INVESTIGATION OF POTENTIAL APPROACHES TO IMPROVE ACCURACY OF LIDAR 3D MAPPING SYSTEMS

Cooperative Education 2/66
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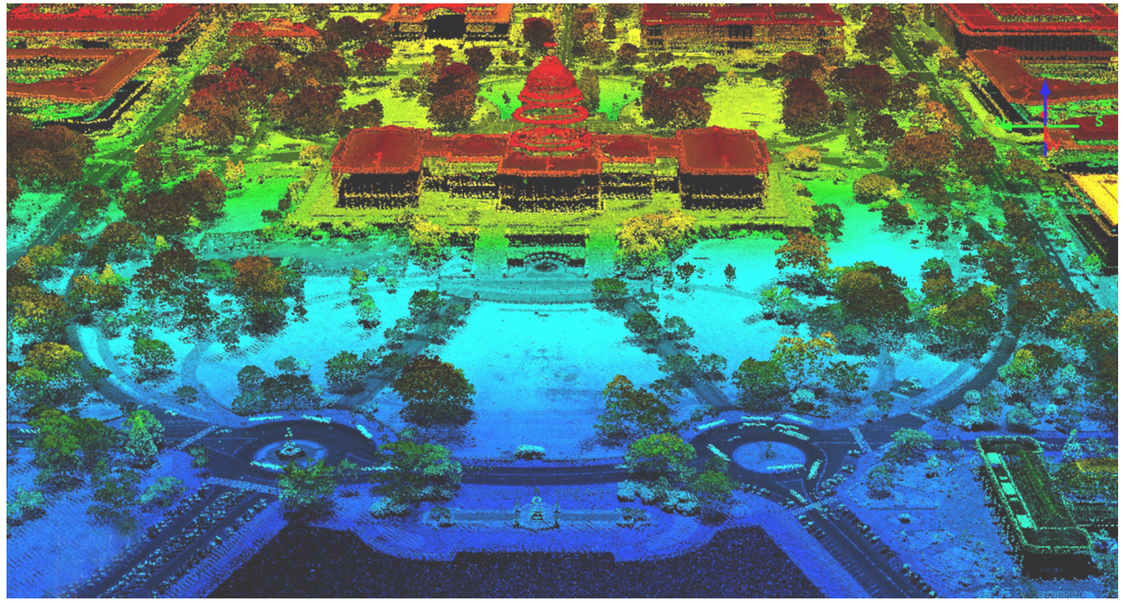
OUTLINE

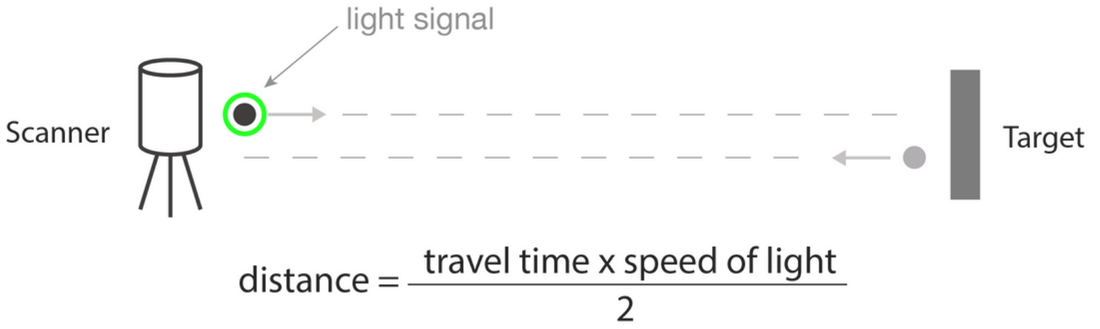
- INTRODUCTION
- PROBLEM & OBJECTIVE
- TIME LINE
- PROJECT
- RESULT
- NEXT PLAN & OBSTACLE
- LIFE at NECTEC

INTRODUCTION

What is LiDAR

- Abbreviated from “Light Detection and Ranging”
- Technology that utilizes laser light to measure distances by shooting light pulses towards objects and timing the duration it takes for the laser to bounce back to determine the distance between the object and the emitting source
- The current significance of this technology lies in various areas, including:
  - Autonomous Driving
  - Construction Applications
  - Geographical Analysis and Research
  - Environmental Monitoring and Management
  - Surveying and Mapping





$$\text{distance} = \frac{\text{travel time x speed of light}}{2}$$

Image sources : https://gisgeography.com/lidar-light-detection-and-ranging/
https://www.opengeomatics.ca/LiDAR-acquisition-and-analysis.html

INTRODUCTION

Smaller LiDAR Technology

As there is a demand for LiDAR technology in various fields with different requirements, this technology has been developed in multiple forms to suit specific applications.

Intel RealSense

It is a camera that simulates LiDAR functionality using Depth Sensing or Active Stereo to create 3D images and measure distances at close to mid-range distances.

Image sources : *https://www.amazon.in/Intel-RealSense-LiDAR-Camera-L515/dp/B0855LWPLN*

PROBLEM

To create accurate 3D maps, 2 factors are crucial, each of which still encounters potential errors:

- **Mapping**: Utilizing LiDAR, RGB-D cameras, or Depth Cameras to generate three-dimensional images of the environment or objects.
  - inaccurate distance measurements
  - signal interference
  - missing data

- **Positioning**: This helps devices used for mapping to determine their position or orientation accurately. Technologies like GPS, Encoders, IMU (Inertial Measurement Units) are used for this purpose.
  - inaccuracies in positioning systems
  - sensor instability
  - slow update rates.

PROBLEM

Comparing the differences between Large LiDAR - Small LiDAR

Characteristic	Large LiDAR	Small LiDAR
Size	*Larger and heavier*	*Smaller and lighter*
Scan range	*Longer*	*Shorter*
Scan resolution	*Higher*	*Lower*
Scan Accuracy	*High*	*Medium - low*
Price	*More expensive*	*Less expensive*

OBJECTIVE

Topic

Investigation of Potential Approaches to Improve Accuracy of LiDAR 3D Mapping Systems

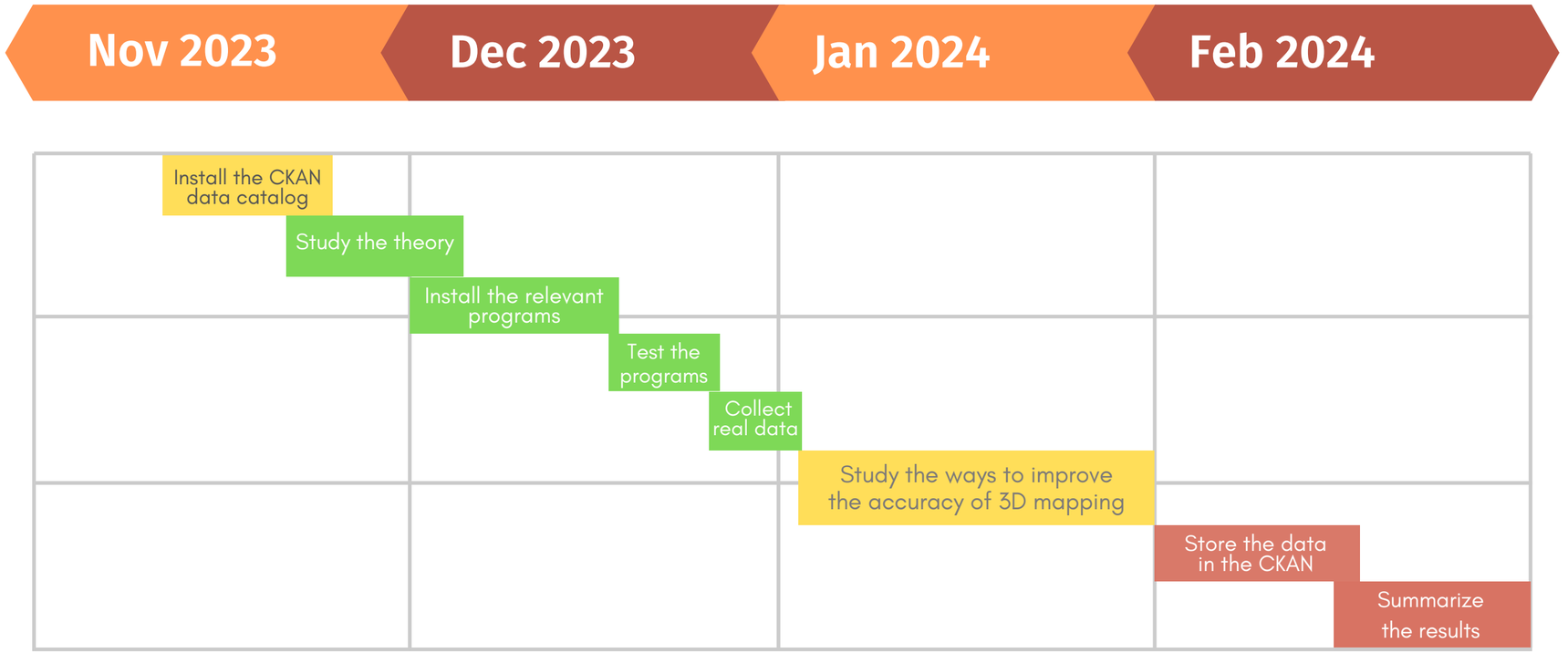
Goal

Study approaches to enhance the accuracy of 3D mapping systems

Key Ideas

Due to the interest of the project members in studying various algorithms related to LiDAR mapping, we employed a comparative mapping approach among the algorithms of interest. This was done in order to find the optimal results.

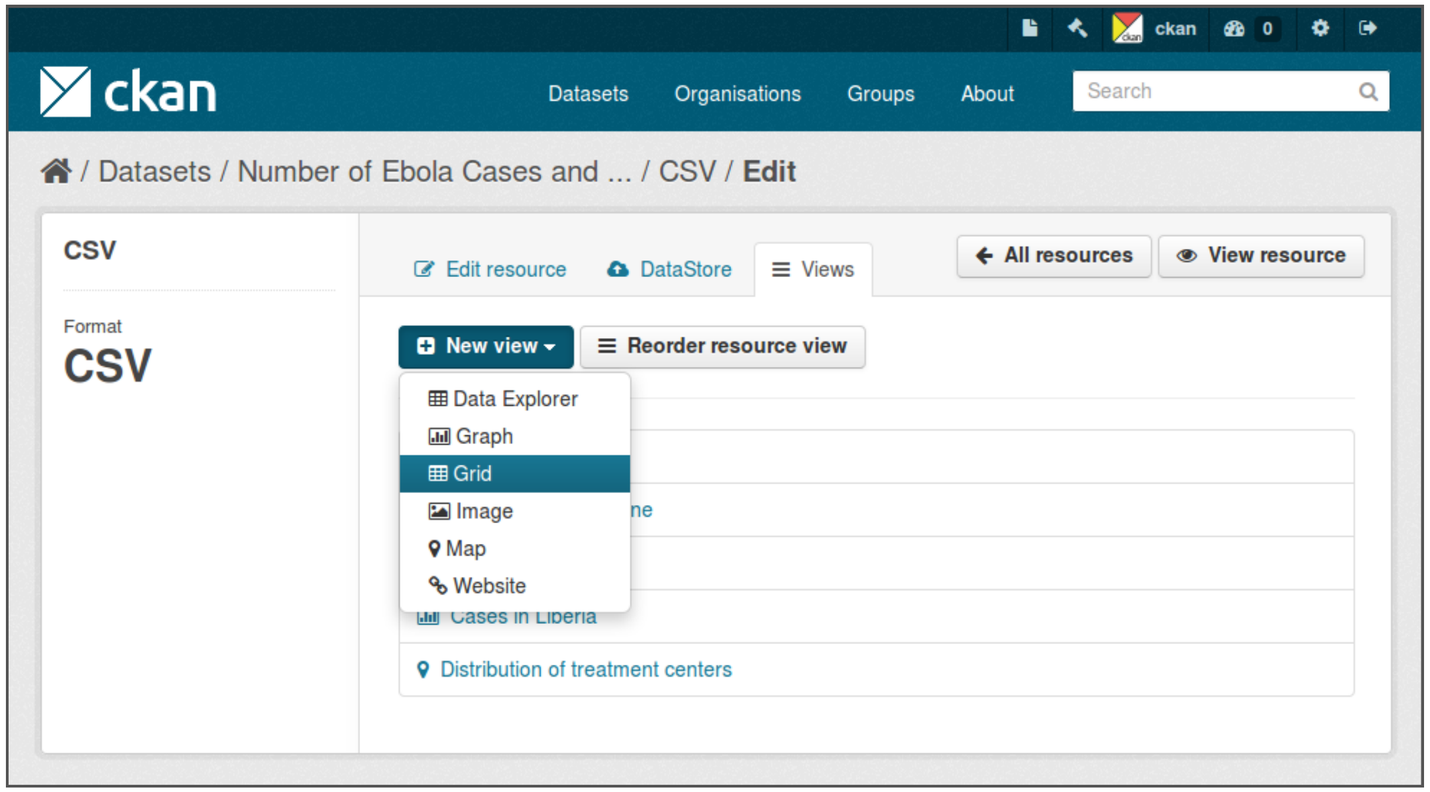
TIME LINE



Tasks

1. *Install the CKAN data catalog*
2. *Study the theory and programs related to 3D mapping*
3. *Install the relevant programs*
4. *Test the programs*
5. *Collect real data from the Intel RealSense L515 camera*
6. *Study the ways to improve the accuracy of 3D mapping*
7. *Store the data collected from the trial in the CKAN*
8. *Summarize the results and make a report*

PROJECT : CKAN



CKAN Data Catalog

- An open-source data management system designed to store and publish open data
- It can be used in a variety of contexts, including government, business, and community.

Sources : *https://docs.ckan.org/en/latest/maintaining/data-viewer.html*

PROJECT : LiDAR Mapping

LiDAR

- Abbreviated from “Light Detection and Ranging”
- Technology that utilizes laser light to measure distances by shooting light pulses towards objects and timing the duration it takes for the laser to bounce back to determine the distance between the object and the emitting source

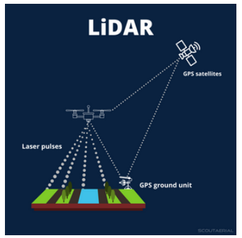
$$\text{distance} = \frac{\text{travel time x speed of light}}{2}$$

Positioning System

- This helps devices used for mapping to determine their position or orientation accurately. Technologies like GPS, Encoders, IMU (Inertial Measurement Units) are used for this purpose.

IMU

Encoder



GPS

Image sources : https://www.gic.co.th/product/21258-16588/rotary-encoders-e50s8-1024-3-t-24
https://www.scoutaerial.com.au/article-lidar-or-photogrammetry/ https://www.zenmicrosystems.co.in/vbox-inertial-measurement-unit/

PROJECT : LiDAR Mapping

Device : Intel RealSense L515

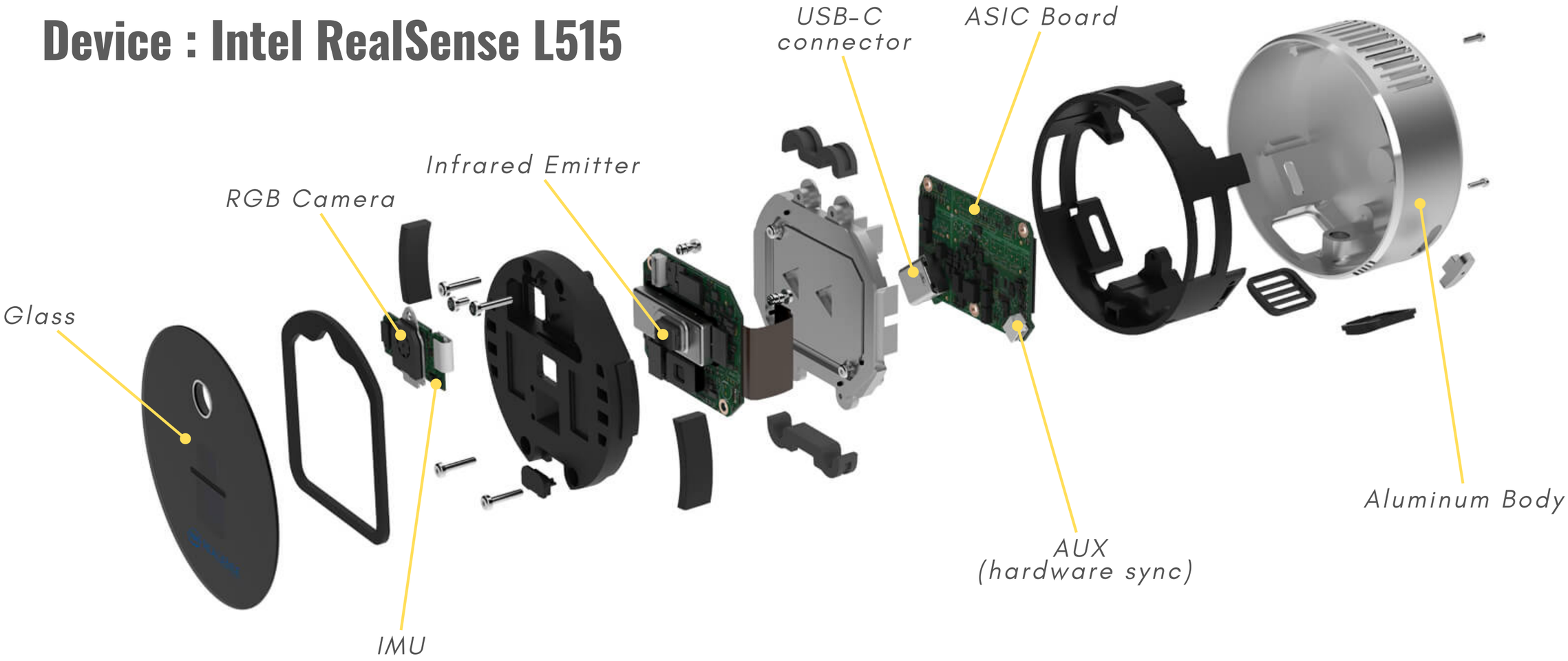


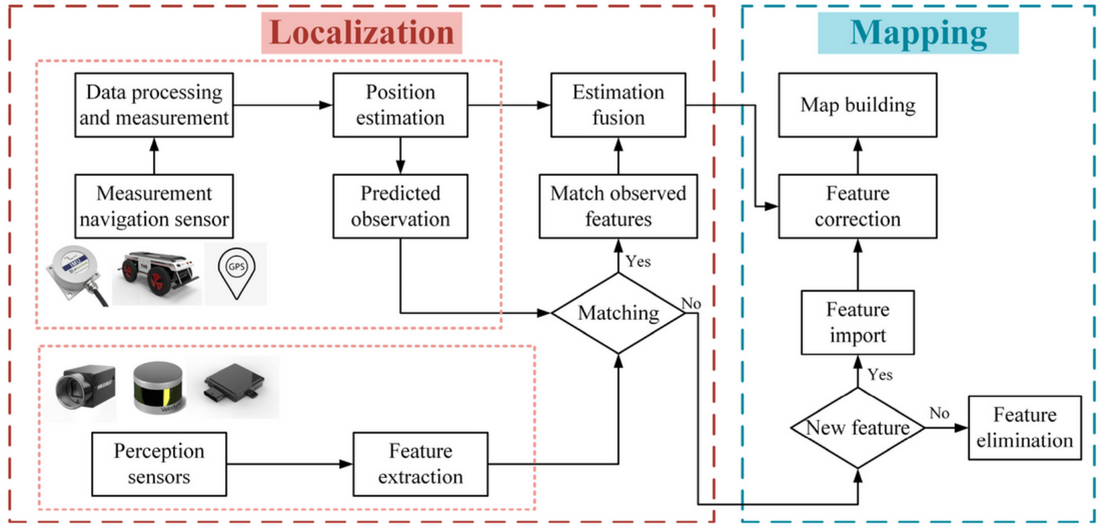
Image sources : https://www.intelrealsense.com/lidar-camera-l515/

PROJECT : LiDAR Mapping

SLAM

- Abbreviated from “Simultaneous Localization and Mapping”

- Algorithm that uses data from LiDAR or other sensors to identify the position and create a map of the environment at the same time



RTAB-MAP

- Real-Time Appearance-Based Mapping
- A SLAM system used in robots and real-time mapping.
- It utilizes scanning and feature recognition to map the environment.

SSL-SLAM

- Semi-Supervised Learning SLAM
- Model employing semi-supervised learning to create maps and determine positions.
- It utilizes supervised learning techniques to aid in the mapping and positioning process.

ORB-SLAM

- Oriented FAST and Rotated BRIEF SLAM
- Employs a fast and efficient method for detecting keypoints in images and constructing feature descriptors.

Image sources : https://www.mdpi.com/2072-4292/14/12/2835

PROJECT : LiDAR Mapping

Robot Operating System (ROS)

- An open-source software platform for robot development
- ROS makes it easier for developers to combine software and hardware from different manufacturers.
- This project has chosen to use ROS Noetic because it is the latest version of ROS1.

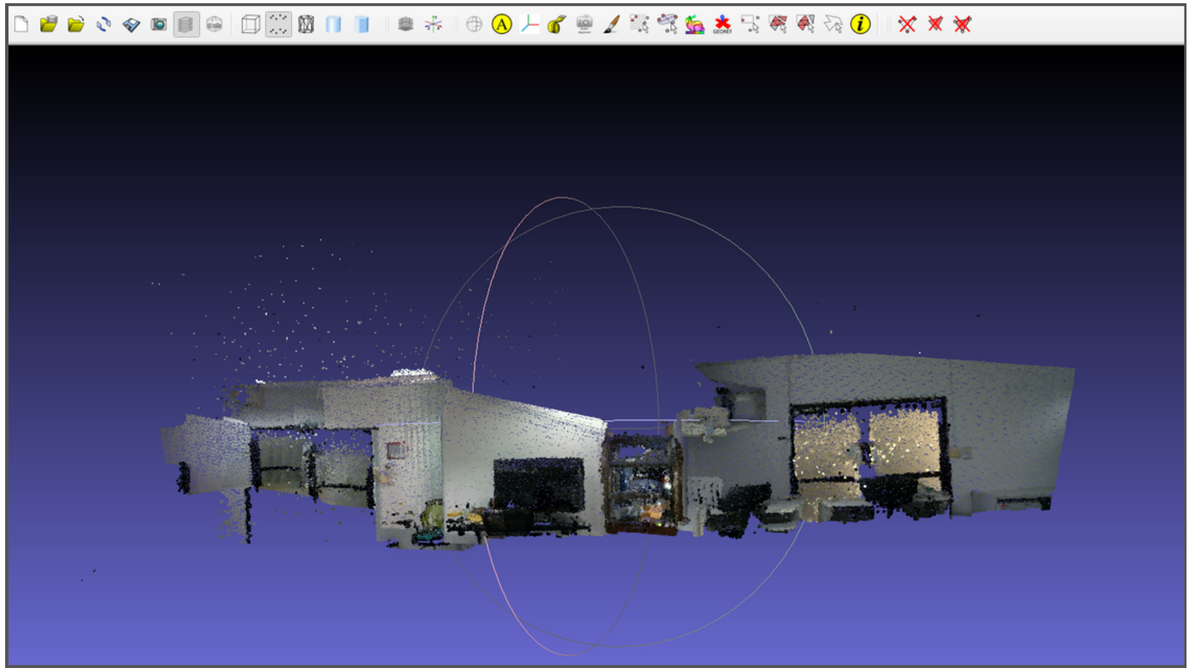
  (Unfortunately, we tried to work with ROS2 but encountered installation issues)

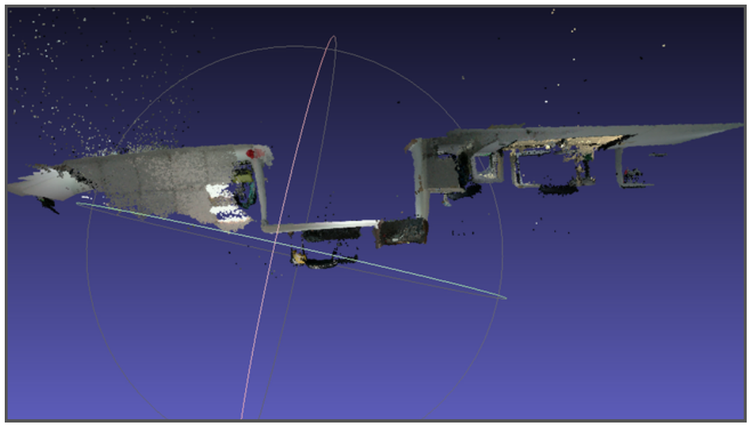
Image sources : *https://www.neobotix-robots.com/products/robot-software/ros*
https://www.openrobotics.org/blog/2020/5/23/noetic-ninjemys-the-last-official-ros-1-release

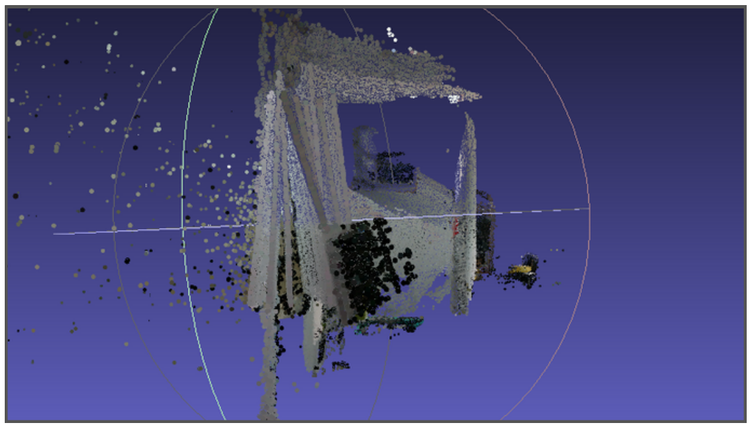
PROJECT : Collecting Data

RTAB-MAP

- unite_imu_method:="copy"
- unite_imu_method:="linear_interpolation"
- no IMU







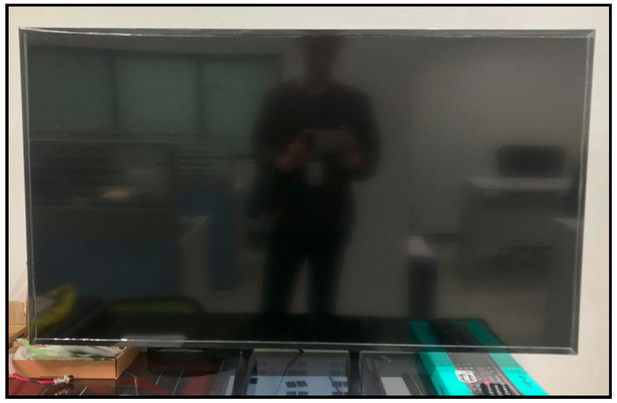
PROJECT : Methodology

RTAB-MAP

1. **Select 5 objects** (reference objects) from the map, **then measure the distances** of the objects **in the 3D map.**

2. **Measure** the distances of the **reference objects in the real world**

3. **Compare both the objects in the 3D map and the objects in the real world**, then calculate the parameter that provides the best results.



PROJECT : Analysis Data

RTAB-MAP

- unite_imu_method:="copy"

COPY-wall1	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.3307	1.026	0.0816	2.0508	1.43464
2	0.31758	1.0485	0.9373	2.0767	1.43982
3	0.3251	1.0087	0.8716	2.0483	1.42886
mean	0.32446	1.027733333	0.6301666667	2.0586	1.43444

COPY-wall2	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.41067	1.01647	0.87608	2.1307	1.4253
2	0.35264	1.02276	0.8646	2.1163	1.42316
3	0.354313	0.9765	0.8683	2.1326	1.41907
mean	0.372541	1.005243333	0.86966	2.126533333	1.42251

COPY-wall3	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.3711	1.0705	0.8812	2.0933	1.4239
2	0.3869	1.0593	0.866	2.1015	1.4203
3	0.3723	1.0726	0.8666	2.1239	1.4124
mean	0.3767666667	1.067466667	0.8712666667	2.106233333	1.418866667

PROJECT : Analysis Data

- unite_imu_method:="linear_interpolation"

Interpolate-wall1	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.3475	1.0376	0.9058	2.0616	1.3676
2	0.3445	1.0576	0.9111	2.0694	1.3894
3	0.3572	0.9858	0.9085	2.0503	1.41106
mean	0.3497333333	1.027	0.9084666667	2.060433333	1.389353333

Interpolate-wall2	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.3735	1.0647	0.9427	2.031	1.429
2	0.371	1.061	0.938	2.0414	1.4585
3	0.3702	1.0588	0.938	2.0452	1.4327
mean	0.3715666667	1.0615	0.9395666667	2.0392	1.440066667

Interpolate-wall3	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.326678	1.063852	0.889689	2.071408	1.460546
2	0.313045	1.053832	0.872837	2.0766	1.440086
3	0.330757	1.074666	0.875379	2.087992	1.438676
mean	0.3234933333	1.064116667	0.8793016667	2.078666667	1.446436

- no IMU

noIMU-wall1	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.339586	1.047737	0.880593	2.087087	1.42688
2	0.329744	1.044299	0.865806	2.071785	1.445653
3	0.329744	1.050129	0.84809	2.070907	1.452248
mean	0.3330246667	1.047388333	0.8648296667	2.076593	1.441593667

noIMU-wall2	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.38433	1.04596	0.832481	2.041534	1.385435
2	0.383914	1.032341	0.814647	2.073051	1.383326
3	0.387586	1.021741	0.819004	2.087292	1.455907
mean	0.3852766667	1.033347333	0.822044	2.067292333	1.408222667

noIMU-wall3	วัตถุสังเกต				
measure round	1	2	3	4	5
1	0.36069	0.996428	0.878089	2.05597	1.465141
2	0.345228	1.030372	0.876878	2.065144	1.459622
3	0.3501	1.046344	0.883419	2.039433	1.427035
mean	0.352006	1.024381333	0.879462	2.053515667	1.450599333

RESULTS : RTAB - Map

Reference Objects

วัตถุสังเกต		
Red Picture (left side)	1	0.34
Black TV screeen (middle)	2	0.965
cabinet (middle)	3	0.8
Door (right side)	4	2.05
middle Table (rigth side)	5	1.35

Absolute Error

	Copy - mean of all	Interpolate - mean of all	noIMU - mean of all
	0.3579225556	0.3482644444	0.3567691111
	1.033481111	1.050872222	1.035039
	0.7903644444	0.9091116667	0.8554452222
	2.097122222	2.059433333	2.065800333
	1.425272222	1.425285333	1.433471889
S.D. of Err	0.0294	0.0462	0.0309

Percent Error

	error (%)		
	Copy - mean of all	Interpolate - mean of all	noIMU - mean of all
	5.136	2.4015	4.8134
	6.8533	8.5196	7.0038
	1.2117	12.7682	6.6985
	2.2725	0.4591	0.7678
	5.4245	5.4254	5.9977
sum of %Err	20.898	29.5738	25.2812

From the experiments with the RTAB-Map algorithm by adjusting parameters in three different ways

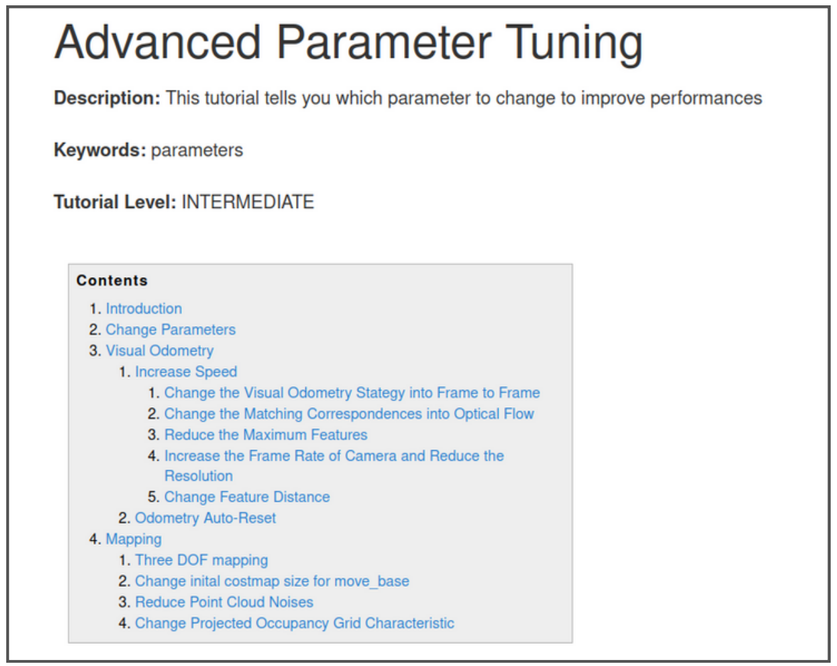
- unite_imu_method:="copy"
- unite_imu_method:="linear_interpolation"
- no IMU

We found that adjusting it to *unite_imu_method:="copy"* yielded the best results. By analyzing the Standard Deviation (S.D.) and Percent Error values, we observed that this configuration produced the lowest errors.

Next Plan & Obstacle

Next Plan

- **RTAB-MAP :**



Advanced Parameter Tuning

Description: This tutorial tells you which parameter to change to improve performances

Keywords: parameters

Tutorial Level: INTERMEDIATE

Contents

1. Introduction
2. Change Parameters
3. Visual Odometry
    1. Increase Speed
        1. Change the Visual Odometry Stategy into Frame to Frame
        2. Change the Matching Correspondences into Optical Flow
        3. Reduce the Maximum Features
        4. Increase the Frame Rate of Camera and Reduce the Resolution
        5. Change Feature Distance
    2. Odometry Auto-Reset
4. Mapping
    1. Three DOF mapping
    2. Change inital costmap size for move_base
    3. Reduce Point Cloud Noises
    4. Change Projected Occupancy Grid Characteristic

Image sources : *https://www.neobotix-robots.com/products/robot-software/ros*

- **Installation SSL-SLAM and ORB-SLAM**

Obstacle

- *Installation of the SSL-SLAM algorithm, there are currently installation issues. This has affected the operation of RTAB-Map, making it impossible to open. We are currently looking for a solution.*

LIFE at NECTEC

DR. Rungroj Jintamethasawat

Spectroscopic and Sensing Devices Research

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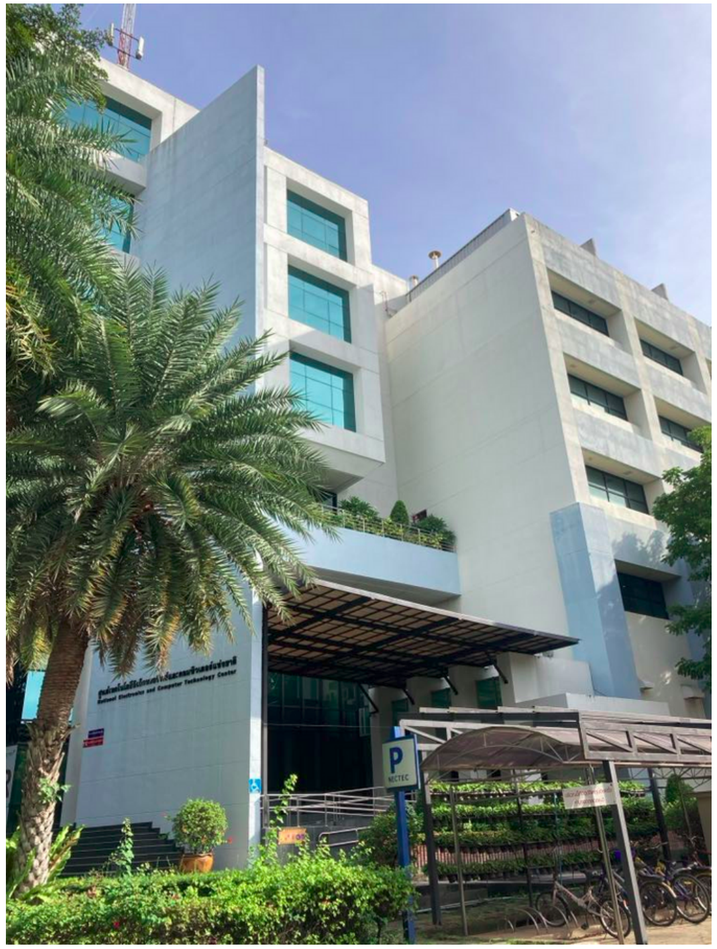

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THANK YOU!

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