A Design Proposal of Software to Support Operation of a Driverless Car

Word count: 548

1. Project Summary

This document outlines design and rationale for three operations to support Perception, Planning and Localisation systems of a driverless vehicle, also known as autonomous vehicle (AV). Terms used to carry out research for the development of this software were “autonomous vehicle systems”, “path planning systems autonomous vehicles”, “localisation system autonomous vehicles” and “object detection autonomous vehicles”. The scope of this assignment assumes the vehicle is at least SAE Level 4 (SAE, 2021).

2. High-level System Overview

The system requirements for an AV are:

1. **Perception System**: responsible for processing inputs from sensors.
2. **Control System**: responsible for core vehicle functions such as braking, accelerating and steering.
3. **Localisation System**: responsible for communication with navigation systems including communicating vehicle position.
4. **Planning System**: responsible for orchestrating the behaviour of the vehicle based on inputs from Perception and Localisation systems.
5. **System Management**: responsible for vehicle management including user input processing, fault reporting and logging.

The above architecture has been proposed and described by Jo, et al. (2014), with multiple subcomponents to support the overarching systems. The scope of this assignment covers three suboperations of an AV:

1. The GPS-IMU Localisation operation of Localisation system
2. The Object Detection (OD) operation of Perception system

3. The Path Planning (PP) operation of Planning system

All three operations are closely linked, as PP requires real-time position information and OD to obtain and maintain a safe trajectory of the AV (Reda et al., 2024), and vehicle localisation and OD interact to ensure a match between expected and actual surroundings (Reddy, 2019). OD in particular is a mission-critical feature of an AV, and recent advances using metamorphic testing are making vehicles safer (Zhou & Sun, 2019).

Figures 1 and 2 cover Use Cases and Classes of all three operations within an AV system.

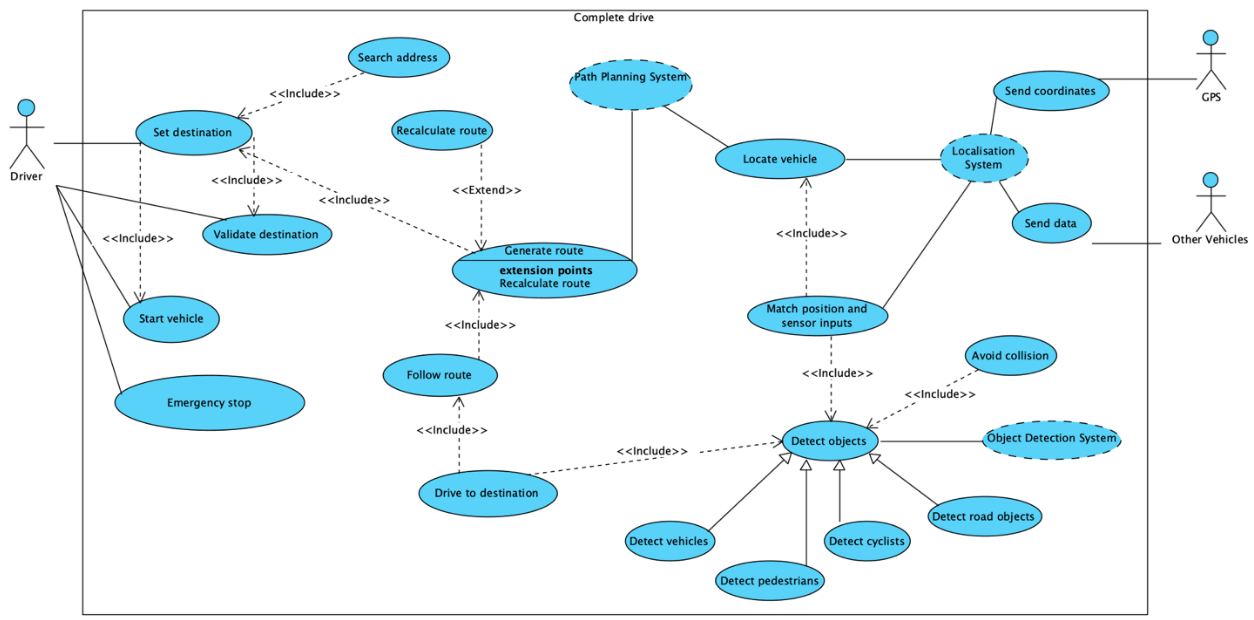

Figure 1. Use Case diagram of selected operations to support the system of an AV.

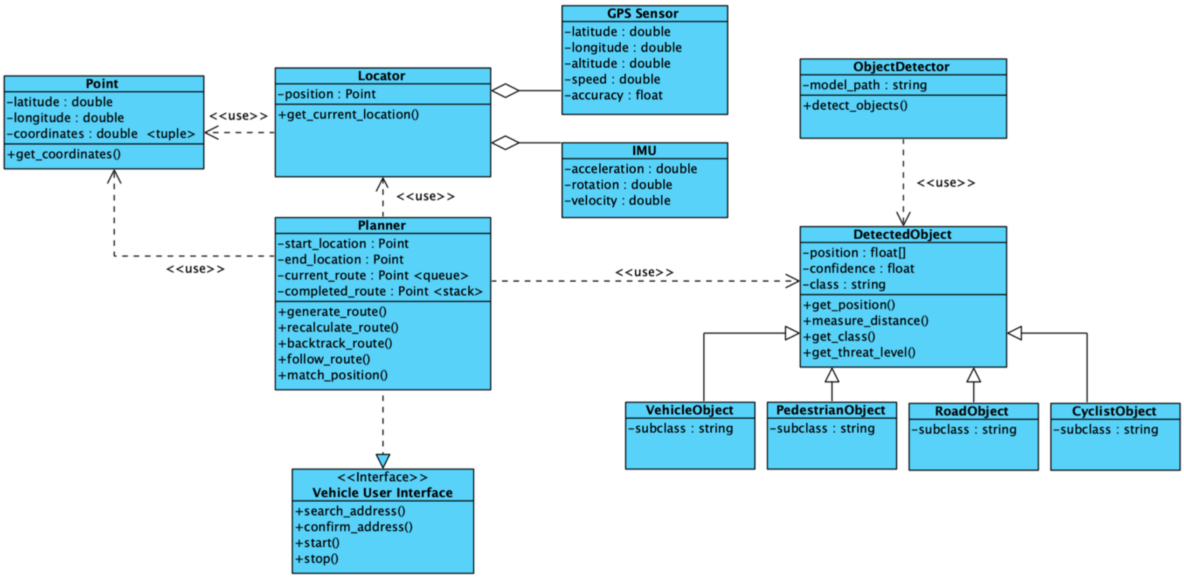

Figure 2. Class diagram of selected operations to support the system of an AV.

3. GPS-IMU Localisation operation

A GPS system takes inputs from a satellite system and the information is fused with Inertial Measurement Unit (IMU) readings to increase precision. This information is critical for navigation and is also used for a priori map-based localisation (Yurtsever et al, 2020). Additionally, an AV must locate itself within the environment it is operating in with accuracy of minimum 0.1m in residential areas (Reid et al., 2019). Figure 3 is a State diagram of GPS-IMU Localisation operation.

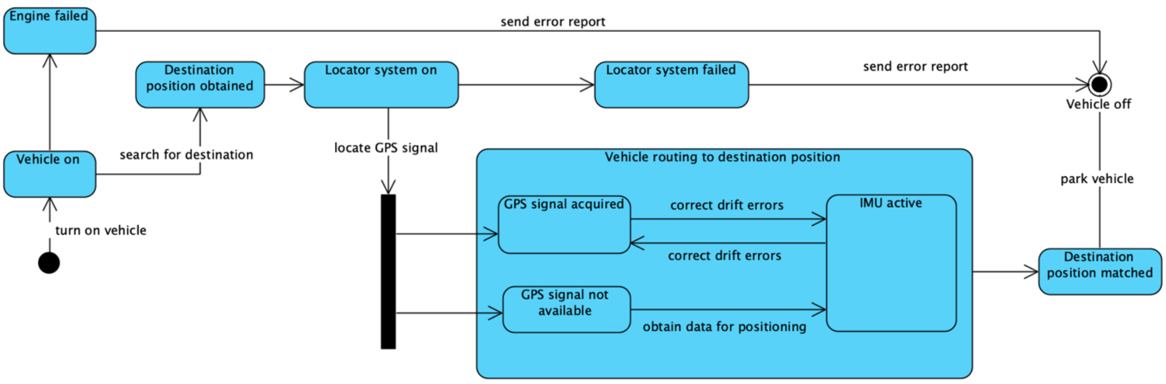

Figure 3. State diagram of GPS-IMU Localisation operation to support the system of an AV.

4. Object Detection (OD) operation

The OD system receives inputs from sensors that detect position of objects and classifies objects based on their properties (Balasubramaniam & Pasricha, 2022). The scope of this operation excludes object tracking, and road/lane detection, which require separate approaches. Objects detected at any one given point will be stored in a *dictionary* format with the following keys: object class (*string*), object position (*array*), prediction confidence score (*float*). Figure 4 is an Activity diagram of the OD operation.

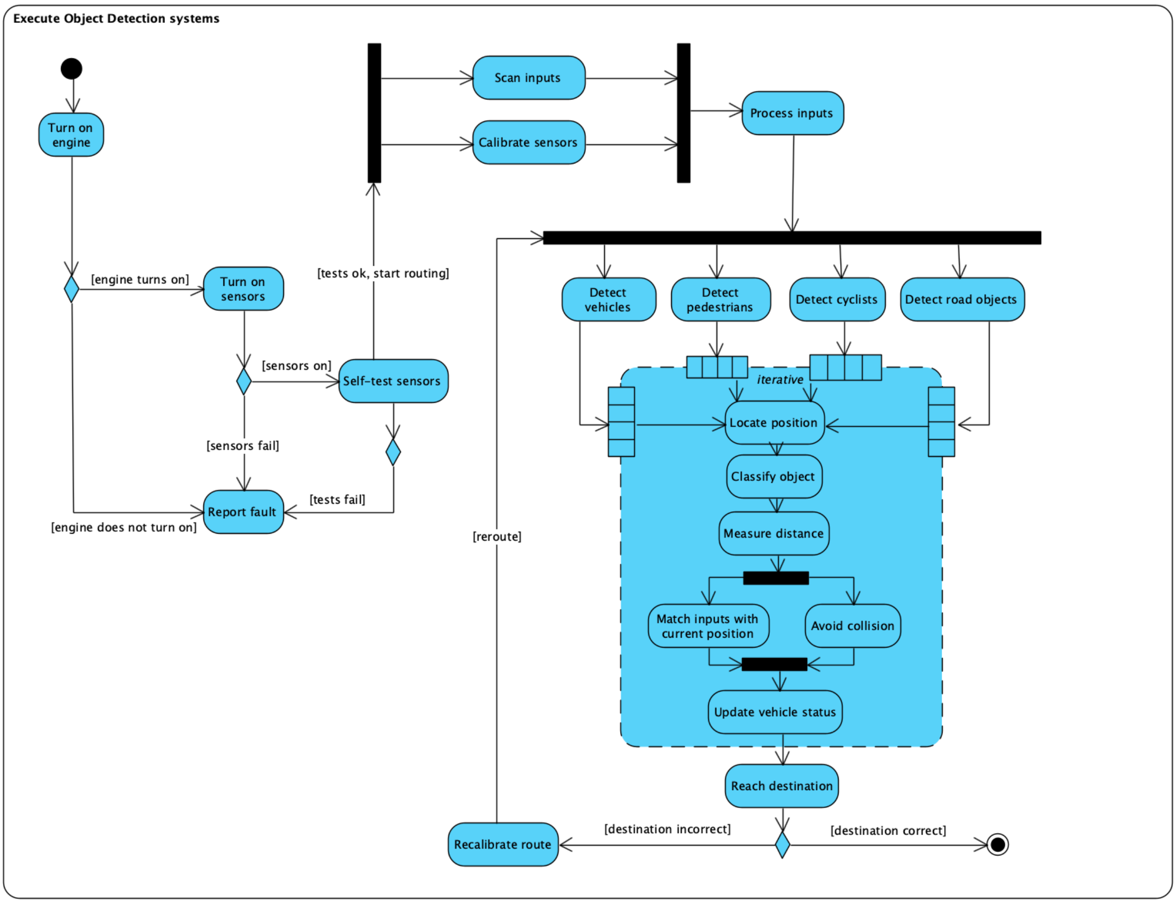

Figure 4. Activity diagram of the OD operation to support the system of an AV.

5. Path Planning (PP) Operation

PP system is required to firstly, generate the route from starting point to destination. In this proposed design, the routing uses the *queue* data structure to follow directions generated. In circumstances where an invalid turn has taken place, system needs to backtrack. A *stack* structure is appropriate here for returning to previous navigation point. Finally, the PP system ensures the vehicle navigates the route safely, avoiding collisions (Reda et al., 2024). Figure 5 is a Sequence diagram of the PP operation.

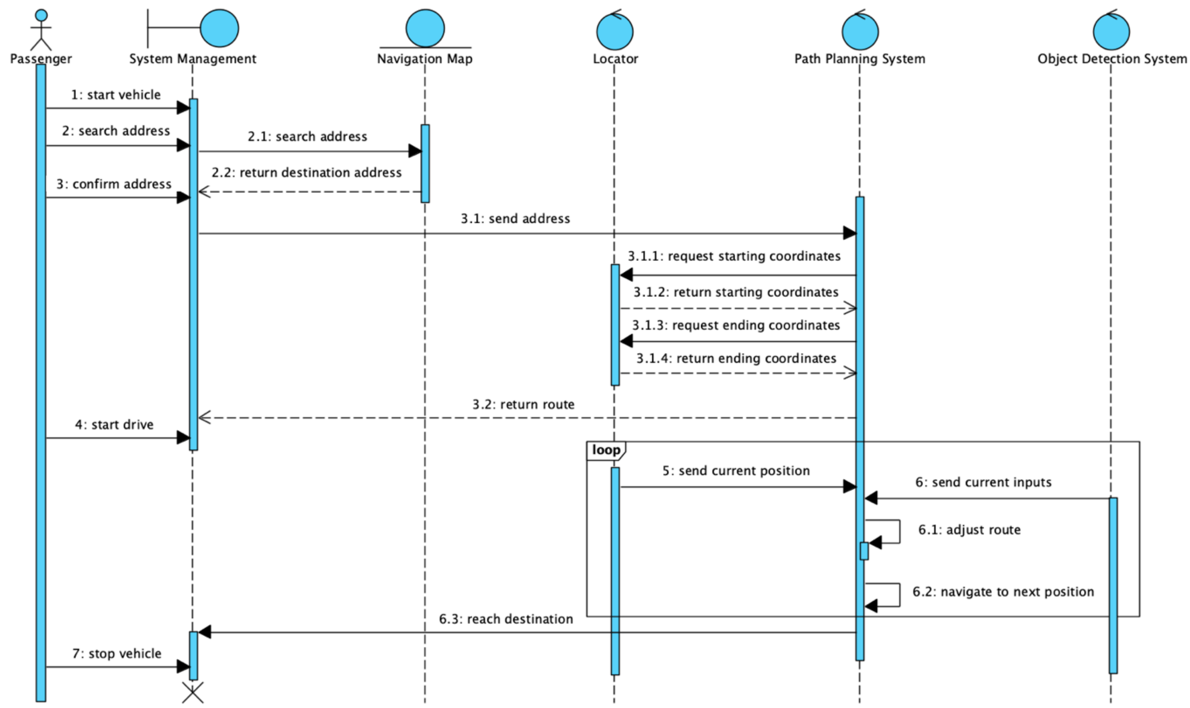

Figure 5. Sequence diagram of PP operation to support the system of an AV.

References:

Balasubramaniam, A. & Pasricha, S. (2022) Object detection in autonomous vehicles: Status and open challenges. *arXiv preprint arXiv*:2201.07706.

Jo, K., Kim, J., Kim, D., Jang, C. & Sunwoo, M. (2014) Development of autonomous car—Part I: Distributed system architecture and development process. *IEEE Transactions on Industrial Electronics*, 61(12): 7131-7140.

Reda, M., Onsy, A., Haikal, A.Y. & Ghanbari, A. (2024) Path planning algorithms in the autonomous driving system: A comprehensive review. *Robotics and Autonomous Systems,* 174: 104630.

Reddy, P.P. (2019) Driverless car: software modelling and design using Python and Tensorflow.

Reid, T.G., Houts, S.E., Cammarata, R., Mills, G., Agarwal, S., Vora, A. & Pandey, G. (2019) Localization requirements for autonomous vehicles. *arXiv preprint arXiv:*1906.01061.

SAE (2021) SAE Levels of Driving Automation™ Refined for Clarity and International Audience. *SAE*. Available at: https://www.sae.org/blog/sae-j3016-update [Accessed 25 April 2024]

Yurtsever, E., Lambert, J., Carballo, A. & Takeda, K. (2020) A survey of autonomous driving: Common practices and emerging technologies. *IEEE access,* 8: 58443-58469.

Zhou, Z.Q. & Sun, L. (2019) Metamorphic testing of driverless cars. *Communications of the ACM*, 62(3): 61-67.