RoboBIM: *A LiDAR-Based Autonomous Building Information Modelling System*

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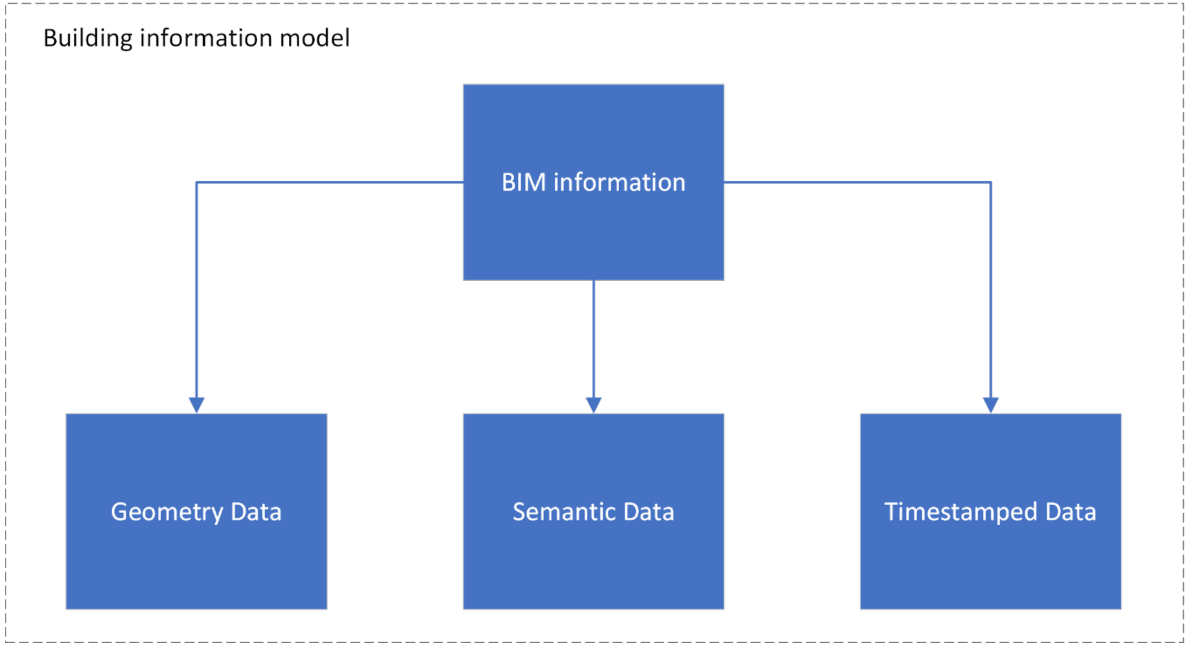
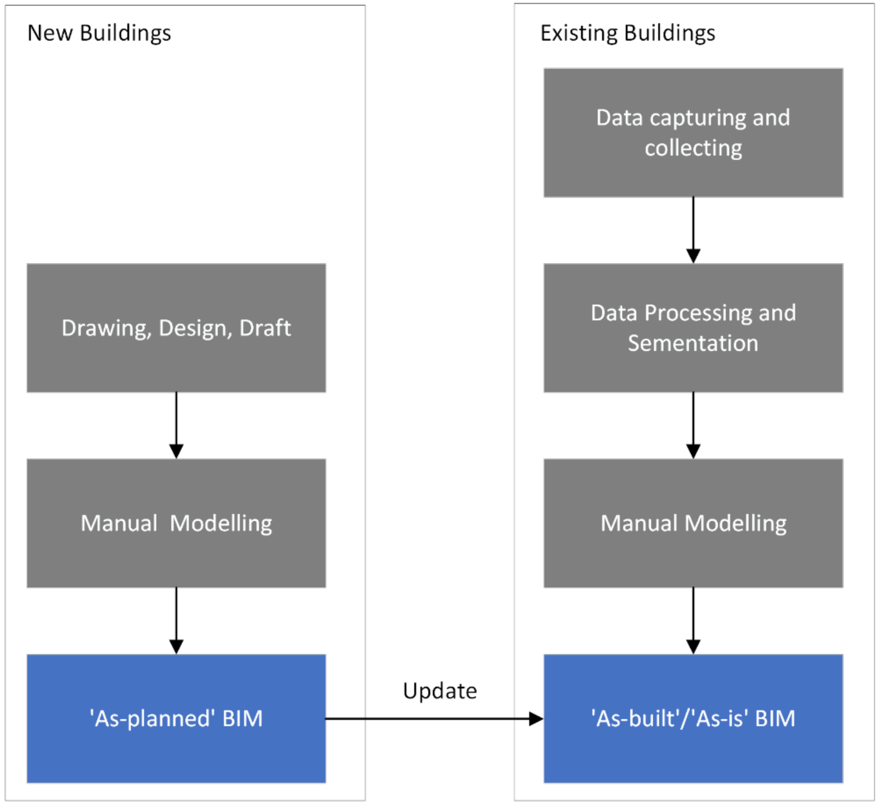
What is and Why BIM?



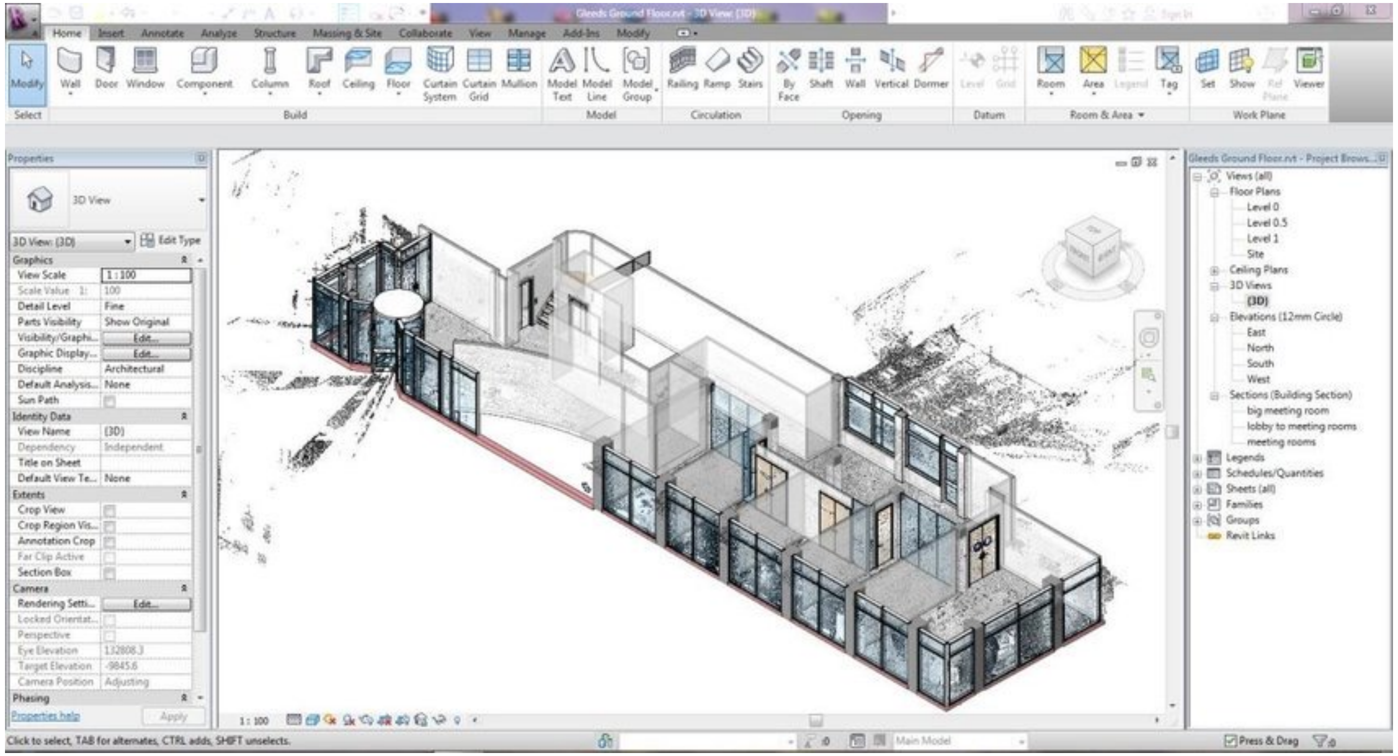
Information in BIM

‘As-Built’ BIM have significant practical meaning in building quality evaluation, heritage building maintenance, and protection and building environment assessment.



‘As-planned’ BIM and ‘As-built’ BIM

Why Unsupervised BIM?



The current building process of the ‘As-built/As-is' BIM model on Revit software (Thomson, 2016)

Motivation of replacing this monotonous, repetitive, time-consuming, and error-prone manual modelling process is raising in recent years.

Aims and Objectives

In this project, an autonomous scanning mobile platform and a supporting software systems is proposed to achieve Level 3 (Adán et al., 2020) autonomous BIM Process.

Class of Autonomous	Description
Level 1	Automatic data acquisition of the building's as-is state
Level 2	Simple geometric building model
Level 3	Recognition and labelling of primary structural elements (SEs) of the building
Level 4	Recognition of openings such as window and doors within SEs of the building
Level 5	Recognition of small building service components (BSCs) on SEs

Chart 1. Level of Autonomous BIM

Objectives

(1) Complete design and setup of a robust mobile scanning platform
(2) Make cost-effective decision in selection of hardware components and custom parts manufacturing to ensure expenditure does not exceed the ¥85,000 budget
(3) Achieve the indoor robot navigation for autonomous building scanning
(4) Getting a reconstructed building geometry model with centimeter level error
(5) Successfully segment the building by main structures, including unobstructed walls, ceiling and floor. For the walls, flat walls larger than 1.5m*1.5m is considered.

Hardware Design and Design Rationale

- Selection of Sensors and Mobile Platform
- Main Structure Design and Setup
- Power System Design and Setup
- Signal Communication Design and Wiring

Description		Differential Wheeled Robots	Ackermann steering wheeled robot	Mecanum wheels robot	Multi-leg robot	Drone
Criteria	Weight	Datum Model	Model 1	Model 2	Model 3	Model 4
Cost	3	0	-	- -	- - -	0
Difficulty of Control	4	0	-	- -	- - -	- -
Resource Available	3	0	0	- -	- -	-
Load Capacity	2	0	0	0	-	- - -
Noise	1	0	0	-	- - -	- -
Durable	4	0	0	-	- -	- -
Adaptability to Environment	5	0	+ +	- -	+ + + +	+ + + +
Safety	5	0	0	0	0	- - - -
+		0	10	0	25	25
0		17	10	2	0	3
-		0	-7	-35	-40	-47
Net Score		0	3	-33	-15	-22

Chart 2. Selection for Platform Type

Description		Wheel-Tech Ackermann Platform	Segway RMP401 PRO	Agilex Hunter 2.0
Criteria	Weight	Datum Model	Model 1	Model 2
Cost	2	0	- -	- - -
Protection Rate	4	0	+ + + +	+ +
Off-Road Ability	4	0	+ + +	+ +
Flexibility	4	0	+	- -
Payload	1	0	+ + +	+ + + +
Range	3	0	0	-
+		0	35	20
0		17	1	0
-		0	-4	-17
Net Score		0	31	3

Chart 3. Selection for Detailed Model of Ackermann-Drive Platform

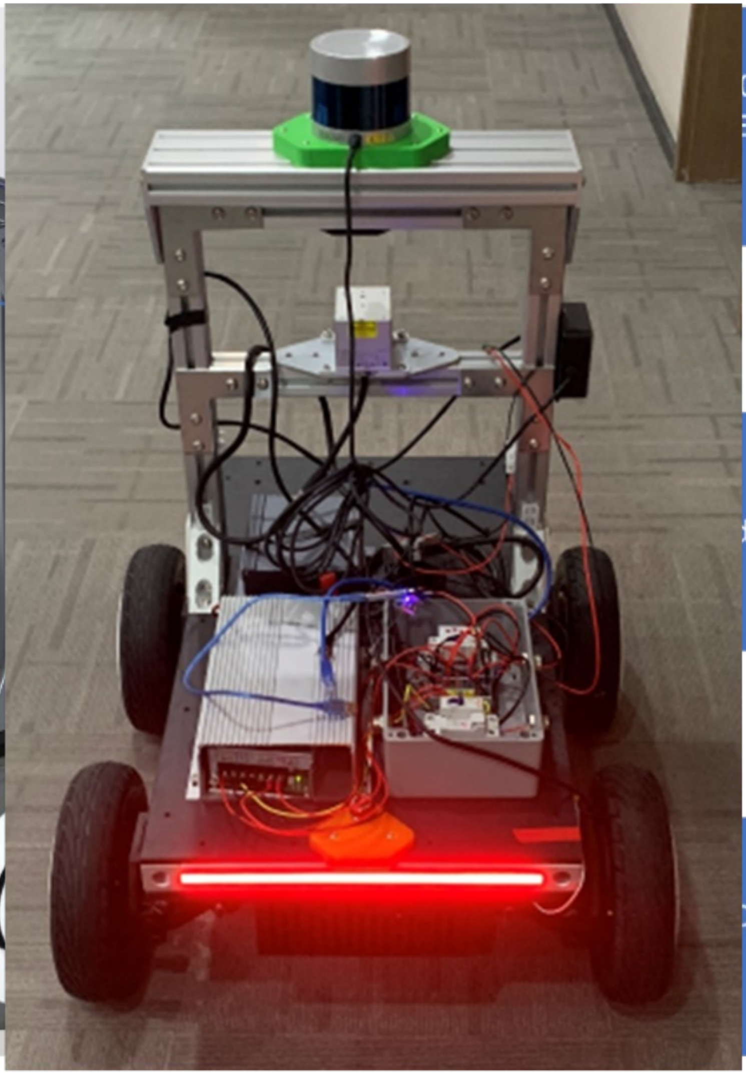
Decision Matrix for Mobile Platform Selection

3D-Printing LiDA
Mount

Laser Cutting AB
Plate

LED Lightband

(a) Front of the vehicle

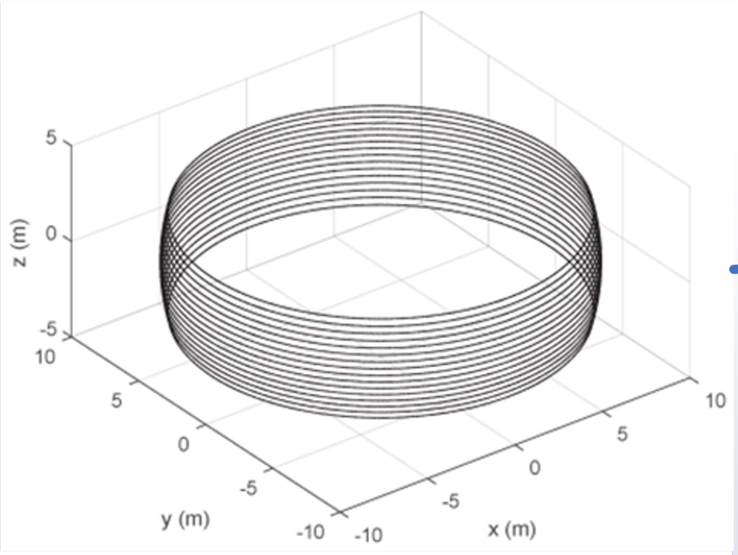


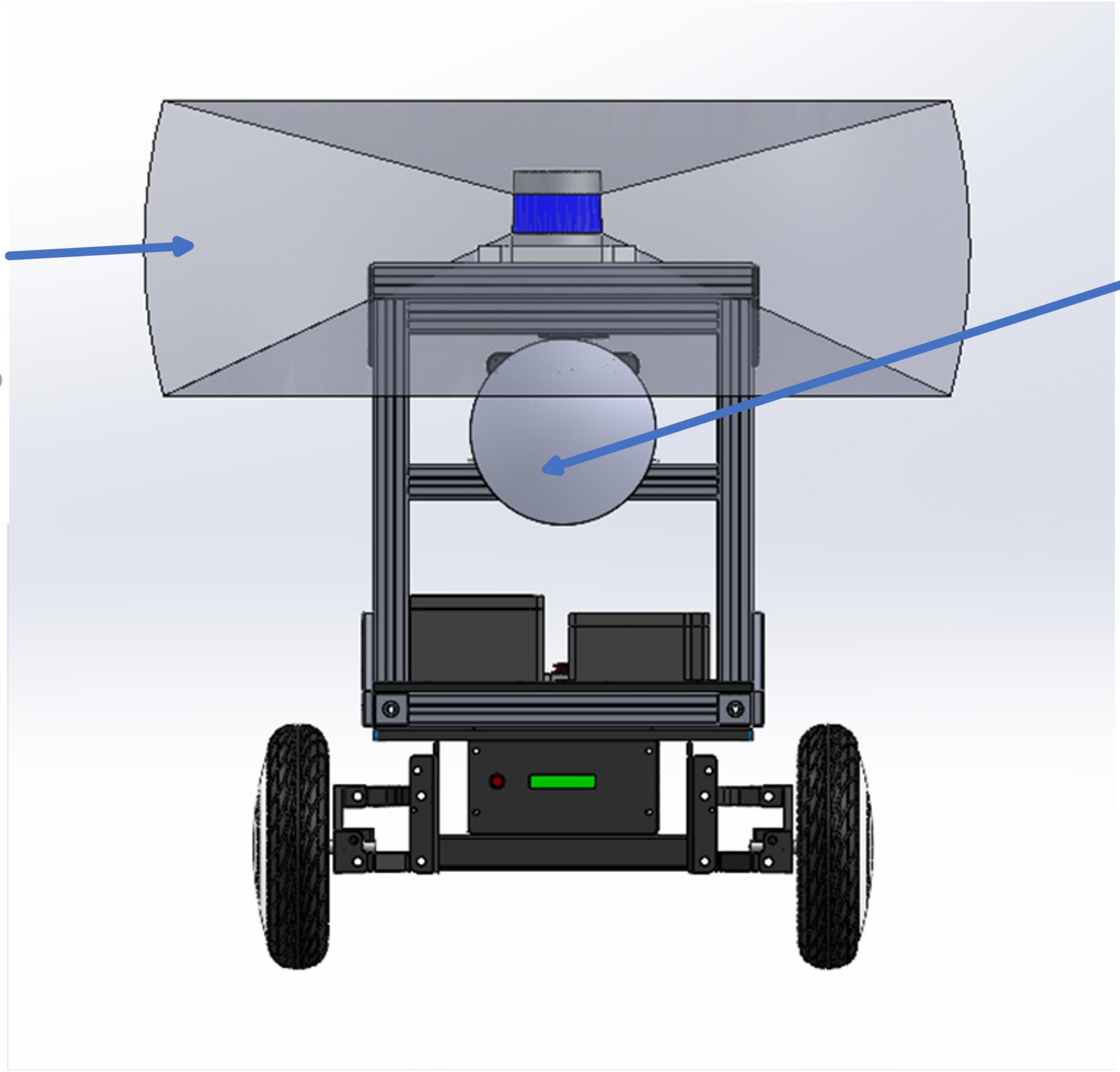
(b) Back of the vehicle

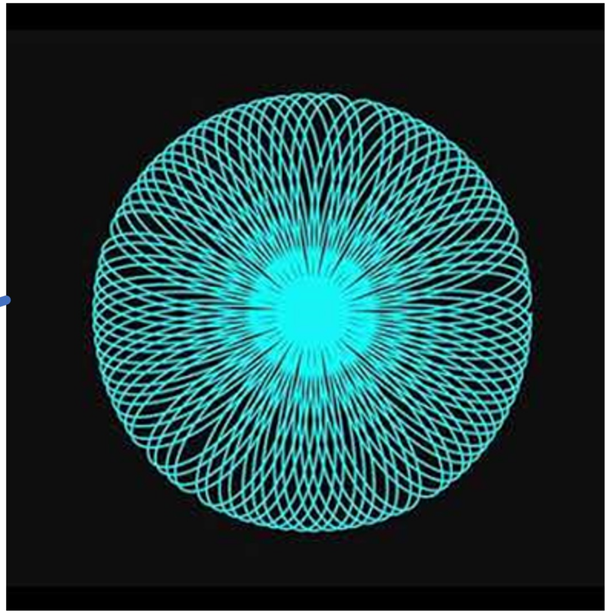
0*40 Aluminium
Extruction Main
Frame

3D-Printing
djustable Camera
Mount

D-Printing E-Stop
Mount







Velodyne VLP-32C LiDAR

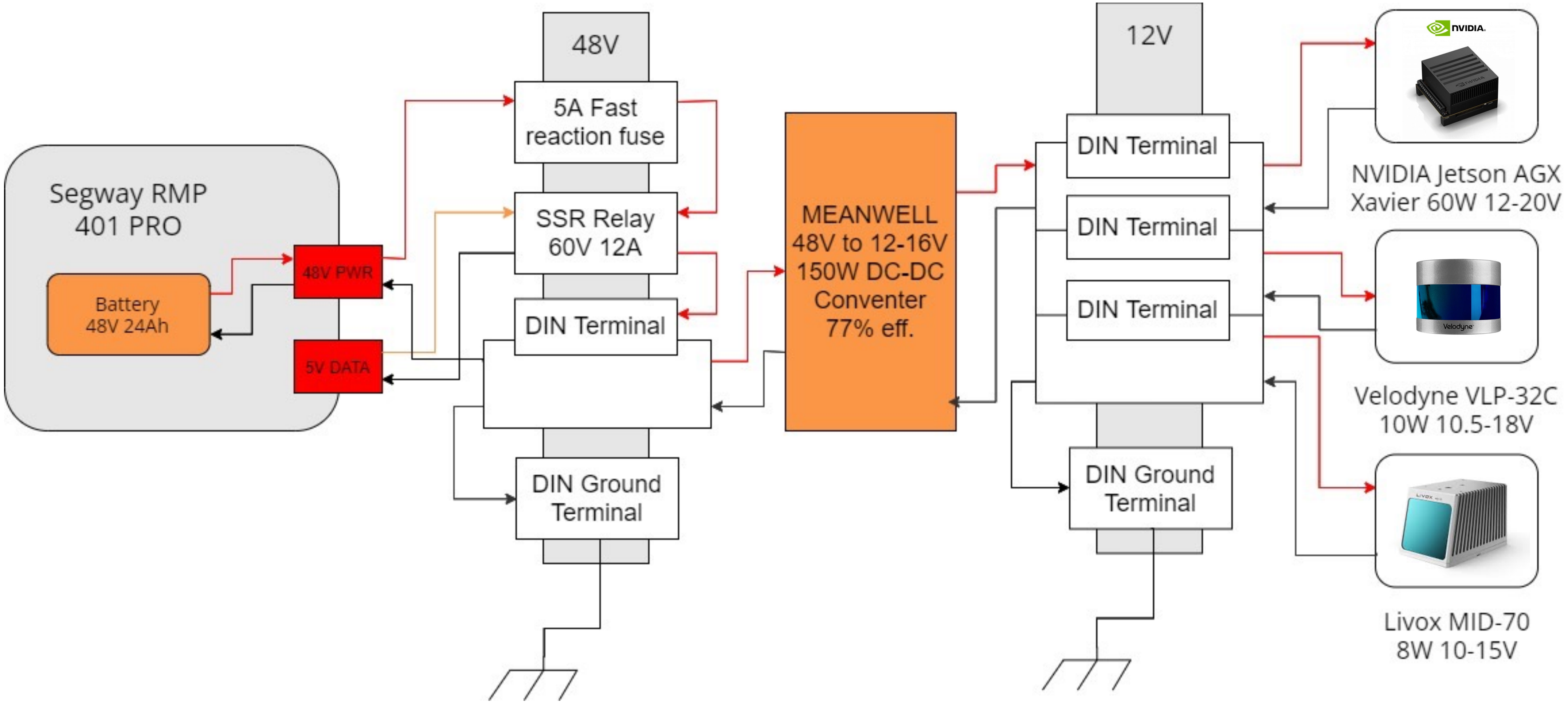
Huge FOV
Mechaninical LiDAR
Spinning Scan Pattern
Repetitive Scanning

Livox MID-70 LiDAR

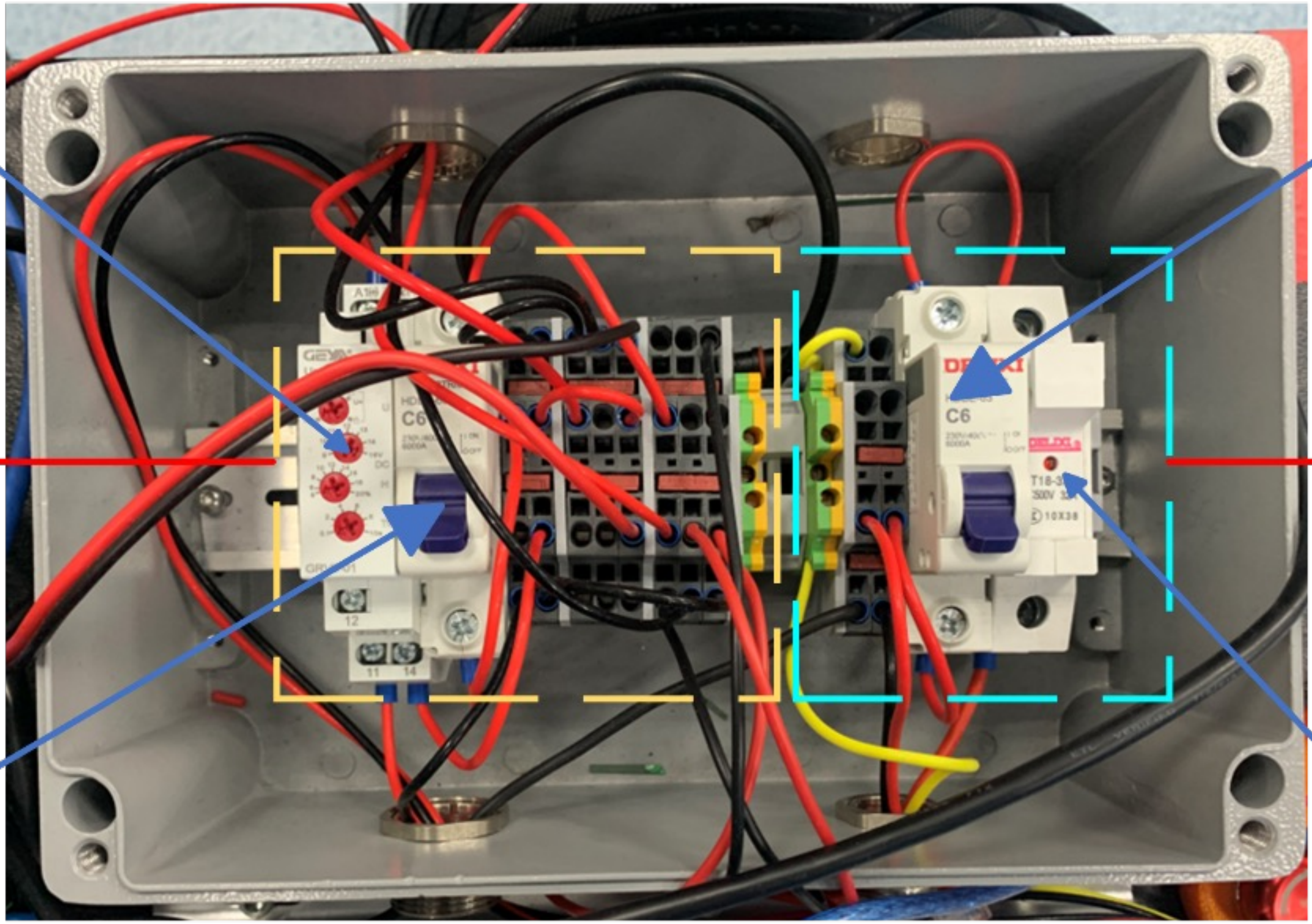
Small FOV
Semi-Solid-State LiDAR
Spiraling Flower Scan Pattern
Non-Repetitive Scanning

Light Detection and Ranging (LiDAR) Sensor Selected for This Project

Power System Initial Design



Power System Final Setup



Over-Voltage Protector

12 Volt Side

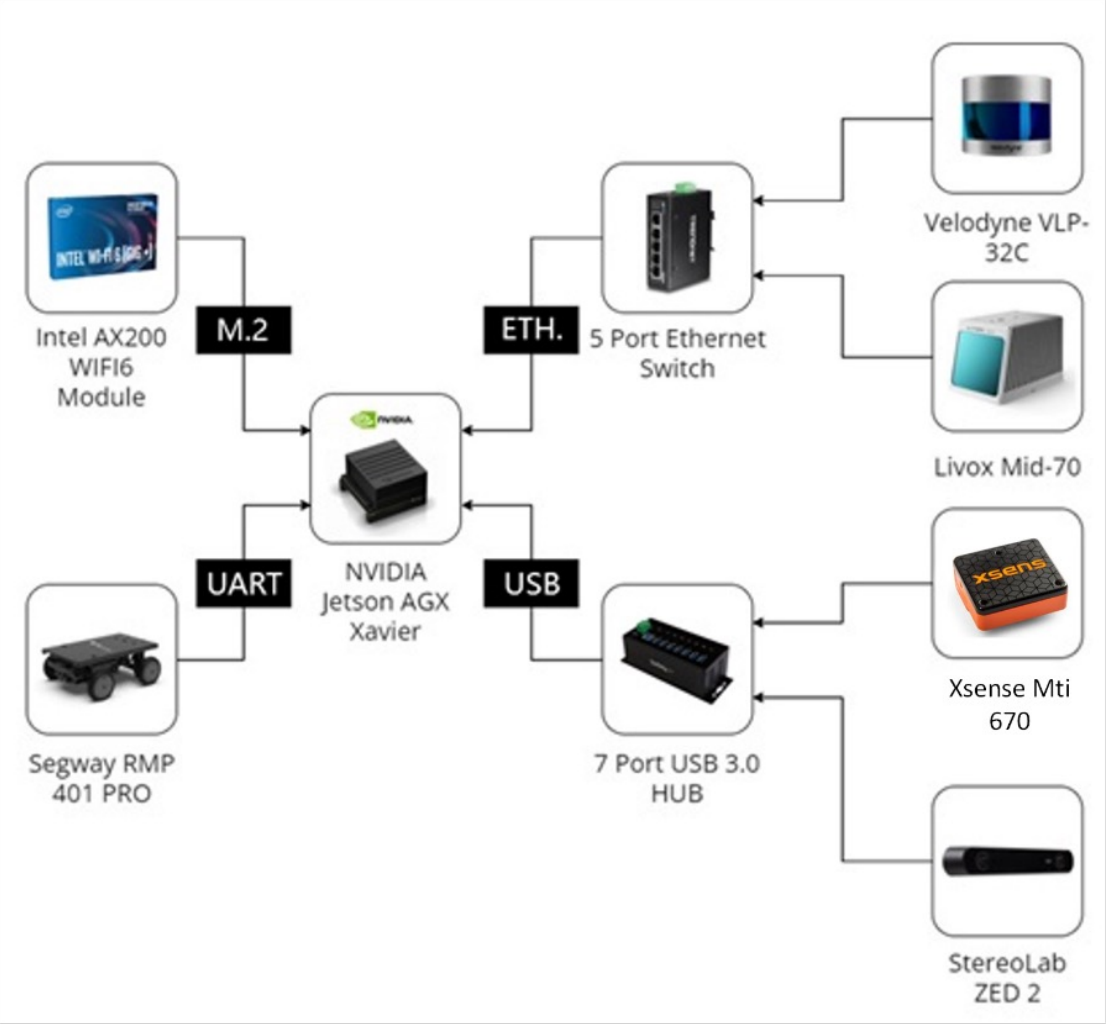
Molded-case circuit breaker (MCCB)

Molded-case circuit breaker (MCCB)

48 Volt Side

Fast-Acting Fuse

Signal Communication System

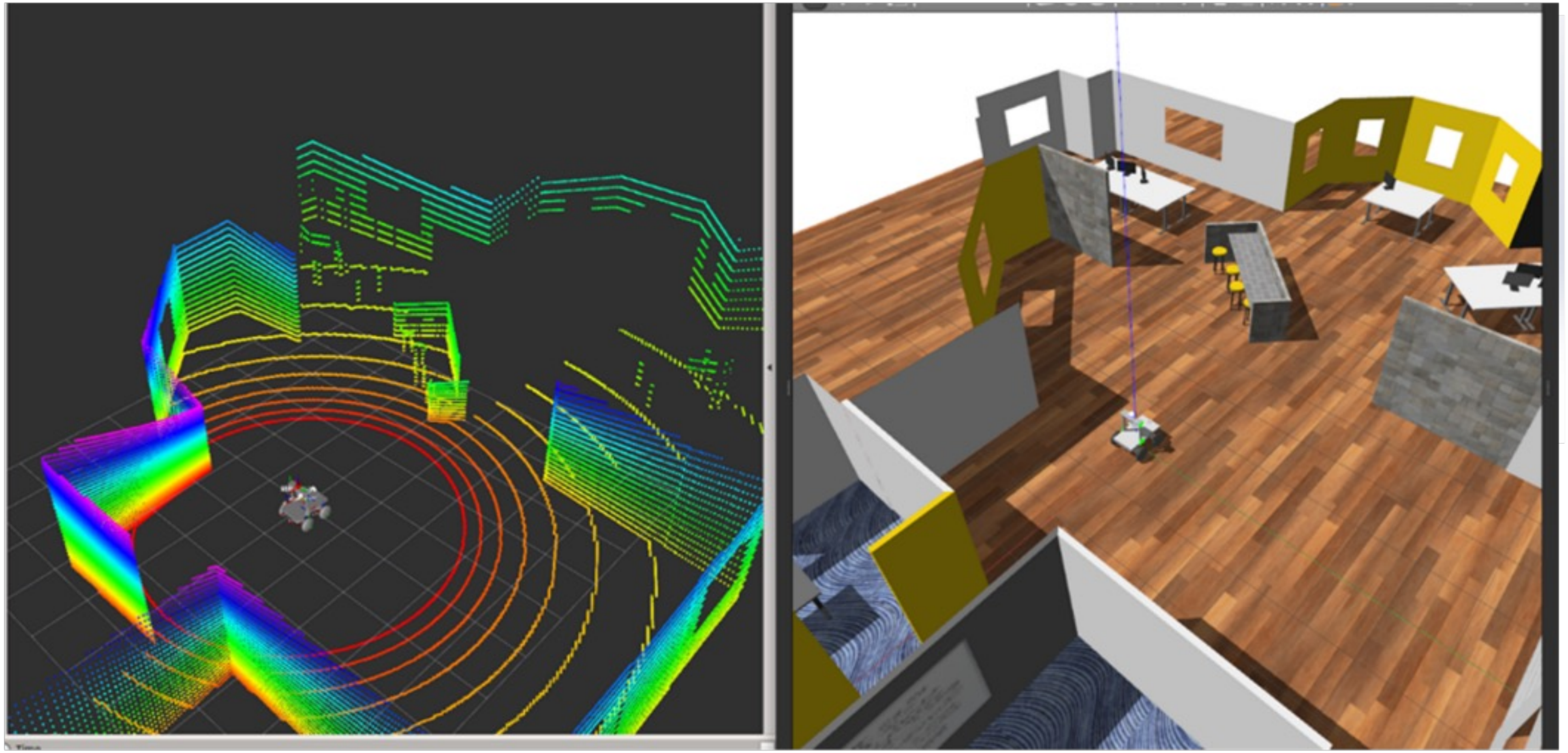


Software Methodology

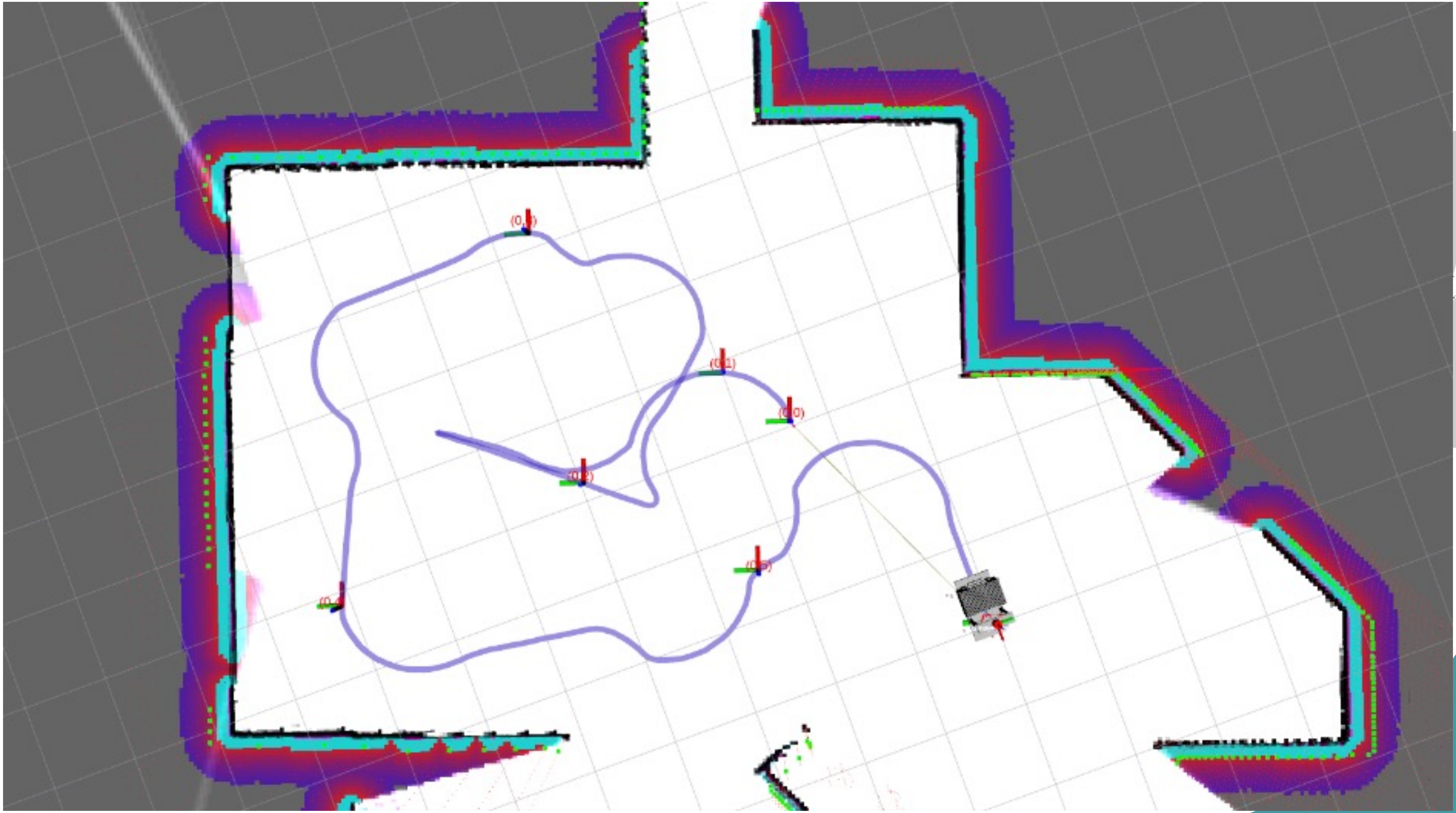
The software environment of all the high-level control will base on NVIDIA Jetpack 4.6.1, a costumed Ubuntu 18.04 Linux system.

Robot Operating System (ROS)(Quigley et al., 2009) will be used for the communication of software and hardware. The achievement of the mapping, navigation and 3D reconstruction will highly rely on the function of ROS.

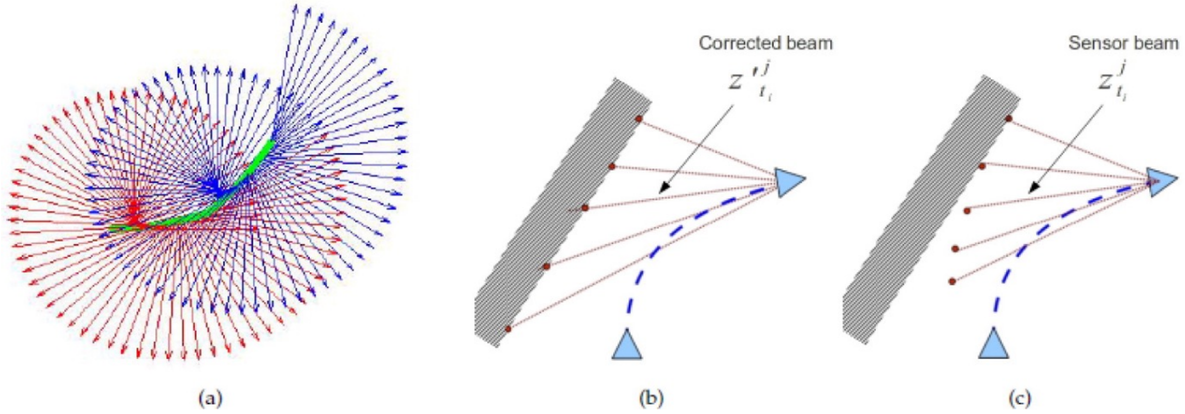
Setup of Simulation Environment



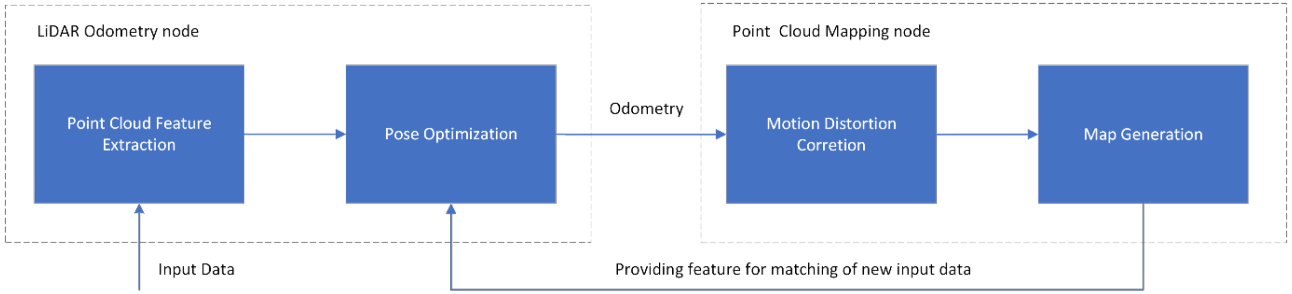
(a) (b)

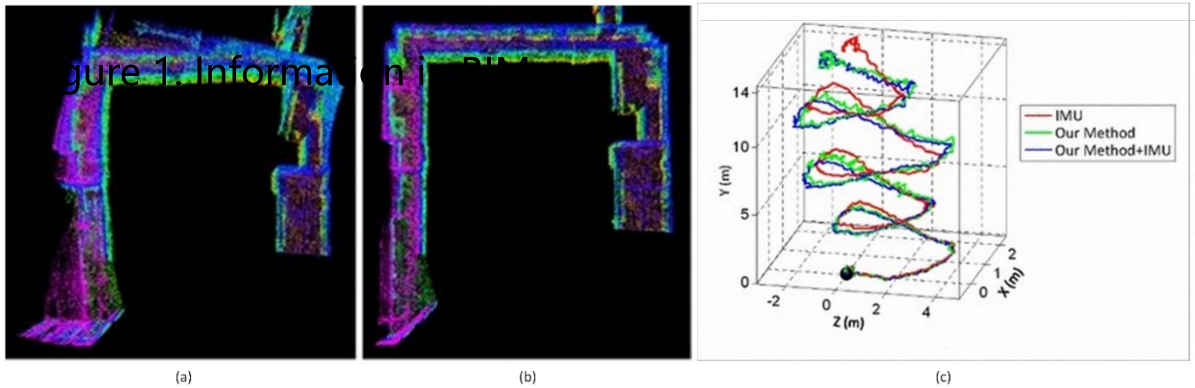


WHY LOAM?



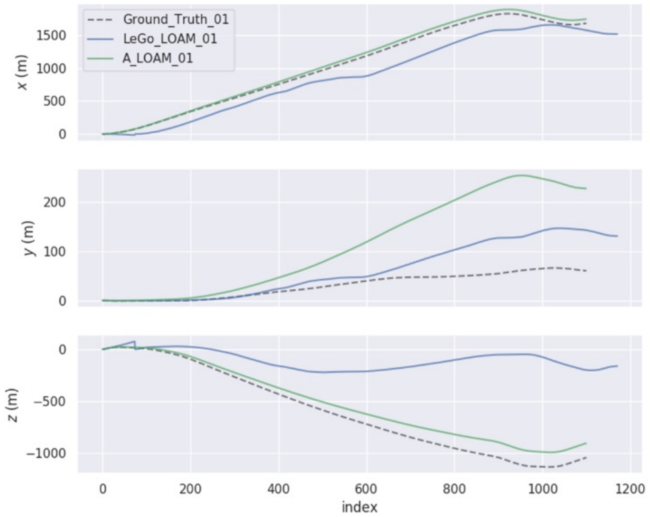
The Motion Distortion Issue (Vivet et al., 2013)

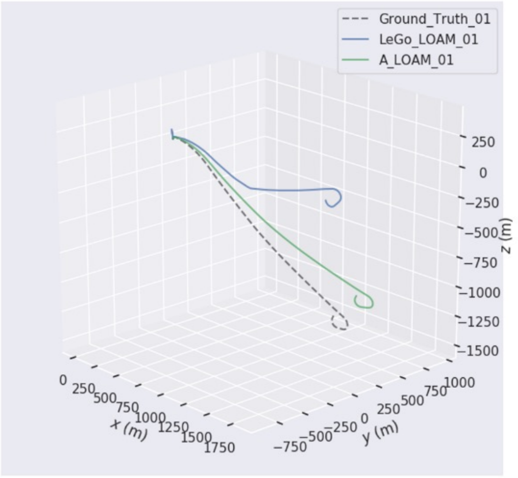


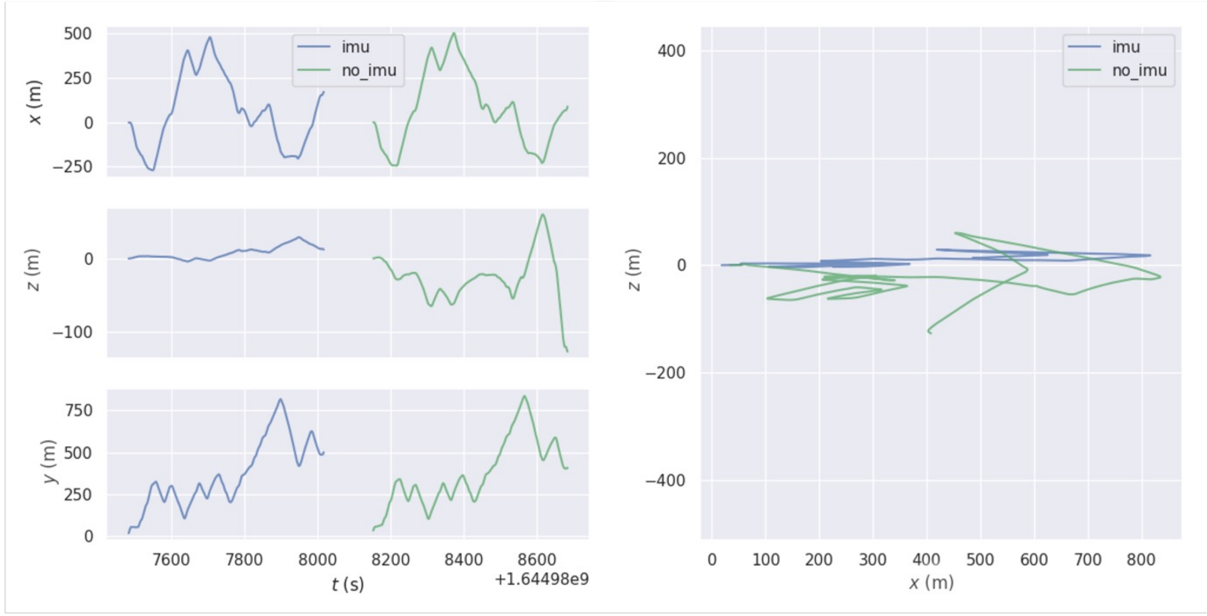


LiDAR Odometry and Mapping (Zhang and Singh, 2014)

WHY Ground-Optimized LOAM?



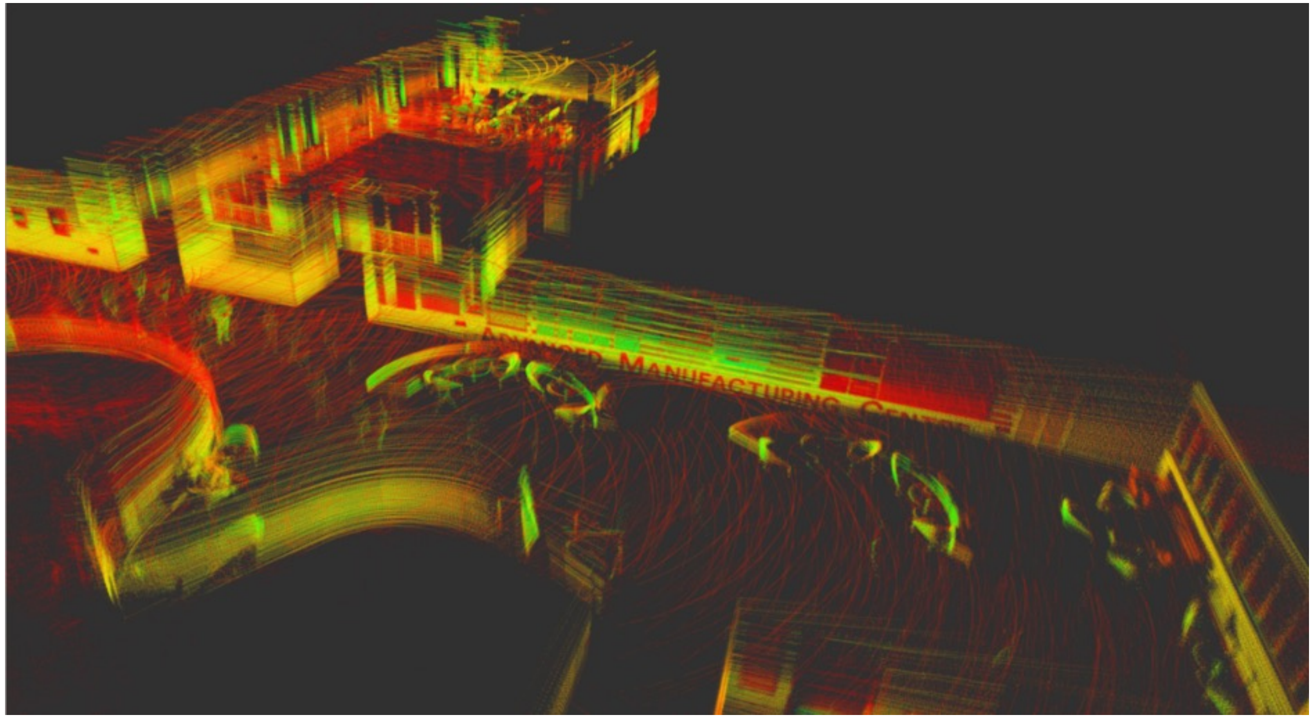


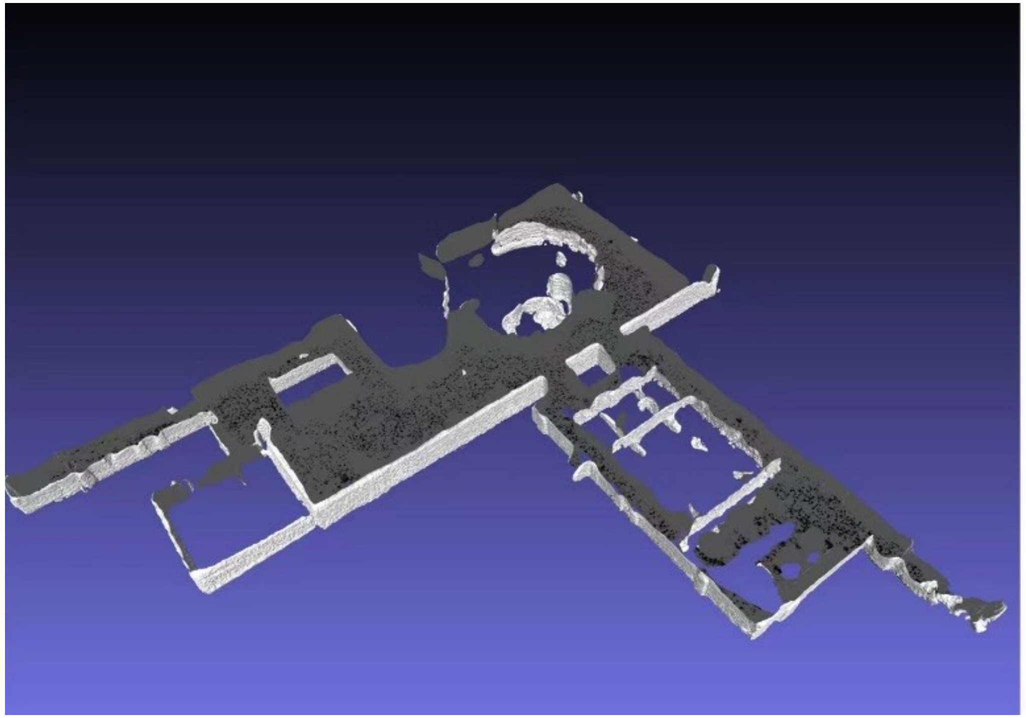


Light-Weight Ground-Optimized LOAM (Shan and Englot, 2018)

KITTI Dataset is used for benchmarking (Geiger et al., 2012)

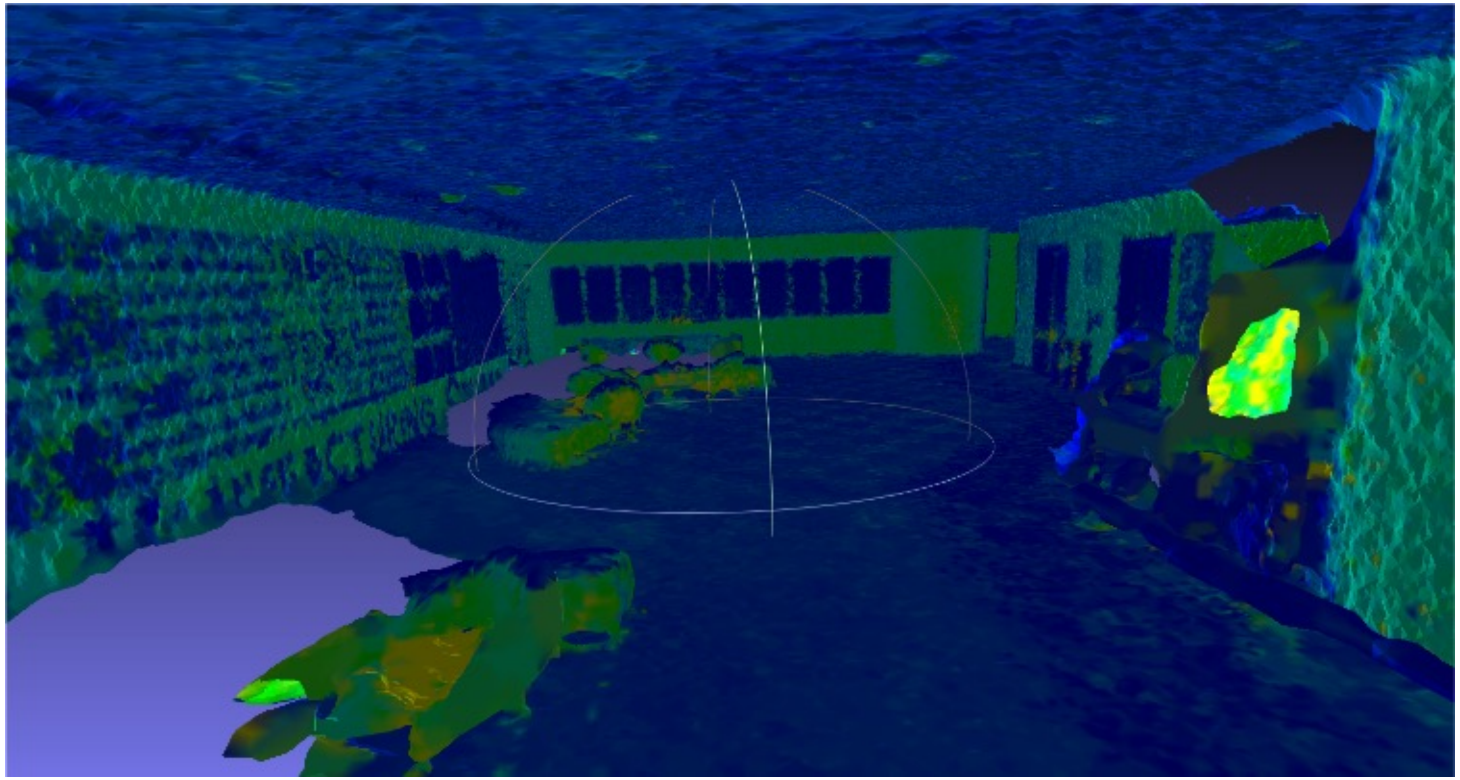
Reconstruction System Setup





LOAM and Poisson Reconstruction (Kazhdan et al., 2006) in IAMET 2F, UNNC

Segmentation System



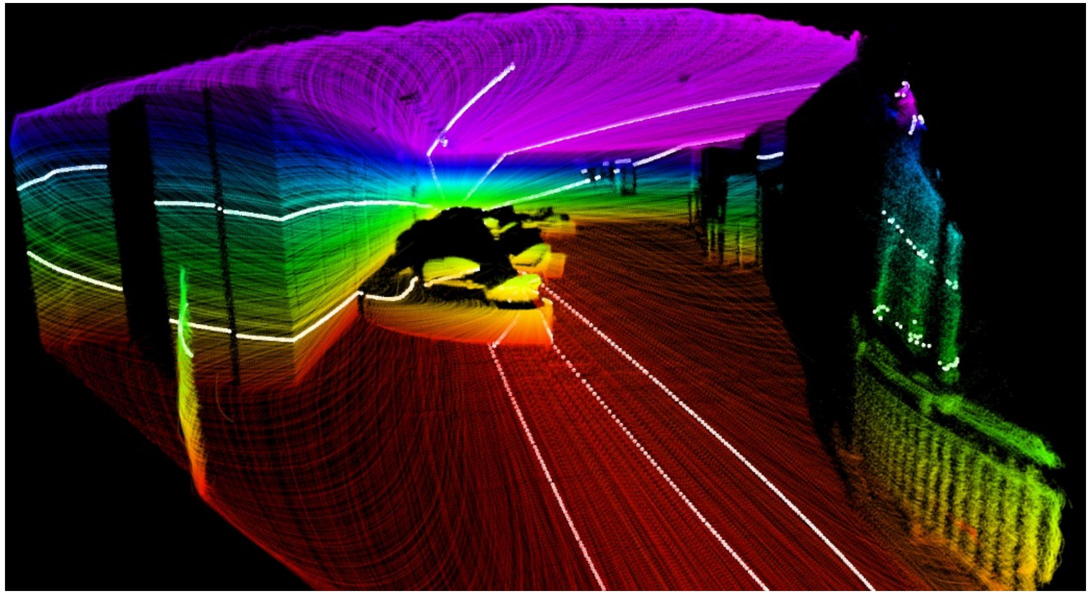
LiDAR Intensity-Based Segmentation

Result and Discussion

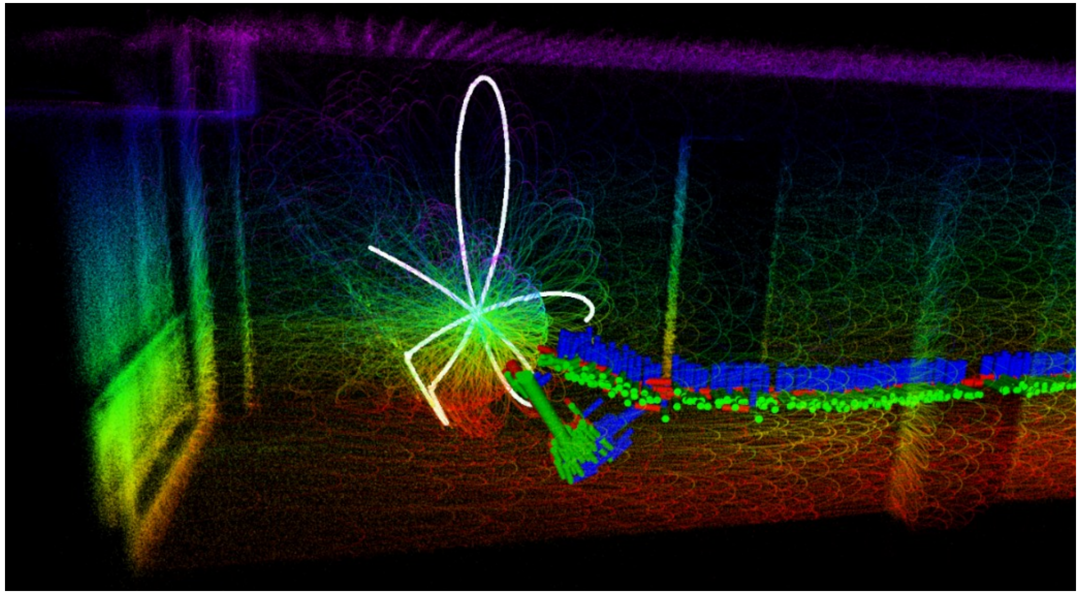
Position	Truth Data (m)	Reconstructed Data (m)	Error (cm)	Percentage Error (%)
1	2.435	2.425	-1.0	0.411
2	19.515	19.478	-3.7	0.190
3	2.294	2.287	-0.7	0.305
4	12.703	12.684	-1.9	0.149

Chart 6. Translational Error Estimation

Result and Discussion



High Quality Scanning from Livox LiDAR



Degenerated Issue of Livox LiDAR

Future Improvements: Multi-Sensor Fusion

Conclusion

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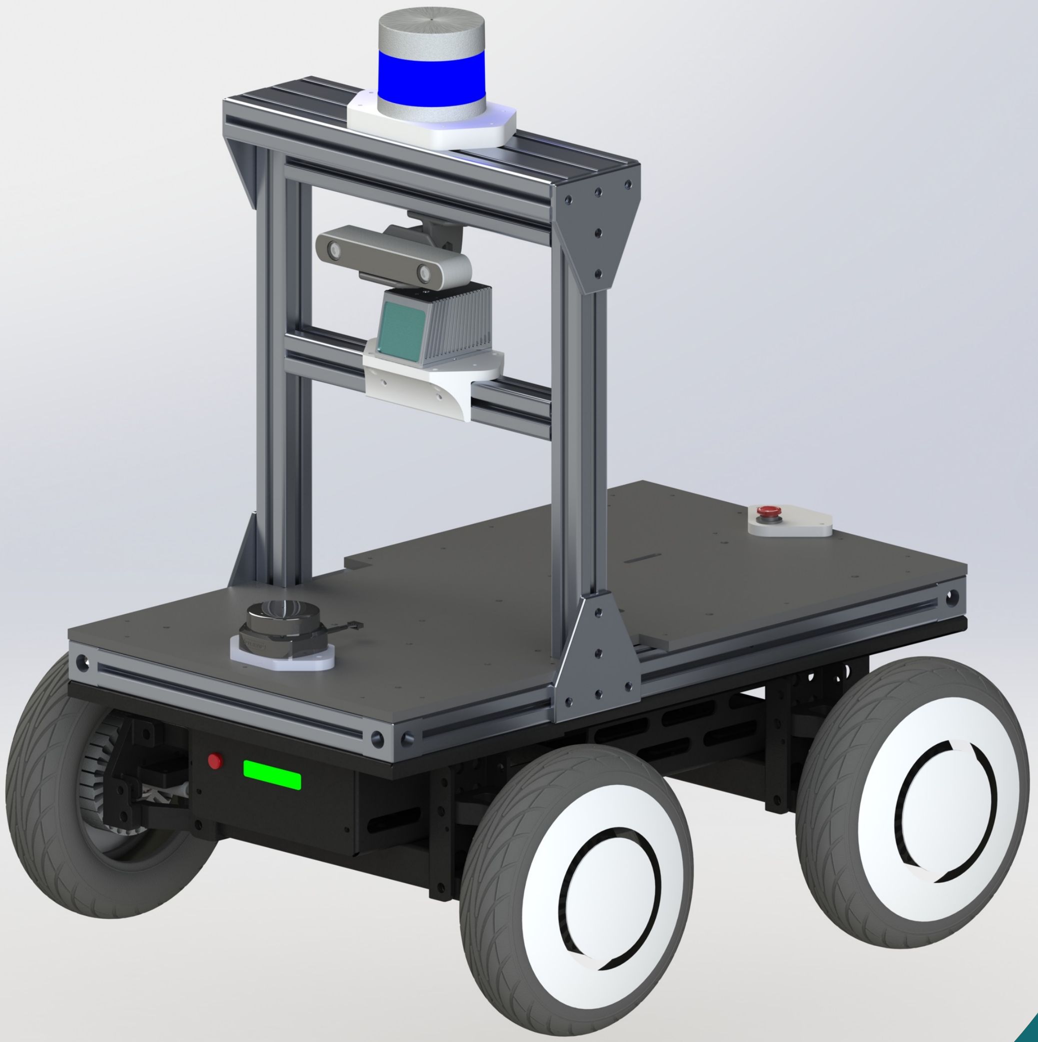

Thanks For Listening

Q&A