Probabilistic Sensor Fusion For Localisation and Mapping In GPS-denied Applications/Areas

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

PROJECT #13

Benjamin Yu and Jilada Eccleston
Supervised By Kevin I-Kai Wang

MOTIVATION

GPS is unreliable for indoor firefighting due to signal attenuation and interference. Currently, firefighters rely on their memory to relay mapping and location information to their comrades, which is inaccurate due to the hostile conditions they are subjected to. Existing systems are not yet robust to be used in real firefighting, hence the development of a mapping and positioning system is crucial for improving the safety of firefighters and civilians.

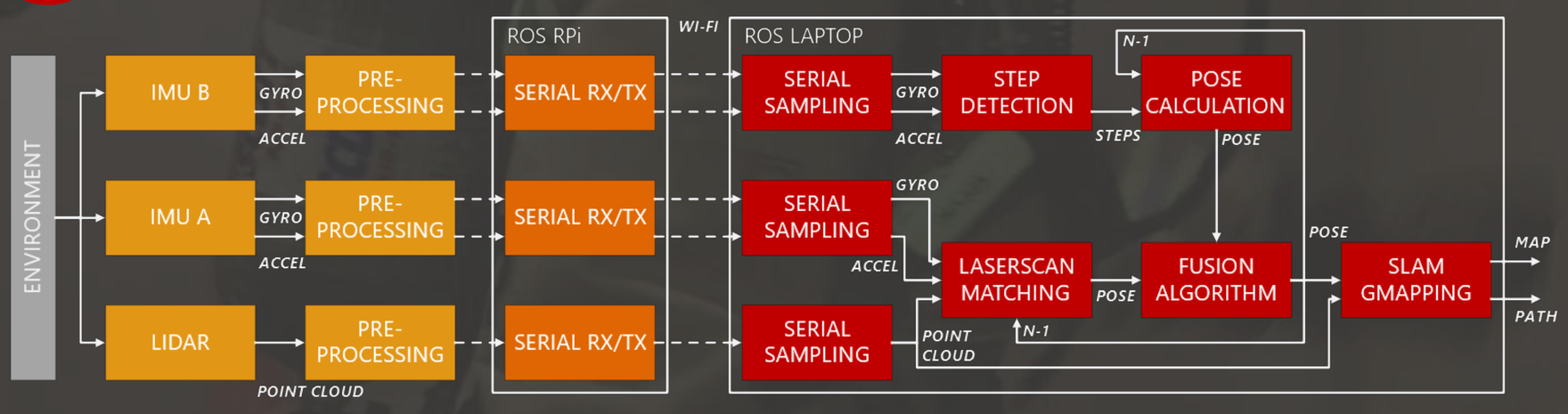
AIM

- Design and test a prototype that performs mapping and localisation for firefighters.
- Investigate firefighter gaits and their environment.
- Investigate the feasibility of LIDARs and Inertial Measurement Units (IMUs).
- Investigate the effects of sensor fusion

REQUIREMENTS

- Non-intrusive
- Lightweight
- Robust / Reliable
- Fire resilient
- Night resilient
- Smoke resilient
- No prior infrastructure
- Wireless
- Real-time

SYSTEM ARCHITECTURE



DESIGN

Inertial Measurement Unit (IMU)

Able to provide 3-axis acceleration and angular velocity in all environments while being lightweight, small and low cost.

LIDAR

Able to map and localise with high accuracy for its size and cost.

Raspberry Pi

Reduces development time for fast prototyping and exhibits wireless functionality.

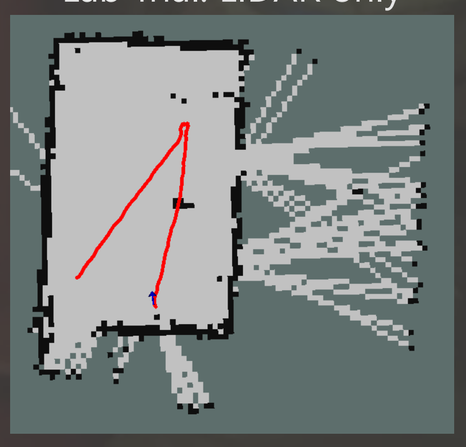
Robot Operating System (ROS)

Provides a well documented framework for positioning systems with real-time effortless communication between nodes.

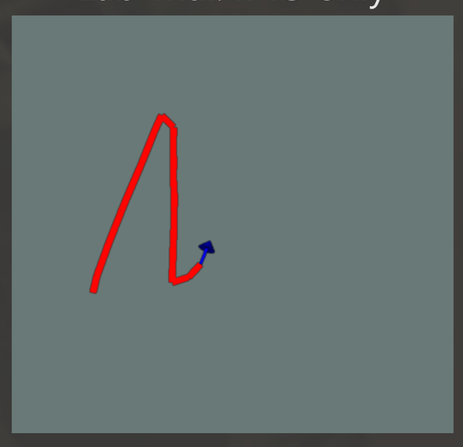
SYSTEM PERFORMANCE

Lab Trial: LIDAR + IMU

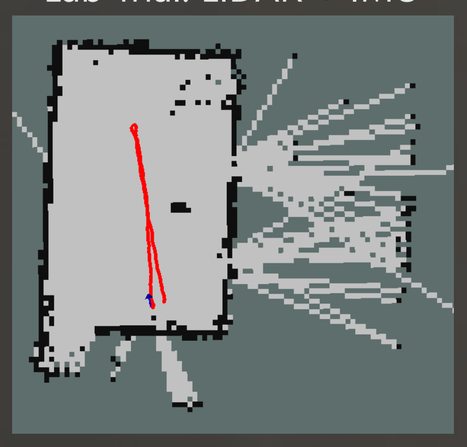
Lab Trial: LIDAR only



Lab Trial: IMU only

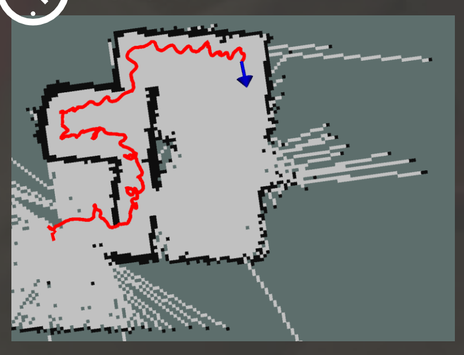


Lab Trial: LIDAR + IMU

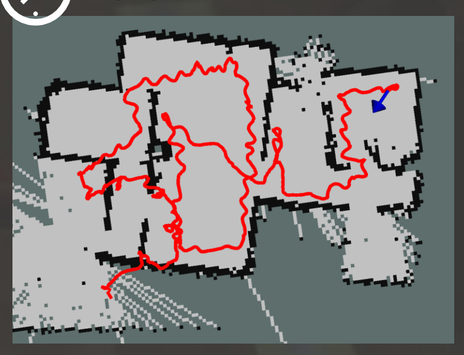


Training Facility Trial: LIDAR + IMU

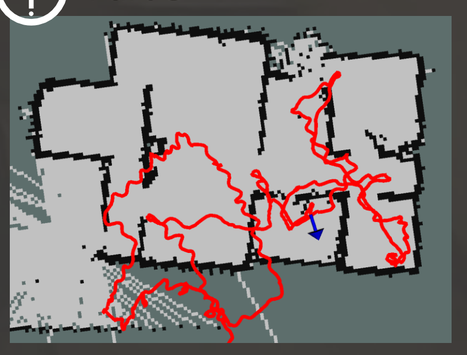
Part 1



Part 2



Part 3



CONCLUSIONS

- Mapping and localisation produces satisfactory results and meets the accuracy requirements for firefighting.
- Pose path and map history drifts over time
- Simple fusion of the two sensors; LIDAR and IMU, greatly improves the individual performance.
- Performance worsens with hallways, windows, and head tilting.
- IMU step length detection has metre level accuracy for normal walking.

FUTURE WORK

- Gait and Pose detection to improve location estimate from IMUs.
- Explore alternative sensor options such as ultrasonic sensors and thermal imaging cameras.
- Map stitching or feedback loops between map generation and pose estimation.
- Explore more advanced sensor fusion techniques.
- Implement real-time navigation services for firefighters.
- Prototype alternative configurations for sensors

DEV 812 DEVONPORT VOLUNTEER FIRE BRIGADE ON CALL SINCE 1885

NEW ZEALAND FIRE SERVICE Whakaratonga Iwi

dta Defence Technology Agency

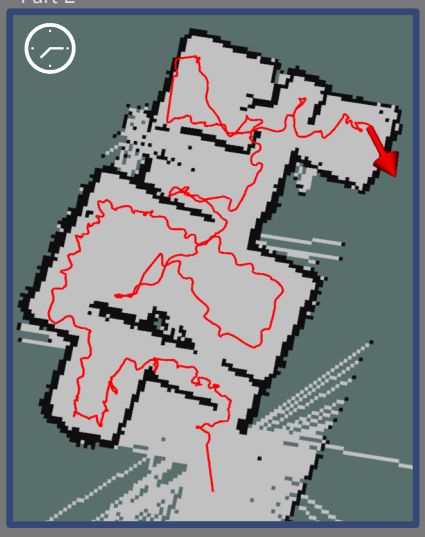
ADDITIONAL SYSTEM PERFORMANCE AT TRAINING FACILITY

NO SMOKE EXPERIMENT

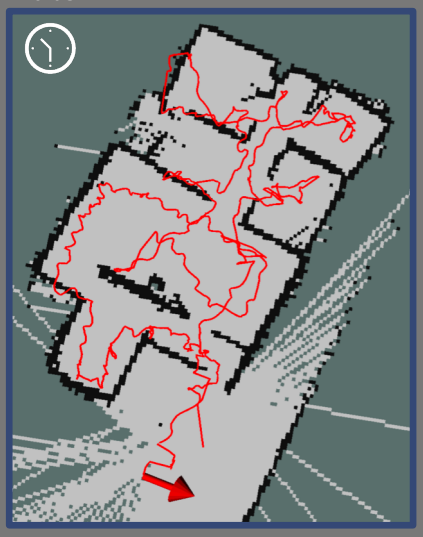
Map and path outputs at different instances in time

Part 1

Part 2



Part 3

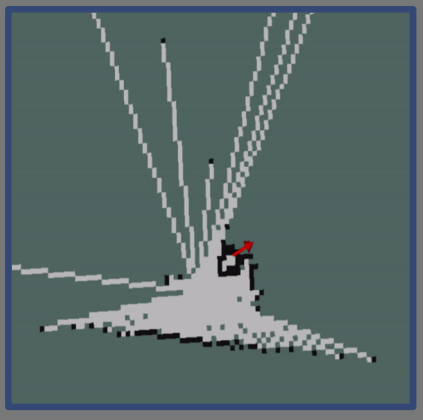


MAPPING PERFORMANCE

Dimensions of the training facility were measured and compared to the map produced.

SMOKE

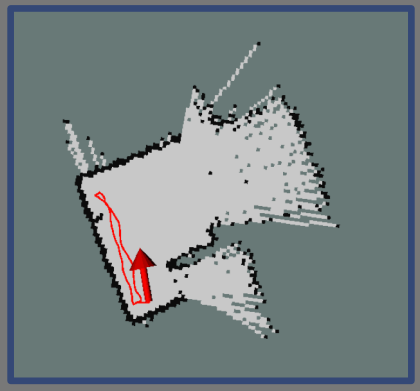
Lidar fails in smoke (dry ice) as infrared signals are scattered by the small particles



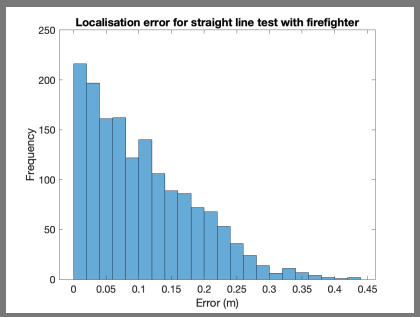
TRAINING FACILITY STRAIGHT LINE TEST

Firefighter was asked to perform various actions along a wall. The path was saved and the error from the true pose of the firefighter was calculated. Localisation error less than 0.5m.

Example 1



Example 2



Histogram of error from straight line test