

CHAPTER 1 – INTRODUCTION

1.1 Background

SDC (Self-Driving Car) or also known as AV (Autonomous Vehicle) is a vehicle that can sense the environment around it, compensate for uncertainties from the environment, and move safely with little or no human intervention (Taeihagh and Lim, 2019). SDC is required as 90% of automotive crashes are from human errors and reducing this risk level is required (*On the Road to Full Autonomy: Self-Driving Cars Will Rely on AI and Innovative Memory*, no date). SDC of the Level 5 Automation according to the driving mode classification by SAE (Society of Automotive Engineers) International, an automotive standard developing organization, would be a great solution to reduce these risks (Thrun, 2010). Even though Level 5 Automation requires a massive amount of data, the so-called fully automated self-driving vehicle will be able to perform all the driving tasks in all circumstances and no human interaction is required (Khayyam *et al.*, 2020). In SDC, the process from when the vehicle senses its environment up to producing the motion is called the AD (Autonomous Driving) Stack which consists of 1) Sensing, 2) Computing, and 3) Actuation. The second process, computing is considered the most complex process as it requires data from the sensing process to produce planning on how the vehicle will move (Kato *et al.*, 2018).

As SDC requires a lot of data, it needs a lot of sensors to only perceive its surroundings. Several sensors are commonly used in SDC. There are LiDAR (Light Detection and Ranging), camera, radar, sonar, and GNSS (Global Navigation Satellite System). LiDAR and GNSS are usually used for localization which is to locate the exact position of the vehicle on a map. Camera and radar are used for object detection for obstacle avoidance (Kato *et al.*, 2018). Different SDC companies use different sets of sensors. Waymo by Google uses cameras, LiDAR, radar, and microphones. Tesla uses ultrasonic sensors, radars, and 2D cameras. Mobileye by Intel uses only cameras (Granath and Lambert, 2020).

The Autoware Foundation is a non-profit organization that provides open-source projects related to self-driving technology. In 2015, Shinpei Kato, a professor at Nagoya University, Japan, started Autoware.AI based on a self-driving project in the university. Now, Autoware.Auto, an upgraded project from Autoware.AI, is managed by an open-source community, applies the best and up-to-date software engineering practices, and detailed documentation. Autoware.Auto initially is used for Autonomous Valet Parking and Autonomous Depot Maneuvering using LiDAR, camera, radar, and GNSS (*Autoware.Auto*, no date a).

AMR (Autonomous Mobile Robot) is a robot that is capable of navigating an environment without external aid and moving in that environment independently. AMR is built like humans, as they should have the ability to make their own decisions and perform an action through its decision. Specifically, AMR is a robot that can 1) perceive or sense its environment, 2) make decisions based on the data it sensed, and 3) actuate a movement to reach its goal. Through these three characteristics of operation, AMR is similar to the basic operation of an SDC. Thus, the overall aim of this thesis is to develop a scaled-down SDC based on the architecture of Autoware.Auto onto an AMR using RTK-GNSS (Real-Time Kinematic), LiDAR, and camera.

1.2 Thesis Problem

In this thesis project, there are several issues to be addressed:

1. The localization of RTK-GNSS an outdoor map with the help of IMU and encoder for robot odometry.
2. Object detection using LiDAR and ultrasonic sensors for obstacle avoidance.
3. Path planning of the robot on an outdoor map.

1.3 Significance of Study

The study is significant for four reasons, which are:

1. The implementation of ROS (Robot Operating Software) 2, an upgraded version of ROS 1 which is the platform used in Autoware.Auto.
2. The implementation of RTK-GNSS outdoor localization with help of IMU and encoder for robot odometry and LiDAR as well as ultrasonic sensors for object detection.

3. The implementation of Teensy 4.1 and MicroROS that is compatible with ROS 2.
4. The concept of scaling down an SDC into an AMR to achieve the same result as an SDC.

1.4 Research Questions

Question #1: How similar is the scaled-down SDC, AMR to a real SDC?

Question #2: What is the reliability of RTK-GNSS in outdoor localization and how reliable is LiDAR and ultrasonic sensor for object detection?

Question #3: What is the reliability of IMU and odometry in localization and feedback for the actuation of the robot?

1.5 Hypothesis

Hypothesis #1: The scaled-down SDC, AMR will be similar to the real SDC with more and higher quality sensors equipped.

Hypothesis #2: RTK-GNSS will have high reliability and high accuracy in outdoor localization and LiDAR will act as the second layer for outdoor localization.

Hypothesis #3: IMU and odometry will provide less-to-none contribution in localization as RTK-GPS and LiDAR are already used for localization, IMU and odometry will be reliable to provide feedback for the control of the actuation.

1.6 Thesis Structure

The book documenting this thesis project will consist of several chapters with a brief description as follows.

Chapter 1 - Introduction

This chapter gives brief background, objectives, problems, scope, limitations, significance of study, and structure of this thesis.

Chapter 2 - Literature Review

This chapter contains information on all components and theories needed to develop the navigation module, as well as a short review of previous related works.

Chapter 3 - Research Methodology

This chapter discusses the methods and steps taken to achieve the objective of the project.

Chapter 4 - Results and Discussions

This chapter contains all data and results acquired while working on this project as well as further analysis, quantitatively and qualitatively, on the data and results.

Chapter 5 - Conclusions and Recommendations

This chapter provides conclusions of this project as well as recommendations to further fine-tune and/or develop the system.