Self-driving Infrastructure: Milestone 1

Integrated Engineering Design Project 2: ENGINEER 2PX3

Design Studio 01

SDI-11

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Executive Summary

The purpose of this report is to provide a comprehensive overview of a new self-driving infrastructure model for automotive intersections. This conceptualized self-driving infrastructure model aims to enhance the safety of drivers and passengers by reducing the risk of accidents with modern technology [1, 2]. The goal of this project is to redesign the traditional intersections in Hamilton with a self-driving infrastructure with various objectives relating to the performance of the system and algorithms which are discussed in the report. Furthermore, with the use of technologies such as vehicle-to-vehicle communication and advanced sensors, self-driving vehicles will be able to maneuver themselves in correspondence with human-driven vehicles thus allowing both forms of transportation to remain on the road. Self-driving vehicles will also have environmental awareness and 3D mapping technology to determine safe and efficient pathways of travel without making aggressive maneuvers. This report will further evaluate the implementation of self-driving infrastructure by analyzing various metrics such as performance, environmental, and regulatory parameters [2, 3]. Overall, this report provides a comprehensive overview of the conceptual implementation of self-driving infrastructure at intersections and the various key stakeholders, designs, and challenges it may pose.

Introduction

The self-driving infrastructure project is built around adapting the current automotive intersection to the rising popularity of self-driving vehicles. Self-driving vehicles possess a vast number of smart features which are not synchronized and compatible with modern traffic intersections [2]. Furthermore, current automotive intersections lack communication between vehicles and often create dangerous situations for drivers. For example, at a left turn signal, a driver may have difficulty seeing incoming traffic as it is blocked by vehicles on the other side of the road, waiting to turn. Additionally, there exists a lack of synchronicity between vehicles which causes a "Phantom effect" which is when one driver fails to accelerate at a green light, causing the delay to compound and affect all the other cars that are waiting [1]. The wide variety of safety and efficiency concerns posed by the current intersection design provides an opportunity for an innovative and new design with modern technology features. A modern design of the automotive intersection is focused on self-driving infrastructure which will reap the benefits of self-driving vehicles to improve the safety and wellness of drivers, pedestrians, and others. With advancements in sensor technology and software systems, self-driving infrastructure can serve to improve the efficiency and safety of all vehicles, drivers, and pedestrians as outlined in this report.

Team Dynamics Description

For this project, as a group of four, each team member will have a weekly administrative job allocated to them, it could be team leader, administrator, coordinator, or communication liaison [4]. For team leader, they must determine the agenda for the week's meeting, facilitate the discussion, and give a progress presentation to the client every week. The administrator is the person who makes sure all worksheets are completed and then submits the team's files. Moreover, the coordinator's responsibilities are recording the meeting minutes, attendance, and individual billable hours for the week. Last but not the least, for communication liaison, their job is to communicate with the client and manager and gather relevant feedback. Every team member should have at least two weeks of experience in each job because the roles will rotate every week. Everyone could understand each role better, resulting in coordination better in the project.

Besides the assigned roles, each team member also has their unique skills and abilities relevant to the project. Our team members are in the stream of Electrical Engineering and Mechatronics Engineering, thus all of us learned the same programming language and have similar coding lectures, which means our coding skills should be on a similar level. However, we each have different strengths or weaknesses. For example, Teghveer is part of the most clubs and has lots of project experiences, so he is good at brainstorming, as well as problem-solving [4]. In the previous weeks, the worksheets that needed to be done were generally based around research and studying the self-driving infrastructure, so the work was distributed evenly per group member. For the following weeks, the work will be generally about coding, so the work will be continually distributed evenly to provide everyone an equal chance to learn and be involved.

Stakeholder Analysis

When meeting with our client for the first time in week 2, they introduced themselves to us as a policymaker who wants our advice to improve existing automotive infrastructure. After deciding on creating an optimized intersection for human and self-driven cars, the client conveyed that they wanted a design made for average-sized cars with verifiable metrics to prove its efficiency [4]. The main metrics that our design should minimize are travel time, bumper-to-bumper traffic, and car collisions. We quickly learned that our team had a great amount of flexibility for this project. We can define the intended location of this intersection and if our team will design for pedestrians and cyclists, we can control all existing traffic systems, and we can implement any new technology all with an unlimited budget. Despite the relaxed requirements, our client stressed that safety must be the top priority in our design proposal.

The key factor of this project that our client specified to us is that our intersection must be capable of supporting both self driven and human cars, and it should utilize the advantages of self driven cars. Self driven cars, unlike human driven cars, are able to communicate with each other and the intersection as well as being able to pinpoint the exact proximity and speed of the vehicle in relation to our infrastructure. Recently, our client has asked for us to graph the average time for participants as a function for load on our designed system. Although this specific task is clear, going forward our team may need to clarify exactly what the client would like to see in our final design proposal in terms of simulations and experiments to prove the feasibility and validity our design.

Other stakeholders that are a part of our project other than are client include the government or regulating body of the area, self driven and human driven vehicle occupants, and manufacturers of the vehicles to be using our infrastructure [4]. Although our primary client specified that we did not have to design for pedestrians, our group decided that another stakeholder for our project would be the pedestrians and cyclists who may want to use our intersection. The vehicles, pedestrians, and cyclists are most obviously impacted by our project as they physically participate in it. We anticipate that their primary concern would be the safety of the intersection, with a secondary concern of the performance of the intersection measured by wait times [4].

The participants of our intersection are our most important stakeholders as we are designing for them, and they will not use the intersection if their needs are not met. The regulating body of the area would also have a primary concern for safety of their residents using the intersection, but also for the socio-cultural impacts of the infrastructure [4]. Lastly, the manufacturers are mainly concerned about the performance of the infrastructure, especially in relation to their vehicles. We also anticipate that manufacturers would have environmental concerns as they are probably being pushed by environmentalists to reduce their carbon emissions and an efficient intersection would reduce the idle time and wasted fuel of a vehicle.

Project Scoping

The goals of this project are to streamline city intersection traffic to eliminate traffic jams, maintain safety for all vehicles on the road, improve driver visibility and confidence at left signal turns, and to improve pedestrian satisfaction via human sensors and faster cross walk activation [5].

Evidently, these goals are related to the PERSEID screening process in engineering design. As such our objectives are to research the different layers to determine parameters associated with them, and then utilize said parameters in the source code provided to determine what parameters yield the best results [3].

To evaluate these goals, we will assess the intersection infrastructure based on various performance, environmental, socio-cultural, and regulatory metrics. The performance metrics we will consider are the average waiting time for each vehicle at the intersection and the average number of vehicles in pile up during a stoppage. During our second client progress meeting, the client inquired on the difference between these two metrics. While both metrics seem to be related, they are not as the number of vehicles in pile up is influenced primarily by traffic density. A longer waiting time certainly could lead to a larger pile up, however, traffic density is directly related; if there is a higher traffic density, there will be a higher pileup at a stoppage [5]. Correlating waiting time with traffic pileup implies that there is another impending wave of traffic from the previous road segment which is not guaranteed. The environmental metrics we will consider are idle time, and area of concrete and pavement relative to grass or plants. By reducing idling time, there would be reduced carbon emissions for internal-combustion vehicles and reduced wasted power in both internal-combustion vehicles and electric vehicles. Preserving greenery surrounding the traffic infrastructure is crucial to human health as plants take in carbon dioxide and yield oxygen thereby reducing the effect of pollution from carbon emissions. The socio-cultural metrics we will consider are the time for priority vehicles to pass through the intersection and the appeal rating (how efficient or appealing is the intersection to residents and users of the intersection) [6, 7]. The regulatory metrics we will consider are the number of collisions, and construction and maintenance costs.

The scope of this project is that we are responsible for implementing a self-driving infrastructure with respect to Greater Toronto Hamilton Area (GTHA). Therefore, we only have to consider localized features instead of foreign traffic features in other countries. Bicycle lanes are optional for this infrastructure, however, should we choose to implement bicycle lanes, they do not necessarily have to be on the road as they can be placed on the sidewalk. Since we are not responsible for the technical development of the software to run the self-driving infrastructure, we do not have to account for random machine errors. For constraints, we only have to consider the surrounding buildings as we cannot expand lanes into someone's property. Finally, we do not need to develop and perform a simulation on our self-driving infrastructure. In our first meeting with our client, the team leader inquired if we need to develop a simulation, but he said that it is not expected and that it is outside the project scope. Instead, we were given the source code for week 6 and we are responsible for improving it by implementing any assumptions that we had with regard to human-driven vehicles and self-driven vehicles.

Simulations are simplified models of reality; therefore, assumptions must made as they cannot account for every parameter in real-life. In week 3, we have devised several assumptions: (1) all self-driving cars at the intersection are fully aware of all other cars, (2) cars will arrive to the system every 30 seconds, (3) there will be no limos, busses, semi-trucks, or otherwise unusually sized vehicles arriving to the system at any time, (4) all self-driving cars at the intersection will be able to communicate with the system's infrastructure and technology (V2X communication technology), and (5) self-driving vehicles are competent [2, 6]. Self-driven vehicles being fully aware of all other cars allows for maximum efficiency as vehicle information (e.g., velocity, direction) would be broadcasted to other vehicles which could reduce the need for stopping. Having a set time when cars arrive at the intersection is an important deterministic value in our simulation. Limiting the vehicle type to be only regular-sized vehicles makes it easier to simulate as larger vehicles would presumably cause more disruptions in traffic patterns. The ability to communicate with the system's infrastructure and technology allows for the reduced stoppage.

Conclusion

The project described in the report is focused on creating an optimized intersection for human and self-driven cars in the Greater Toronto Hamilton Area. The main stakeholders in the project are the client, consumers, regulating body, vehicle occupants, manufacturers, and pedestrians/cyclists. The project's goals are to streamline city traffic, improve safety, and increase pedestrian and driver satisfaction. The team will assess the intersection based on performance, environmental, socio-cultural, and regulatory metrics. Additionally, the team is responsible for conceptualizing the self-driving infrastructure and has the flexibility to implement new technology within an unlimited budget. However, simulations are outside the project scope and the team is only responsible for improving the source code they received in week 6. Furthermore, the team must prioritize safety as the client stressed it to be the top priority in their design proposal. The project must take into consideration the needs of all stakeholders and design the intersection to meet their expectations to make it a success. In week 4, the clients requested the team to graph the average travel time as a function of load on the system within 2 weeks, thus this job will be having priority for the following days.

References

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[2] “2022-2023 Self Driving Infrastructure Project Summary,” class notes for ENGINEER 2PX3, Faculty of Engineering, McMaster University, Winter, 2023.

[3] “2PX3 Communication Lecture Wk-4&5 - Oral Communication and Presentation - ENGINEER 2PX3: Integrated Engineering Design Project 2,” https://avenue.cllmcmaster.ca/d2l/le/content/514013/viewContent/4057583/View (accessed: Feb. 9, 2023).

[4] “Wk-2 Synchronous Design Studio Worksheet – SDI,” class notes for ENGINEER 2PX3, Faculty of Engineering, McMaster University, Winter, 2023.

[5] Wei, Hua, Guanjie Zheng, Vikash Gayah, Zhenhui Li. "A survey on traffic signal control methods," arXiv [Online], vol. 1904, no. 08117, April 2019. Available: https://arxiv.org/abs/1904.08117

[6] Jee-Hyong Lee, Hyung Lee-Kwang, "Distributed and cooperative fuzzy controllers for traffic intersections group," IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) [Online], vol. 29, no. 2, pp. 263-271, May 1999, doi: 10.1109/5326.760570. Available: https://ieeexplore.ieee.org/abstract/document/760570/metrics#metrics

[7] S. Kamijo, Y. Matsushita, K. Ikeuchi, M. Sakauchi, "Traffic monitoring and accident detection at intersections," IEEE Transactions on Intelligent Transportation Systems [Online], vol. 1, no. 2, pp. 108-118, June 2000, doi: 10.1109/6979.880968. Available: https://ieeexplore.ieee.org/abstract/document/880968

Appendix

Team Charter

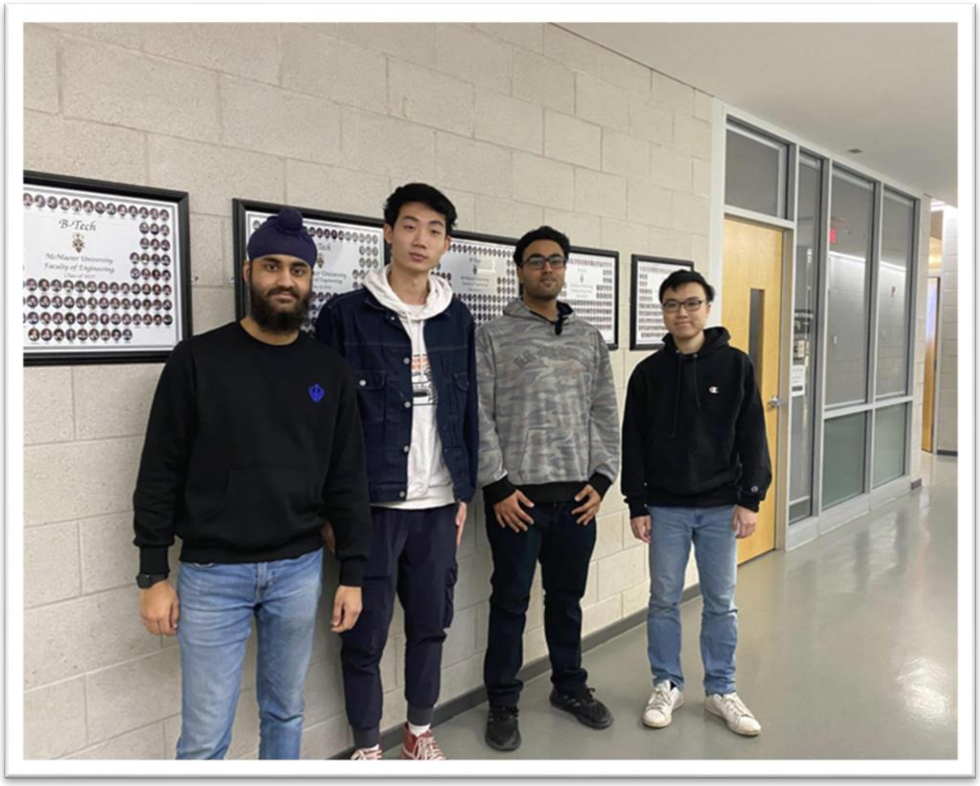

Figure 1: SDI-11 Team Image from Wk-2 Team Charter

In order to stay accountable to each other throughout ENGINEER 2PX3, our team has decided that each member will take accountability for their assigned tasks and be present during group meetings.

Week 3 Meeting Minutes

Kush Rana – Coordinator – Week 3

Role	Name	Mac ID	Attendance (Yes/No)
Team Lead	Michael	Yipm10	Yes
Administrator	Teghveer	Atelieyt	Yes
Coordinator	Kush Rana	Ranak6	Yes
Communications Liaison	Harry Shi	Shiz40	Yes

Agenda Items

1. Take attendance.
2. Share asynchronous studies and general research during group discussion.

Meeting Minutes

1. Reviewed presentation with Michael the team lead.
    a. Practiced potential client questions.
2. Consolidated asynchronous worksheets in synchronous worksheet.
    a. Everyone completed the asynchronous worksheet.
3. Discussed and completed synchronous worksheet.
    a. Safety concerns of bicycle lanes and how they interfere with self-driving infrastructure.
    b. Pedestrian automobiles and motorcycles self-driving capabilities
    c. Discussed GPS systems, 3d mapping tools, computer vision, radar, vehicle to vehicle communication.

d. Discussed dilemmas in software bias in the admittance of human-driven vehicles vs. self-driving vehicles.

Post-Meeting Action Items

1. *Next week's manager presentation [Harry]*
2. *Wk-5 Asynch Worksheet [All]*

Week 4 Meeting Minutes

Teghveer Singh Ateliey – Coordinator – Week 3

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Team Lead	Harry Shi	Shiz40	Yes
Administrator	Michael Yip	Yipm10	Yes
Coordinator	Teghveer	Atelieyt	Yes
Communications Liaison	Kush Rana	ranak6	Yes

Agenda Items

3. Take attendance.
4. Share Technical Performance Research pre-lab with team members.

Meeting Minutes

4. Reviewed presentation with Harry the team lead.
    a. Added notes on agenda items.
    b. Practiced potential questions from the client.
    c. Discussed timing of the slides

5. Consolidated asynchronous worksheets in synchronous worksheet
    a. Everyone completed the asynchronous worksheet.
6. Discussed and completed synchronous worksheet.
    a. Added various parameters to watch out for in our design.
    b. Talked about how they can affect our design
    c. Discussed how we can measure or improve the discussed aspects.

Post-Meeting Action Items

3. *Milestone 1 [All]*
4. *Reflection 1 [All]*
5. *Next week's manager presentation [Kush]*
6. *Wk-5 Asynch Worksheet [All]*