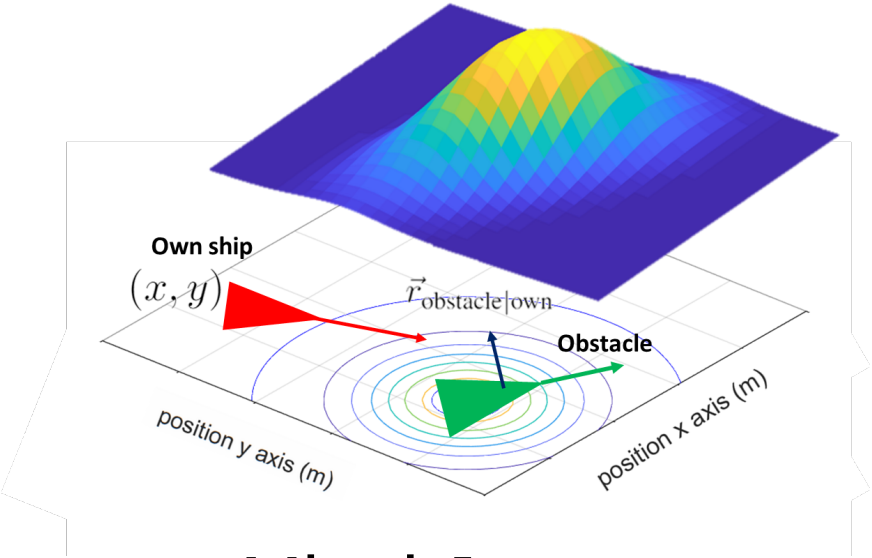
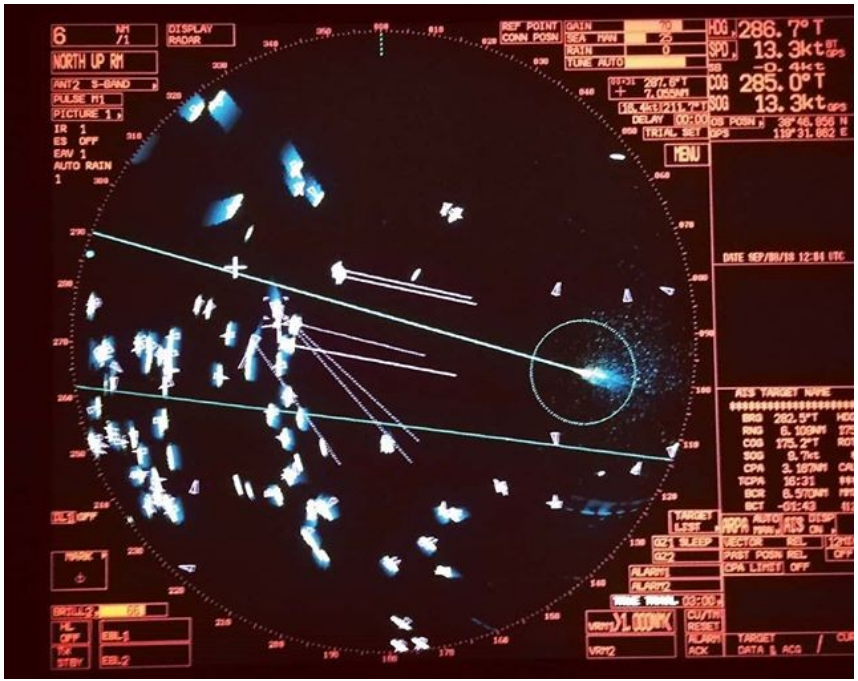
Obstacle Detection and Abnormality Monitoring for Collision Avoidance of ASV



Mingi Jeong

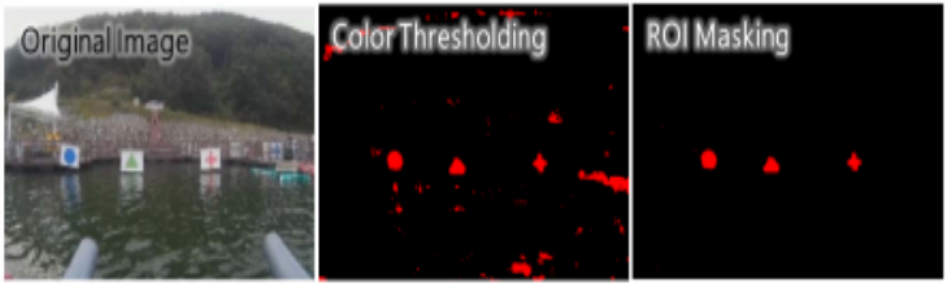
Introduction

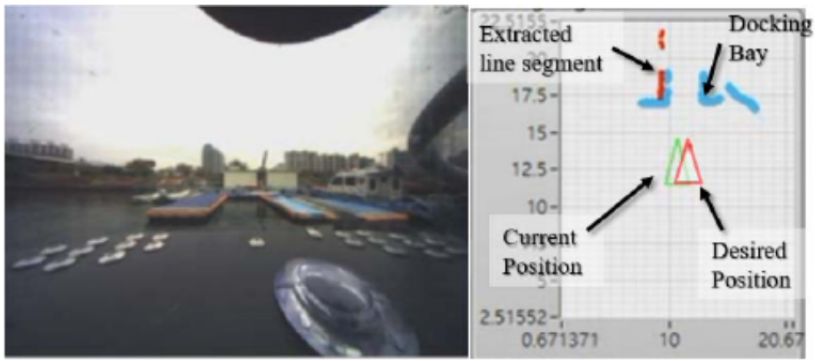


Literature Review

Marine domain

- Sensor fusion: main sensor as a camera and auxiliary as a LiDAR
  (Lee et al. 2017, Vision and 2D LiDAR based Autonomous Surface Vehicle Docking for Identify Symbols and Dock Task in 2016 Maritime RobotX Challenge)

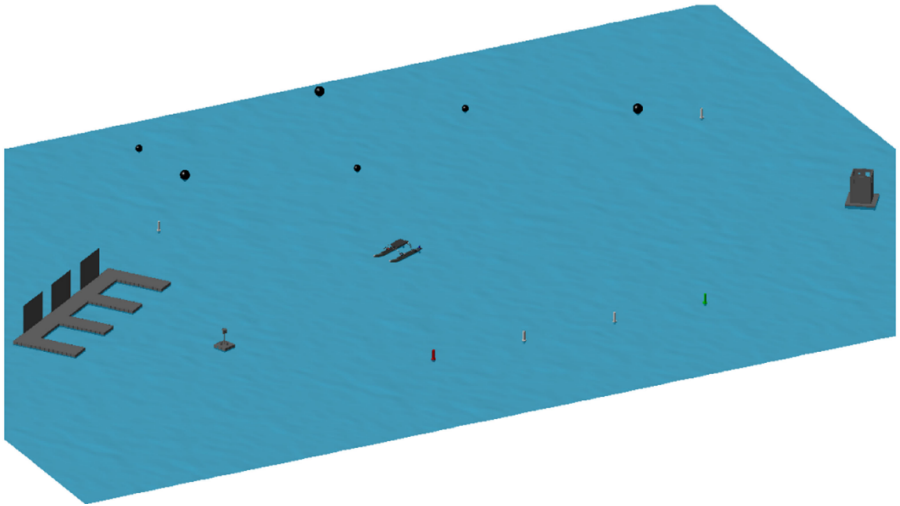


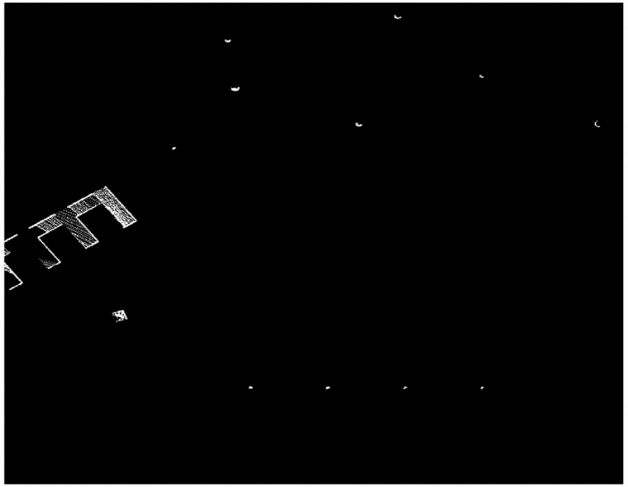


Literature Review

Marine domain

- Sensor fusion as camera with LiDAR
- **LiDAR obstacle detection with simulation**
  (Thompson et al. 2019, Efficient LiDAR-Based Object Segmentation and Mapping for Maritime Environments)



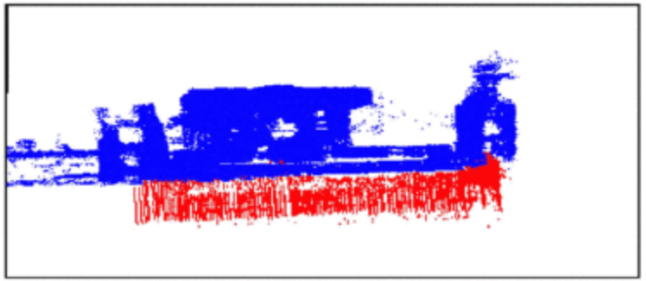


Literature Review

Marine domain

- Sensor fusion as camera with LiDAR
- LiDAR obstacle detection with only simulation
- **LiDAR mainly used for mapping**
  (Papadopoulos et al. 2011, 3D-surface reconstruction for partially submerged marine structures using an autonomous surface vehicle)

(a) Picture of the front part of the structure



(b) Above- and below-water parts of marine structure, point cloud-based map. In red color below water part, in blue color above water part.

Problem Statement

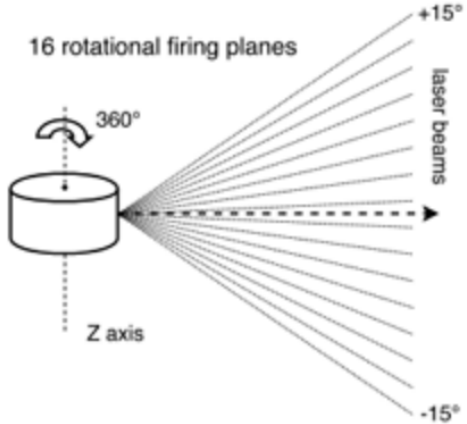
Ideal	This project's approach
Two categorized obstacles: Static (buoy), Dynamic (other boat, swimmer)	Swimmer not swimming but walking indoors
Compatible with our LiDAR model Velodyne VLP-16 and simple (+ROS)	• Velodyne_height • DATMO • Multi-KF tracker
Open-source, fast, and efficient algorithm	
3D point clouds measurement	2D laser scan + 3D point clouds

Experiment Setup

- **Object**: Mingi Jeong
- **Goal**: Detect and track the object
- **Environment**: Sudikoff building 2nd floor
- **Metric**: CPA, position, detection and tracking capability

Sensor Model and H/W Configuration

- Velodyne VLP 16 Lidar
- ROS Kinetic on Ubuntu 16.04
- Intel Core i9 CPU, 32GB RAM



Assumption

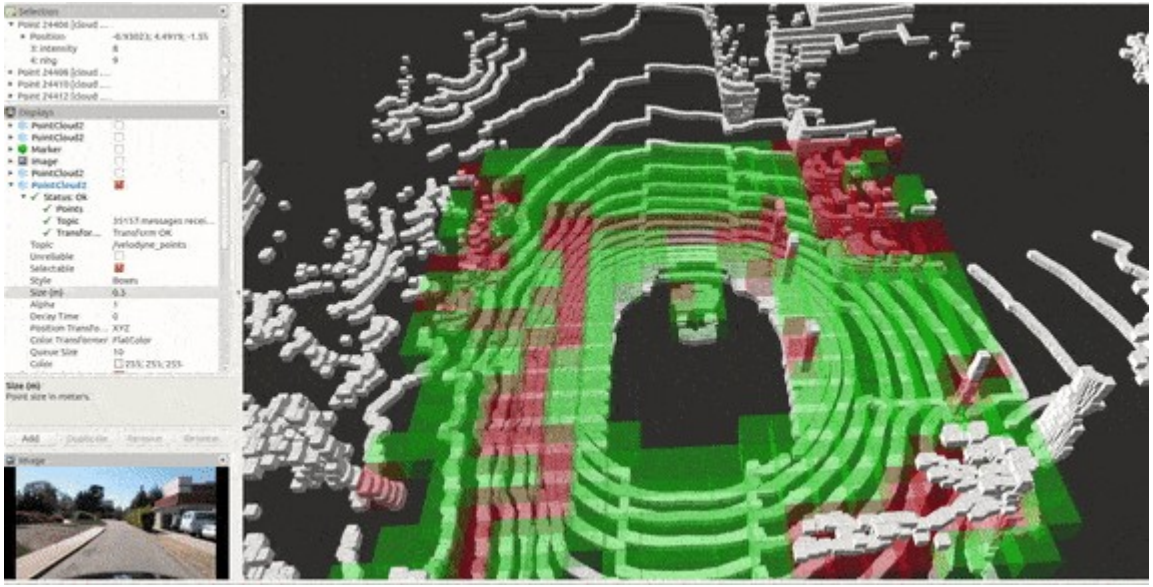
- Object detection and movement tracks in 2D space
  2D State and distance from sensor (0,0)

$$(x, y, \theta)$$

- Map reference frame = sensor reference frame
  ROS tf static_publisher

Method

1. **Velodyne_height_map**

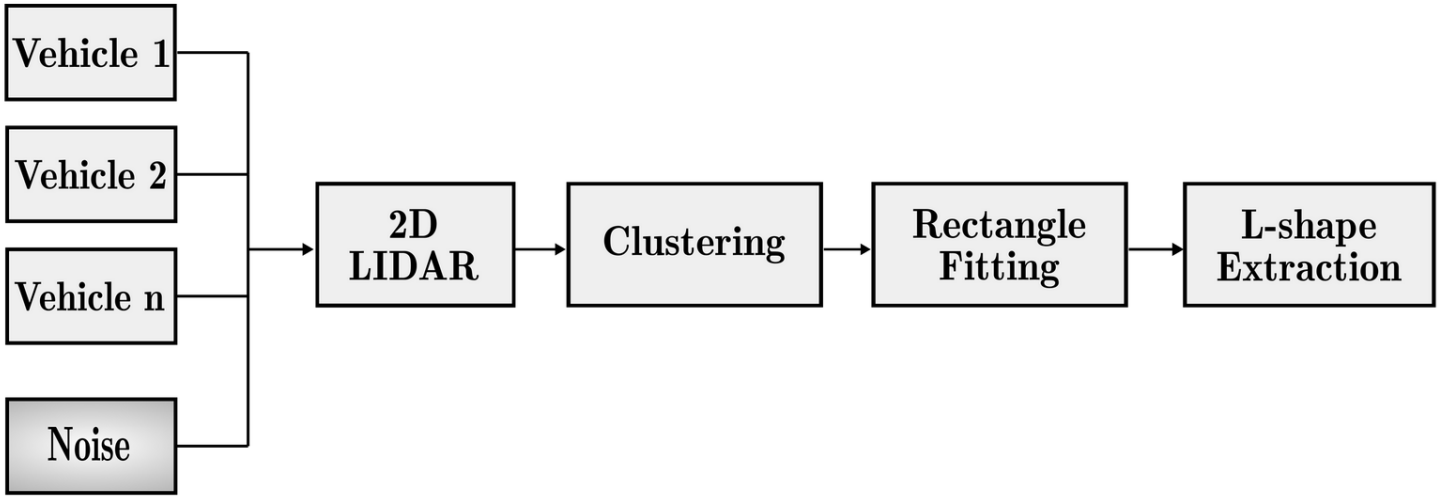


Source: https://wiki.nps.edu/pages/viewpage.action?pageId=925958215

Method

2. DATMO

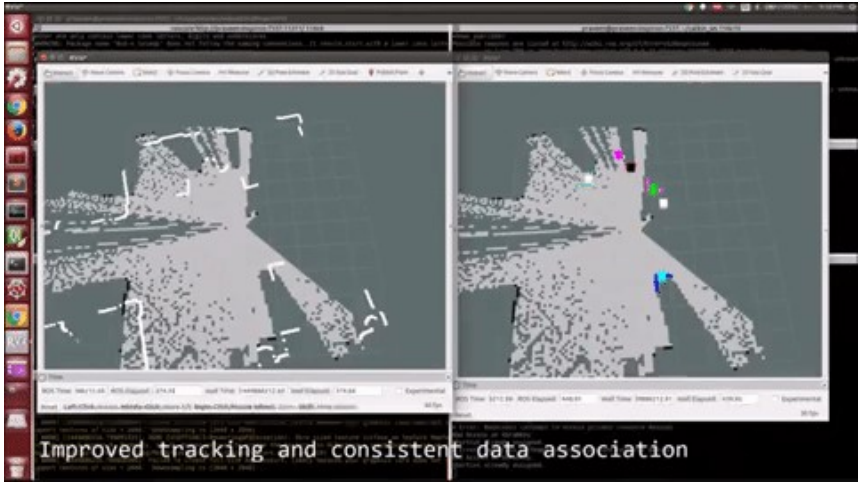
- UKF (Unscented Kalman Filter)



Method

3. Multi KF tracker

- **K-D tree** based point cloud processing for object feature detection from point clouds
- **Unsupervised k-means clustering** based on detected features and refinement using **RANSAC**
- Stable tracking (object ID & data association) with an ensemble of Kalman Filters
- Robust compared to k-means clustering with mean-flow tracking



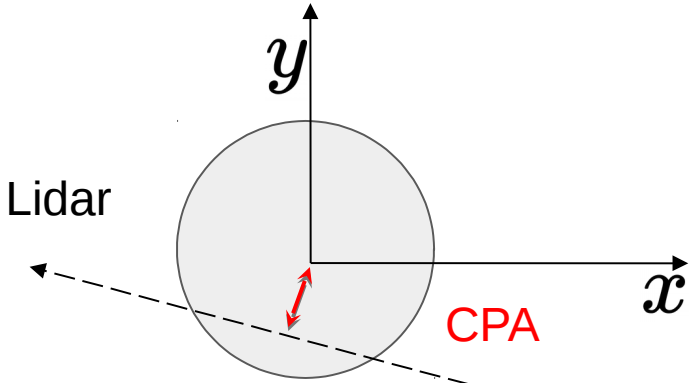
https://github.com/praveen-palanisamy/multiple-object-tracking-lidar

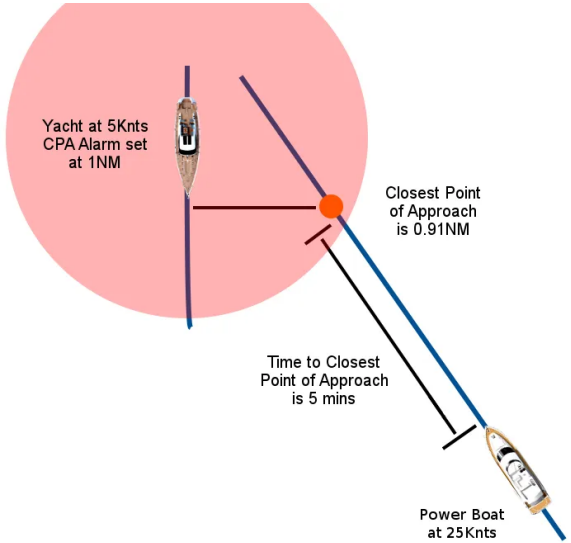
Method

Summary

	Velodyne_height	DATMO	Multi-KF tracker
Datainput	3D pointcloud	2D laserscan	3D pointcloud
Topic for main use	velodyne_points	scan	filtered_cloud
Output	Grid-based clear and obstacle data	Bounding box around the obstacle	MarkerArray
Obstacle information	Not specific	Not specific	position, orientation, etc

CPA calculation -1



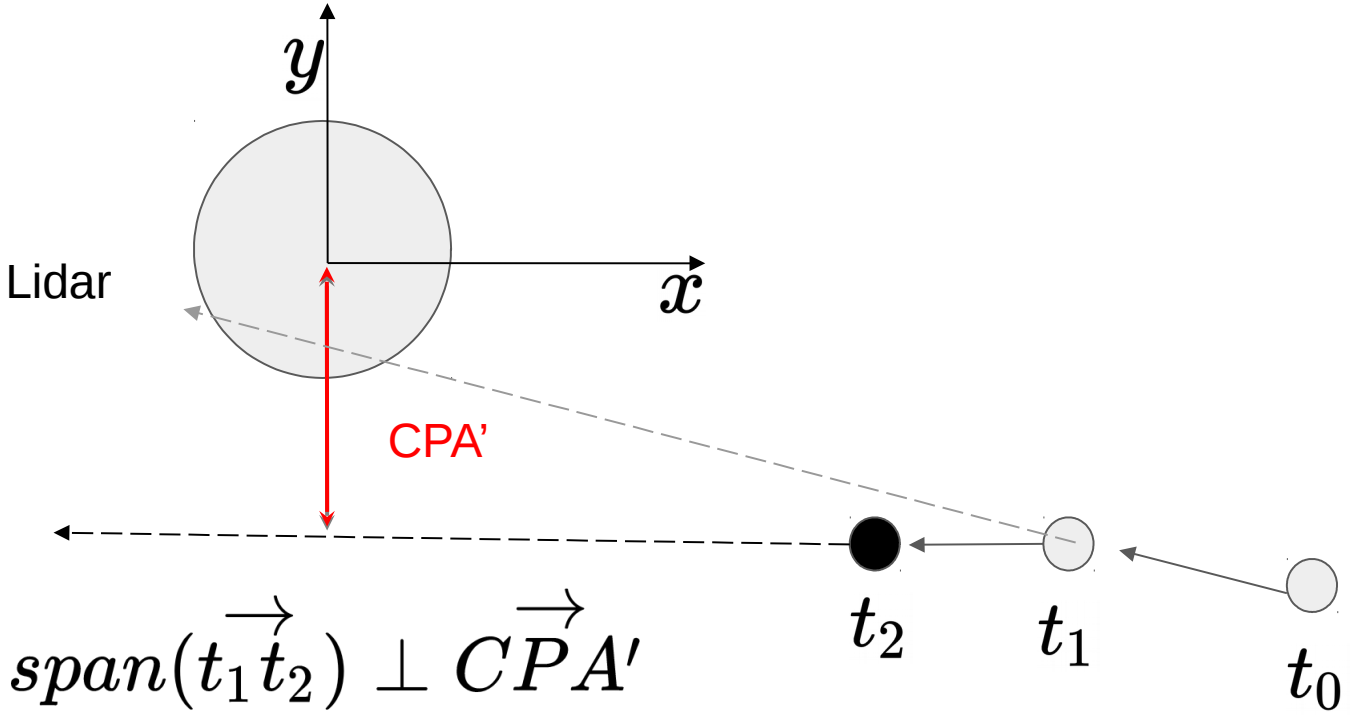


$$span(\overrightarrow{t_o t_1}) \perp \overrightarrow{CPA}$$

t_1

t_0

CPA calculation -2



Analysis

Data collection

Case 1
Walk far-away and back

Case 2
Approach

Case 3
Running

Case 4
Drunken driving

Velodyne height

DATMO

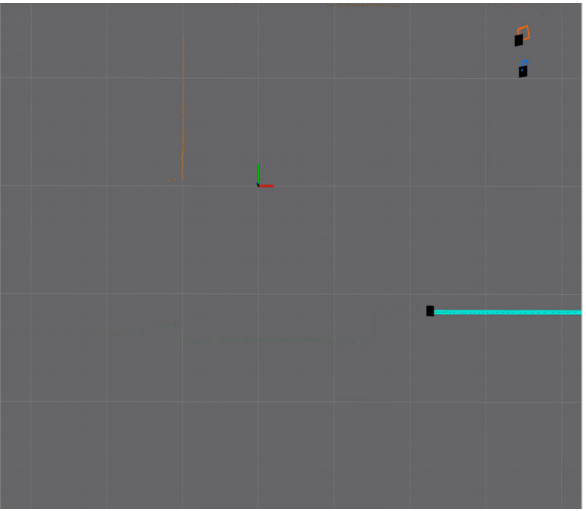
Multi KF

Qualitative analysis

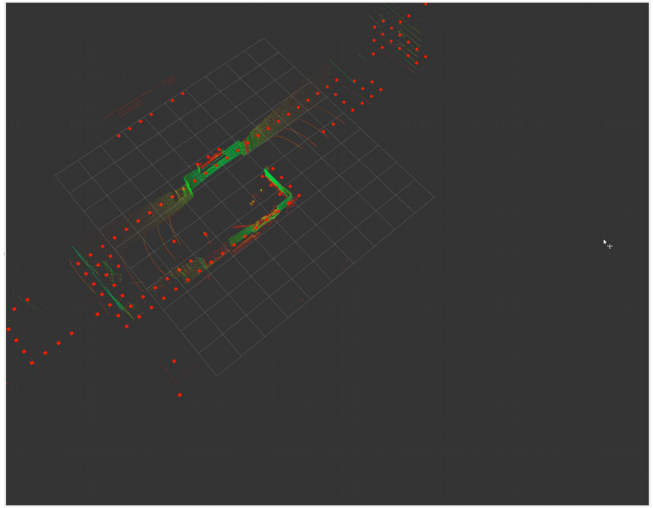
Quantitative analysis

Qualitative Analysis – case2

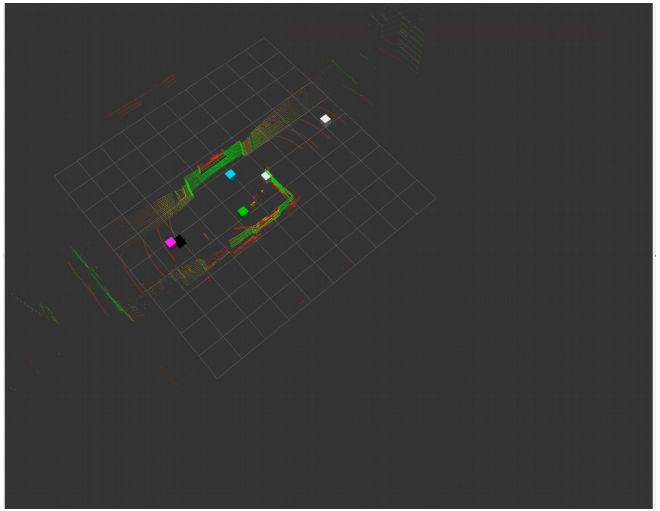
Datmo



Velodyne_height

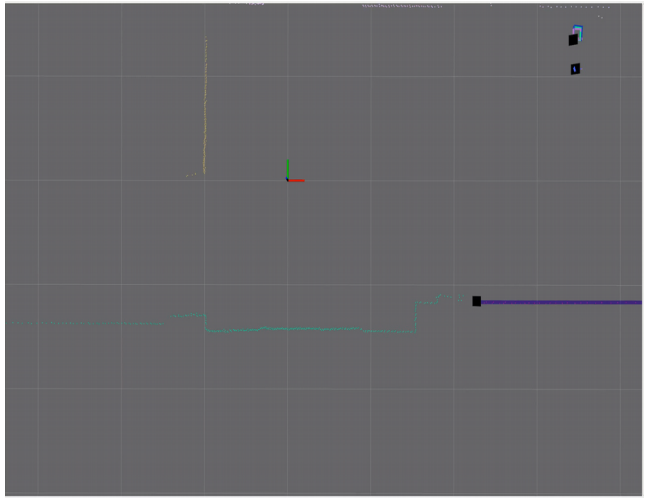


Multi-kf

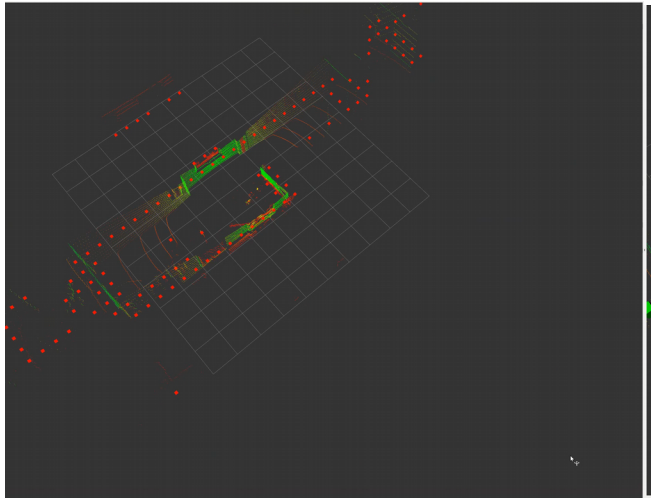


Qualitative Analysis – case3

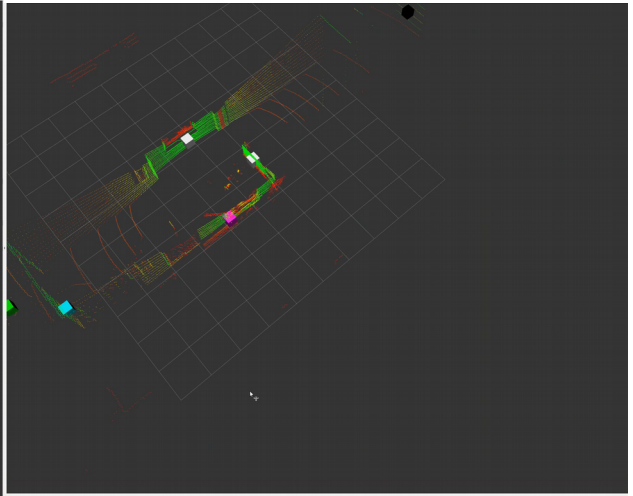
Datmo



Velodyne_height

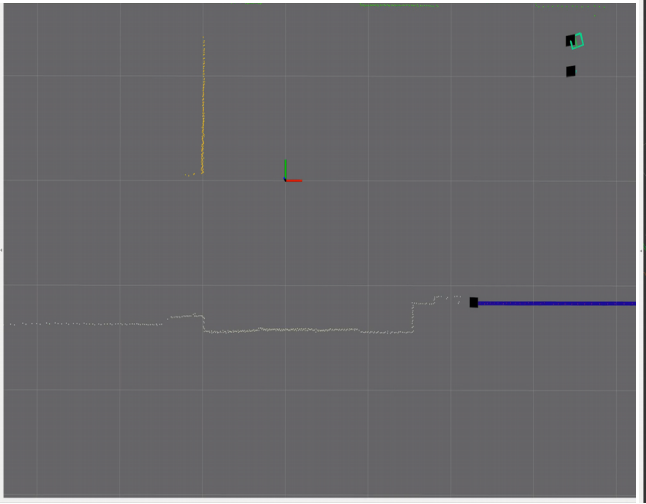


Multi-kf

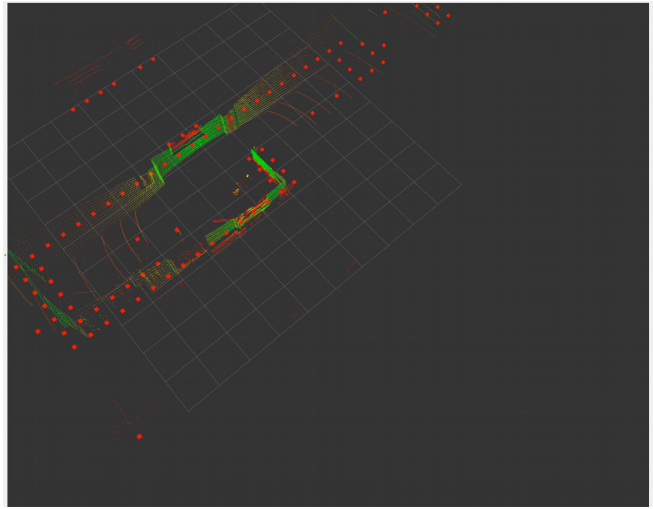


Qualitative Analysis – case4

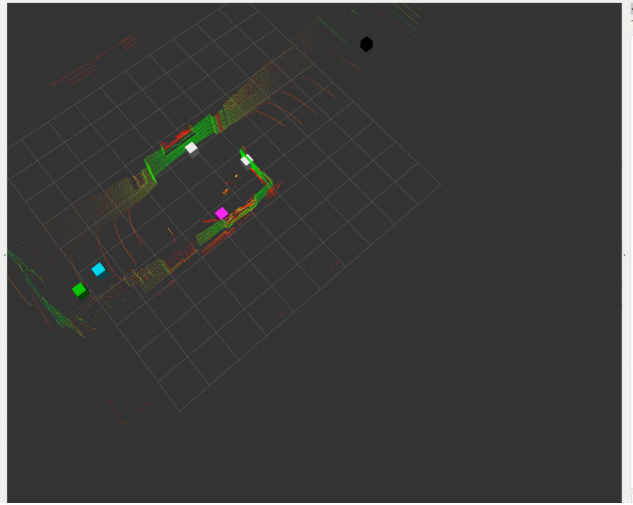
Datmo



Velodyne_height

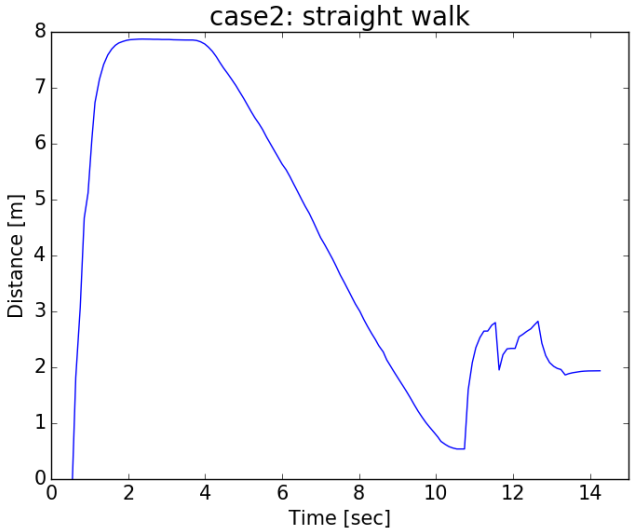


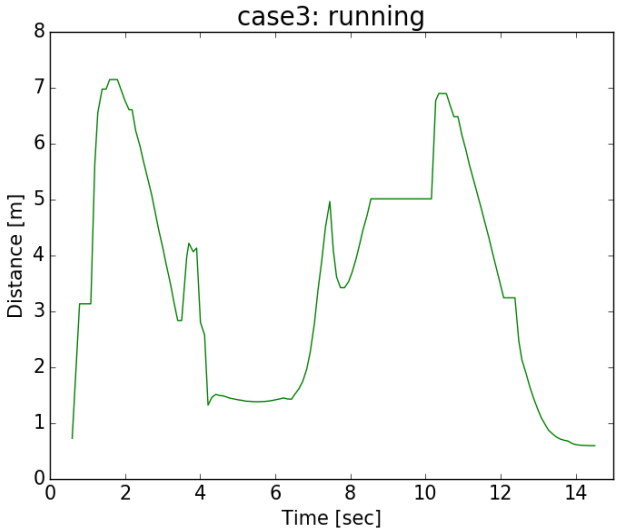
Multi-kf

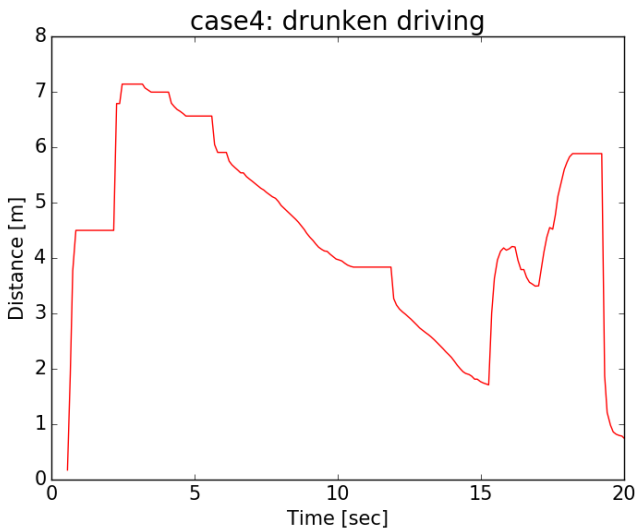


Quantitative Analysis

- Distance monitoring

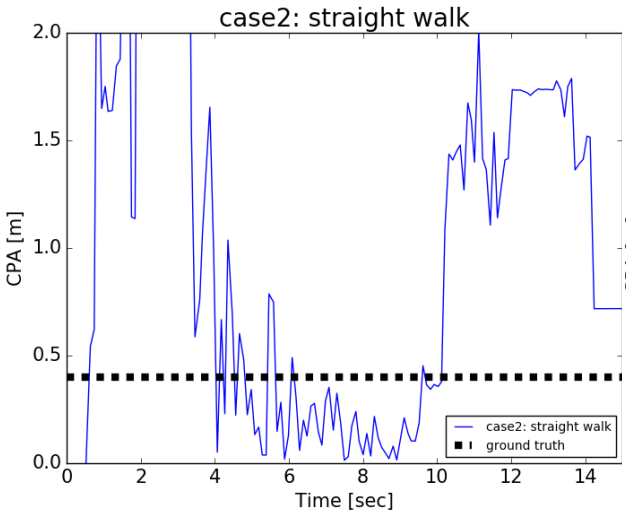


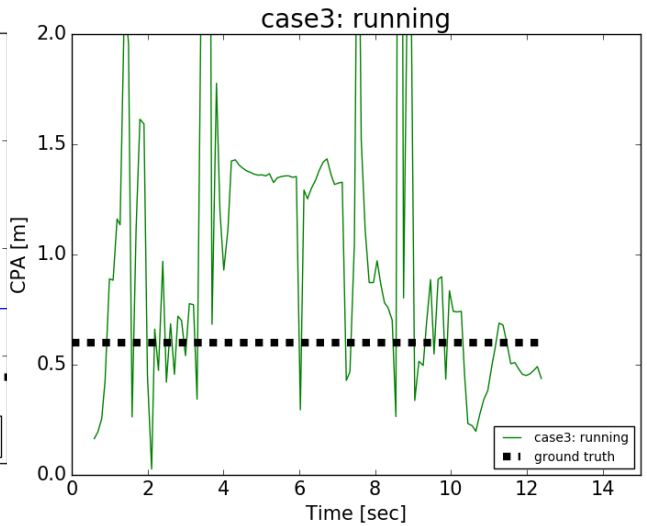


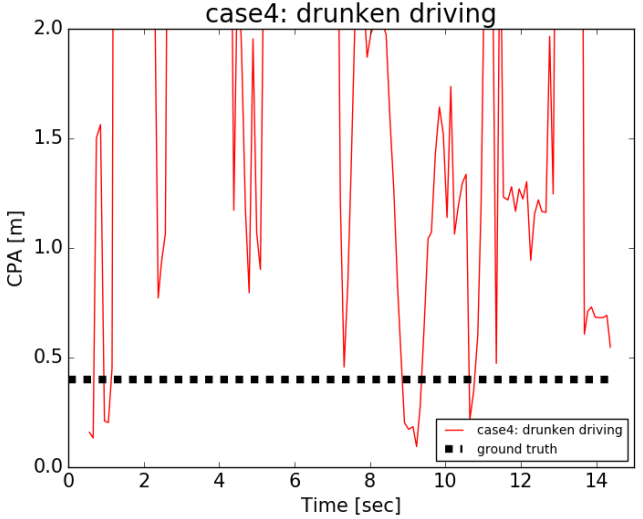


Quantitative Analysis

- Predicted CPA monitoring







Ground truth: 0.4 m
Sensor: 0. 0.6496 m

Ground truth: 0.6 m
Sensor: 0.4375 m

Ground truth: 0.4 m
Sensor: 0.5476m

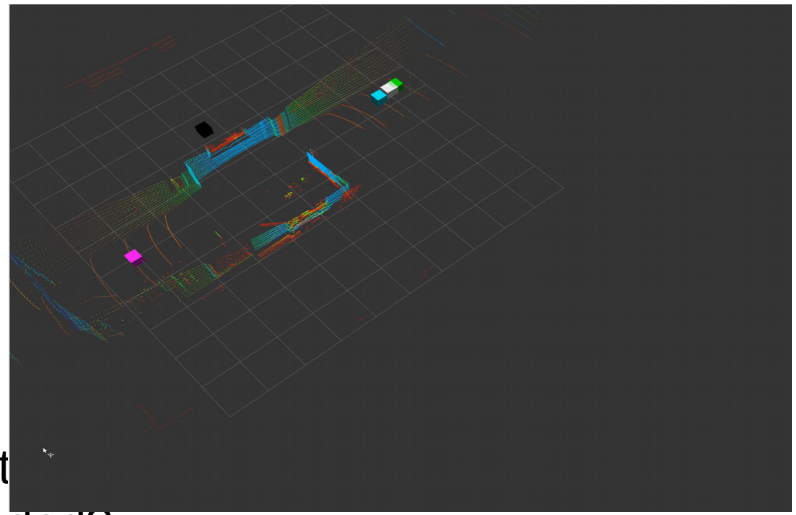
Metrics

- Detection of swimmer
- Not following in real-time / Abnormality

- CPA prediction
- **Accuracy**
  - DATMO > Velodyne Height > Multi-KF tracker
- **Real-time response**
  - Velodyne Height > DATMO > Multi-KF tracker
- **Feature tracking**
  - DATMO > Multi-KF tracker >> Velodyne Height (no recognition)

Limitations

- **Transform** 2D Scan to 3D point cloud (multi kf tracker)
  - Why not 3D point clouds directly? ⇒ video



- Not fully quantitat
- Another filter needed?

Conclusion and Future Works

- **Marine domain** obstacle detection
- **Sensor fusion**: RGBD camera + LiDAR + RADAR
- Integration with **risk vector-based real-time obstacle avoidance**