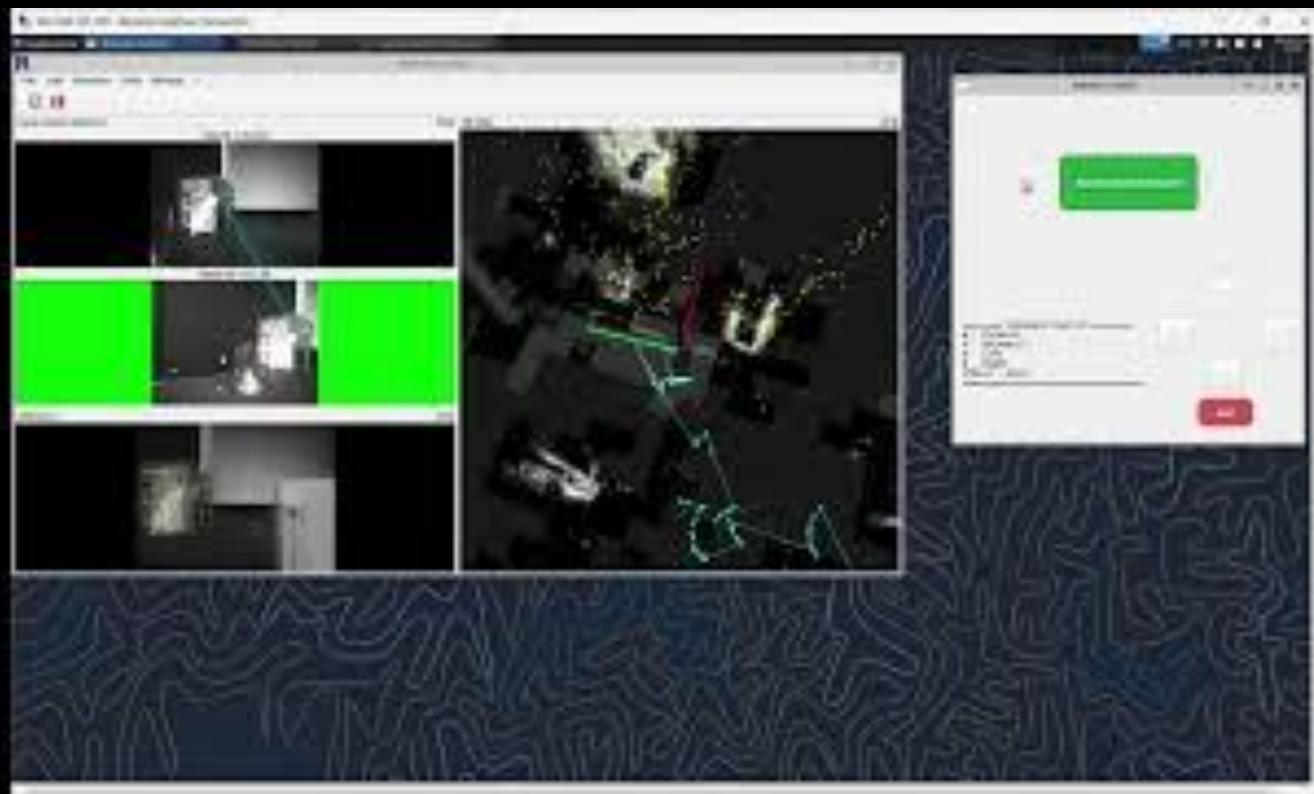
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Demo Video

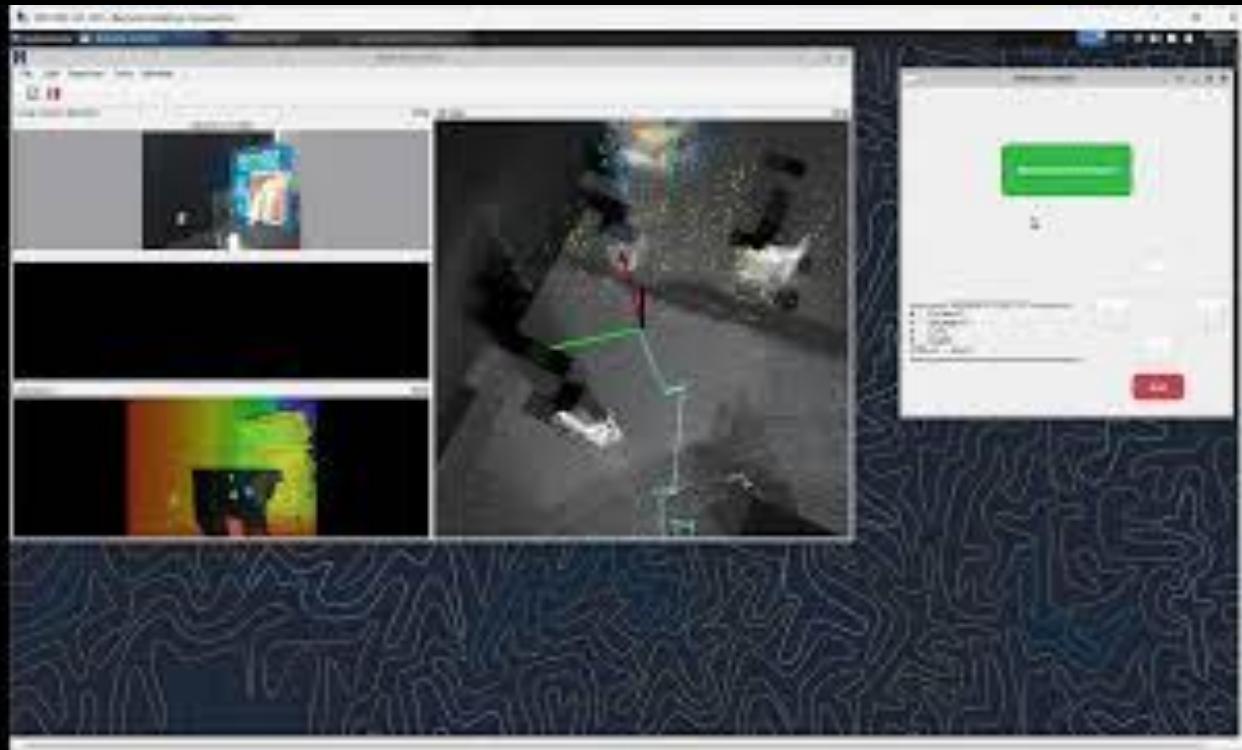
Detecting Transparent Glass on Infrared Method



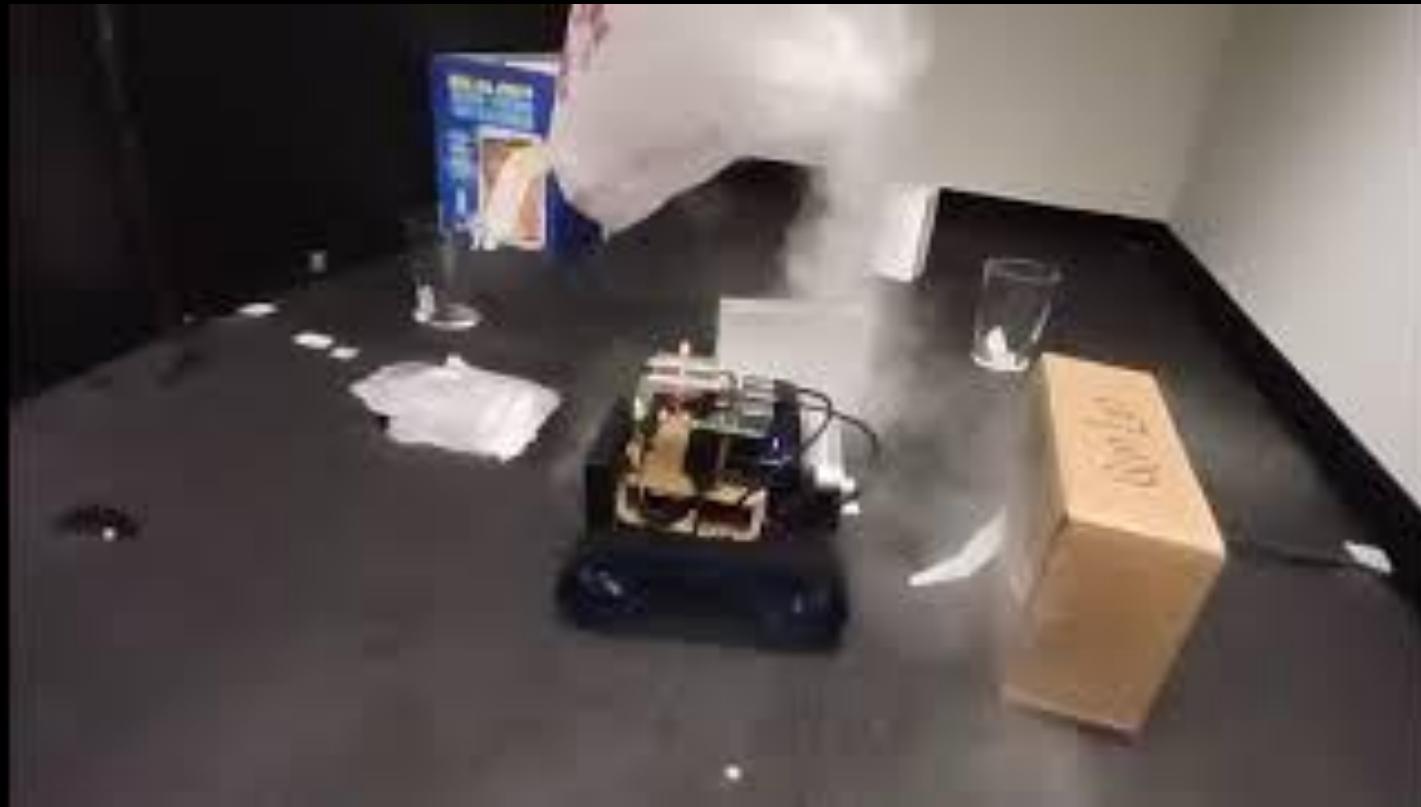
Detecting Transparent Glass on Stereo Method



Detecting Transparent Glass on RGB-D Method



Real Condition in Fog Condition



Navigating in Smoke Environment using Stereo



A large, silver and orange robot in a firefighter's suit stands in a smoky, post-apocalyptic landscape. It has a circular head with a blue light, a chest plate, and a suit with reflective stripes. Its right arm is extended, giving a thumbs-up gesture. In the background, other firefighters in similar gear are visible through the haze.

Thank you!

Gracias!

谢谢!

Terima kasih!

ধন্যবাদ!

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0x79 0x6F 0x75