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

Background

In this paper, I propose a system design to support the operation of a driverless car. A driverless car is a car capable of sensing, planning, and acting on behalf of a driver, with little input from them. This definition derives from the sense-plan-act model of robot capabilities, explored by Srivastava, 2019. I propose a design for a SAE level 3-4 system, suitable for a localised driverless taxi, with further details about the operations of motion planning, localisation, and data transmission.

The overall system design of this paper is portrayed using UML diagrams. The following diagrams are included in this proposal: use case, activity, class, sequence, and state transition diagrams.

The following key phrases were used to find relevant sources for this proposal.

Key Phrases: autonomous vehicle, internet of things, robot architecture, smart cities software architecture, UML

Use Case Diagram

Figure 1 contextualises Srivastava's sense-plan-act capability model, and highlights use cases which are directly relatable to the systems users. Additional perception and planning details have been included as well, which are simple to incorporate.

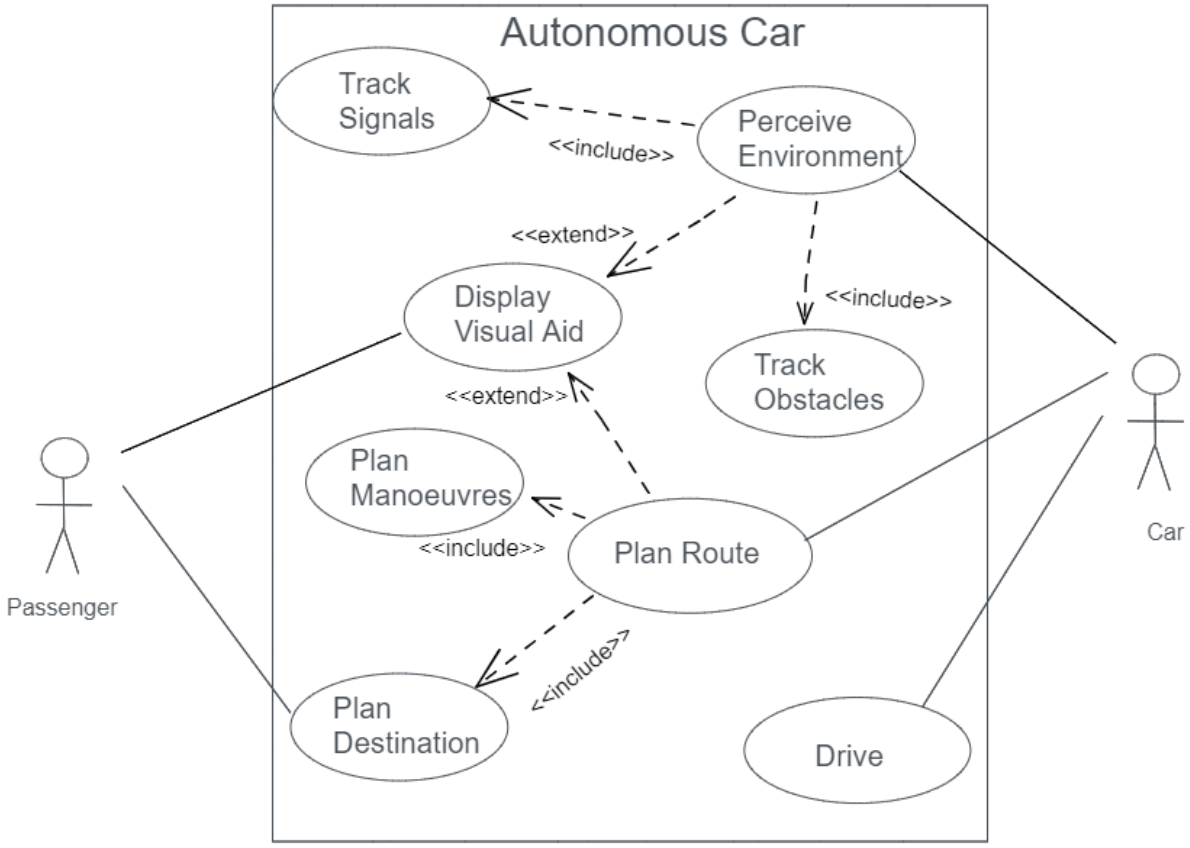

Figure 1 – Use case diagram.

Activity Diagram

Figure 2 presents a sense-plan-act architecture that's compatible with both reactive and planned actuations, thus making it hybrid according to Srivastava's taxonomy, 2019. Perception and navigation suboperations are taken from Reddy's description of key operations, 2019. The first loop of the diagram encapsulates configuration prior to motion. The second loop encapsulates motion. The activity "fetch updates" refers to Srivastava's behavioural updates (2019), Shahzad's cloud-based updates (2016), tracked obstacle or sign updates, and a passenger's requests.

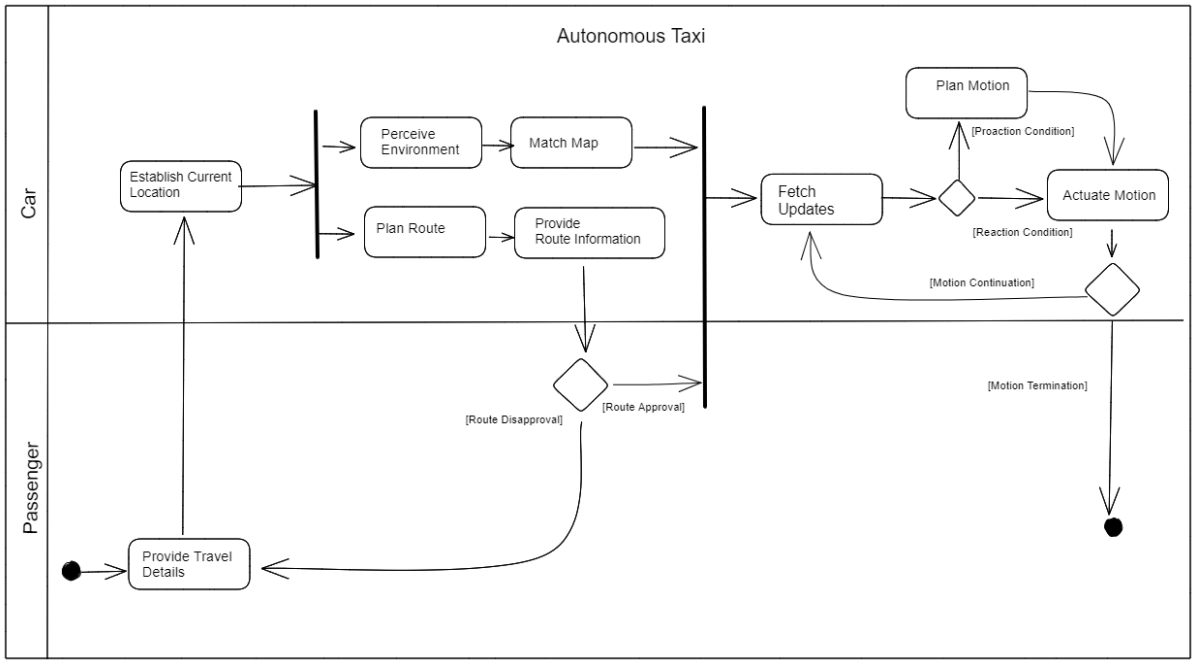

Figure 2 – Activity diagram.

Class Diagram

Figure 3 presents a network design to manage data transmission between car components, drawing from Zong et al., 2018. The design extends to data transmission within an urban internet of things (IoT) too, described by Zanella et al, 2014.

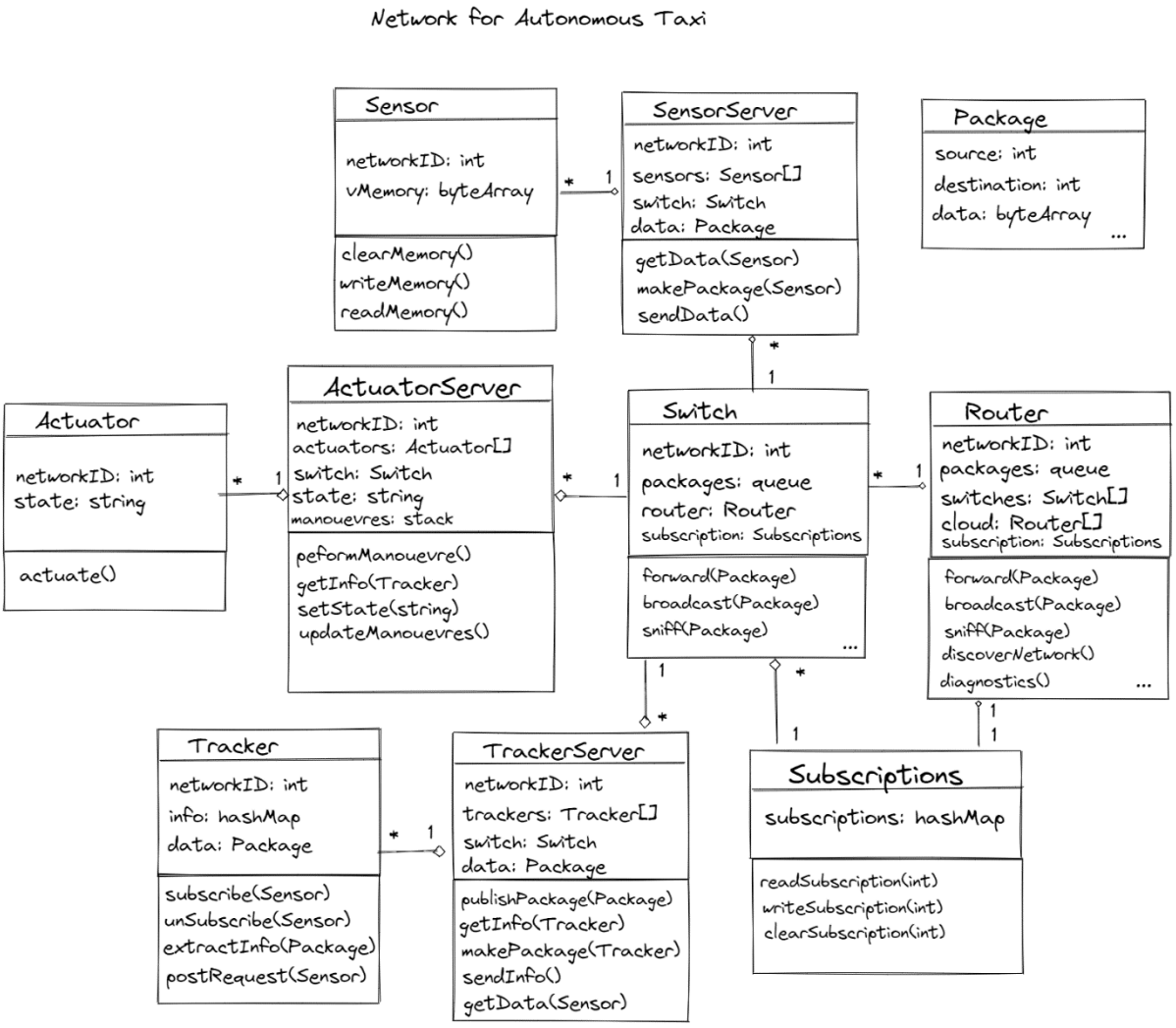

Figure 3 – Class diagram.

Design patterns include the mediator and observer design patterns to simplify network behaviour, drawing parallels to typical network components. Data structures include arrays to store objects of the same type, hash maps to store versatile information, queues to store packages in transition, ‘packages’ for network transmission, and stacks for when a priority mechanism is desirable.

Sequence Diagram

Figure 4 presents the sequence of messages involved in a localisation operation. A location tracker requests and then extracts information from the response it receives from a global positioning system (GPS) sensor. Requests and responses are communicated by virtual servers, communicating with each other across the network.

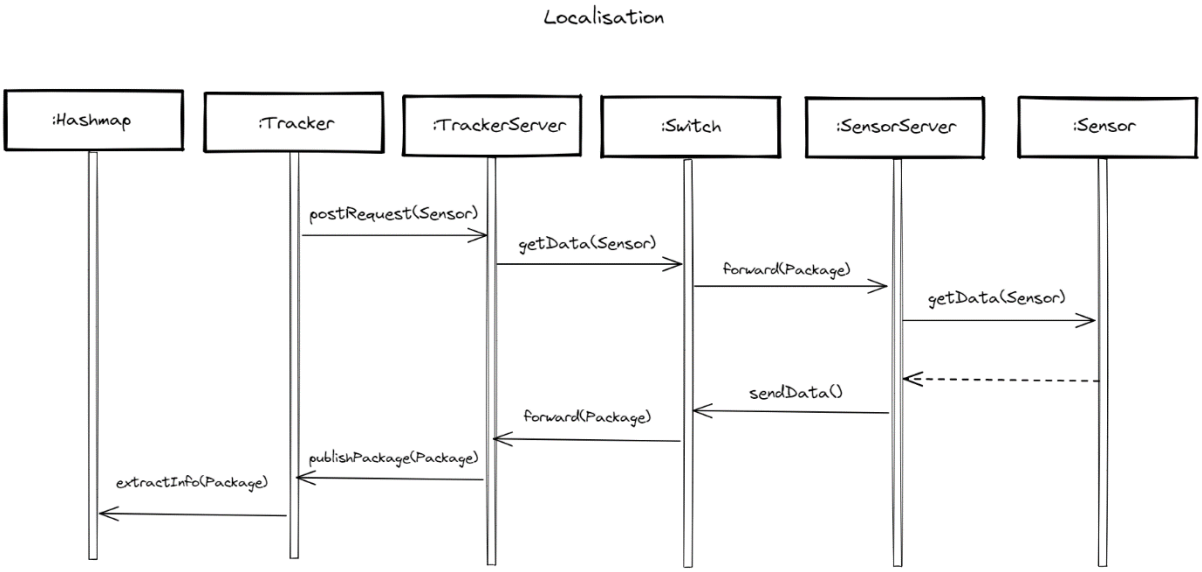

Figure 4 – Sequence diagram.

State Transition Diagram

Figure 5 present a state-based model of motion planning. There exists three different possible transitions to the manoeuvring state, to compliment hybrid sense-act-plan architecture, with urban IoT integration. The four main states contextualise Garzon and Spalanzani's four-stage model for the performance of complex manoeuvres by autonomous vehicles.

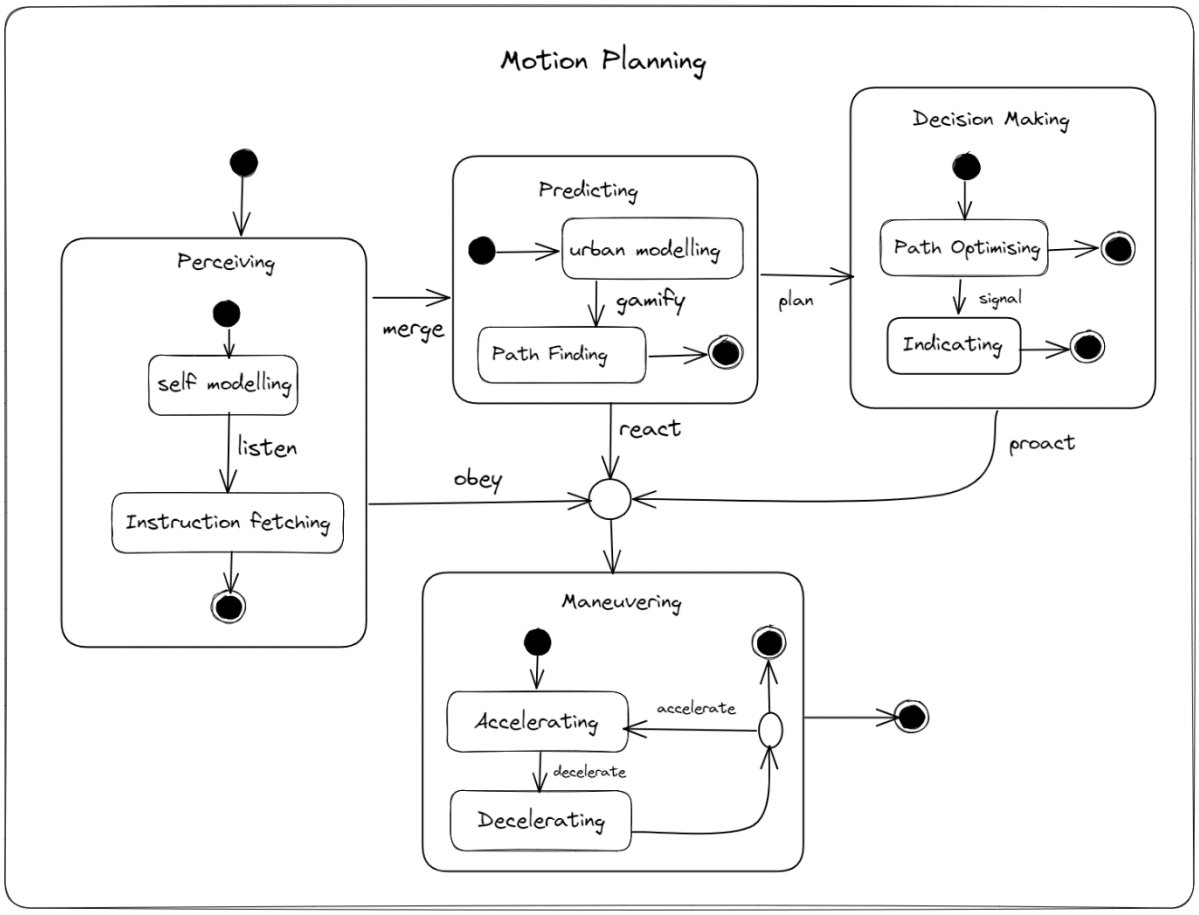

Figure 5 – State transition diagram.

References

Garzon, M. & Spalanzani. (2019) ‘Game theoretic decision making for autonomous vehicles’ merge manoeuvre in high traffic scenarios’, *2019 IEEE Intelligent Transportation Systems Conference (ITSC)*. Auckland, New Zealand, 2019. New York: IEEE. 3449-3453. Available from: https://doi.org/10.1109/ITSC.2019.8917314 [Accessed 13 Mrch 2023].

Reddy, P, P. (2019) Driverless Car: Software Modelling and Design using Python and Tensorflow. Available from: https://easychair.org/publications/preprint/k7wj [Accessed 05 March 2023].

Shahzad, K. (2016) ‘Cloud Robotics and Autonomous Vehicles’, in: Zak, A. (eds) *Autonomous Vehicles*. London, UK: IntechOpen. 13-31. Available from: http://doi.org/10.5772/64064 [Accessed 09 March 2023].

Srivastava, A. (2019) Sense-Plan-Act in Robotic Applications. Available from: https://doi.org/10.13140/RG.2.2.21308.36481 [Accessed 05 March 2023].

Zanella, A., Bui, N., Castellani, A., Vangelista, L. & Zorzi, M. (2014) Internet of Things for Smart Cities. *IEEE Internet of Things Journal* 1(1): 22-32. Available from https://doi.org/10.1109/JIOT.2014.2306328 [Accessed 12 March 2023]

Zong, W., Zhang, C., Wang, Z., Zhu, J. & Chen, Q. (2018) Architecture Design and Implementation of an Autonomous Vehicle. *IEEE Access* 6: 21956-21970. Available from: https://doi.org/10.1109/ACCESS.2018.2828260 [Accessed 11 March 2023].

Bibliography

Rumbaugh, J., Jacobson, I & Booch, G. (1999) *The Unified Modelling Language Reference Manual*. 1st Edition. Massachusetts, USA: Addison-Wesley. Available from: https://people.ucalgary.ca/~far/Lectures/SENG609-23/PDF/uml_refman.pdf [Accessed 05 March 2023].

SAE International. (2021) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. Available from: https://www.sae.org/standards/content/j3016_202104 [Accessed 05 March 2023].