Pre-planning intersection traversal for autonomous vehicles

M.Sc. Thesis Proposal

Oliver, Ian Dahl
ian.oliver@post.au.dk
Student

Esterle, Lukas
lukas.esterle@ece.au.dk
Supervisor

14/12-2024

1 Introduction

Autonomous driving as we know it today has been in development for almost a decade, with all major car companies developing their own systems and methods for having their vehicles drive with as little driver input as possible. Common among them is the fact that they rely on deep learning to some extent. Tesla is removing anything from their cars that is not a sensor to rely solely on cameras and computer [4], while most other companies keep using radar hand-in-hand with cameras.

Computer vision is thus heavily relied upon in any autonomous driving system. This means that systems will have to capture and generalize all scenarios within the model. This is proving difficult in many scenarios, as intersections and roundabouts are rarely the same. When driving a car with some kind of autonomous steering, it quickly becomes apparent that they do not react to intersections. The closest we get to this is that some cars will show down when reaching a roundabout.

This project aims to aid autonomous vehicles in traversing intersections by plotting the path that should be taken through it. This will help further the field of vehicle autonomy. Current infrastructure supporting technologies for better autonomous driving is largely only available around large cities, so this project will also help create a more generalised help for intersection traversal.

2 Technologies

Some technologies already exist that are meant to assist vehicles in driving safely through certain scenarios and environments. Volkswagen Group has developed the Car2X technology [5], which allows their cars to communicate with other cars and traffic infrastructure. Autonomous Intersection Management (AIM) is also a field that aims to tackle this problem. A reservation-based method was imagined in 2015 by splitting the intersection into tiles and having an intersection manager that cars announce their arrival to and then gets instructions on allowed tiles to traverse as they will be reserved for that vehicle [2]. While methods like that do appear to be thorough and allow for smooth autonomous driving in an intersection, it still requires many new components, like the intersection manager and very precise mapping. The authors do also point out that this is more of a vision and will require a long time to become reality.

Another aspect of vehicles approaching an intersection, is the fact that there might be road crossings, bike lanes, and stop lines or shark teeth to be accounted for. While AI has improved with identifying these and more [3], severe challenges are still posed by uncertainty. With so many camera-based systems, adverse weather can heavily and negatively impact the performance of these, like heavy rain blurring the cameras' view and otherwise distorting what the computer vision model processes. This is largely handled by requiring the user to take over, but with certain companies removing the steering wheel, a robust way of identifying road crossings in poor visibility weather is needed.

Furthermore, many kinds of intersections exist. Some have signalling, others, like many T-junctions, simply consist of a stop line. Some are very straightforward and others requirement an odd angle of exit. Autonomous vehicle do handle these rather well when seeing them in action, but solely relying on camera inputs, means that can't see better than human drivers. Thus, having images from above, like satellite imagery, will help vehicles better grasp the overall structure of an intersection better. Path-planning will then also enable the vehicle to guide through when some scenarios where something might be out of view, leading to high uncertainty. It will give vehicles an idea of how to drive through an intersection before seeing it. This aligns with research indicating that decision-making at intersections without signalling remains a challenge due to partially observable environments, requiring robust planning and prediction algorithms to ensure safety and efficiency [1].

3 Methodologies

At the heart of this project lies the utilization of satellite imagery fed to a deep learning model and getting out a path that the car should follow. Multiple paths for each objective can be explored to achieve this. For the satellite images, different APIs will be looked into, where the most appropriate one will be chosen. Parameters include clarity and fidelity of the image, meaning that no abstractions should be made to the image, such as a simplification of the roads as typically seen in Google Maps' default view or OpenStreetMap. The methods for path-planning will take some consideration. Alternative methods could include the deep learning model generating the entire path that can easily be plotted, generating a heatmap of best places for a car to go, or placing a certain amount of points along the optimal path and then connection these using splines or other path algorithms.

If time allows, many other aspects can be implemented or considered. Deciding whether the computation should happen on-board or using cloud computing could prove to be an interesting aspect of this task. Cloud computing might allow for greater and more precise results as larger models may be run, but on-board computing will greatly reduce latency and dependence on connectivity, outside receiving the satellite image of course. Another aspect could be the optimization of the deep learning model and its inputs. The inputs could potentially be cropped in such a manner that unnecessary parts are removed and the intersection itself is more appropriately centred and cropped. Considerations about the scope are also important; should the system look at just an intersection or can it be generalized to any road, or should it look just a bit ahead or compute every intersection along a route. If time allows, these will be considered and attempted to be implemented.

4 Project Goals and Roadmap

While technologies like that proposed by Au et al. might be possible in the far future, autonomous vehicles are still being pushed to the streets today and therefore need realistic alternatives. Such an alternative is the goal of this project. The goal is to create realistic paths that an autonomous vehicle would be able to follow to smoothly and safely drive through and intersection. Additional goals include identifying road crossings and stop lines and marking potentially dangerous areas to pay extra attention when moving into an intersection. While the outcome of this project may vary a lot depending on findings and challenges encountered, the desired milestones are as follows:

- Use an API to get satellite imagery.
- Create deep learning model.
- Train model to plot paths.
- Test the system on a wide variety of real world scenarios.

After the system has been created, if time constraints allow it, the following milestones will also be attempted to be reached:

- More intersection understanding, such as stop lines and road crossings.
- Improve performance of deep learning model.
- Compare cloud computing vs on-board computing.
- Test intersection-by-intersection functionality versus entire route.

This technology would of course not replace any systems currently in-place in modern vehicles, but rather be another component that would greatly increase the driving pleasure of using autonomous driving features. This also allows for easier testing, as the separated nature means it will not conflict with other systems during said testing.

A Gantt chart of the outline of this project is shown in figure 1.

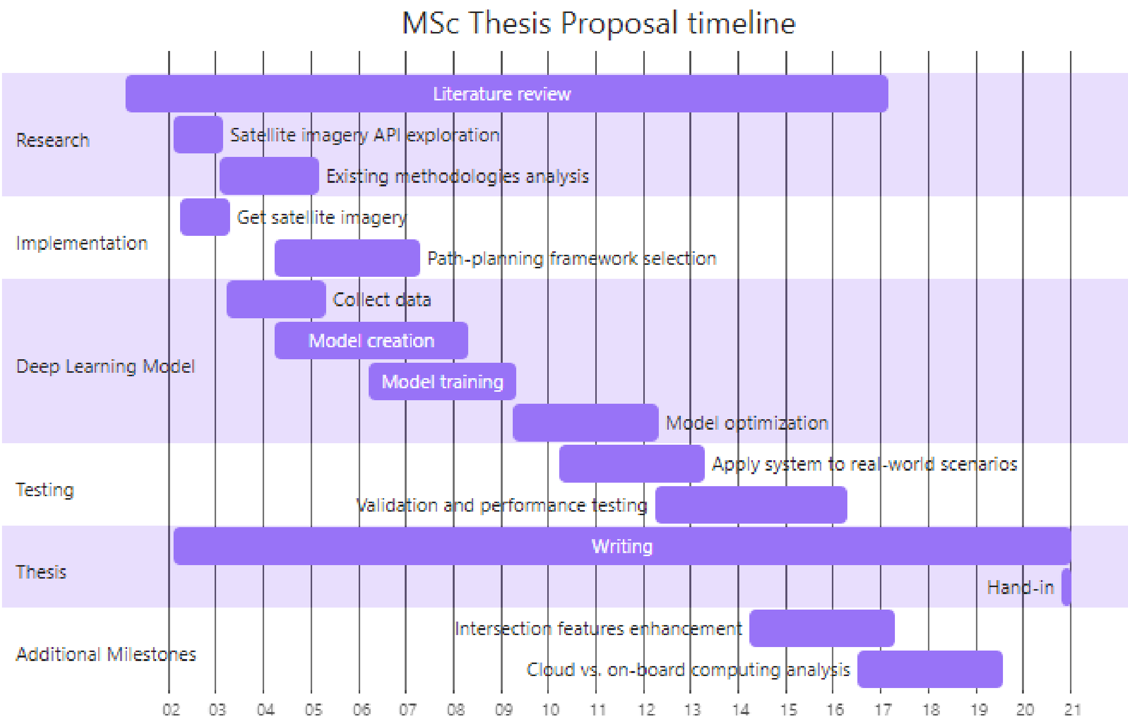

Figure 1: Gantt chart showing the planed timeline of this project.

References

[1] Mohammad Al-Sharman, Luc Edes, Bert Sun, Vishal Jayakumar, Mohamed A. Daoud, Derek Rayside, and William Melek. Autonomous driving at unsignalized intersections: A review of decision-making challenges and reinforcement learning-based solutions, Sep 2024. available at: https://arxiv.org/abs/2409.13144.

[2] Tsz-Chiu Au, Shun Zhang, and Peter Stone. Autonomous Intersection Management for Semi-Autonomous Vehicles. In *Handbook of Transportation*. The University of Texas at Austin, May 2015. Available at: https://www.cs.utexas.edu/~ai-lab/?au:hot15.

[3] Neda Cvijetic. NVIDIA Blogs: How AI Helps AVs Understand Intersections, May 2020. Available at: https://blogs.nvidia.com/blog/drive-labs-how-ai-helps-autonomous-vehicles-understand-intersections/.

[4] Tesla. Tesla Vision Update: Replacing Ultrasonic Sensors with Tesla Vision, 2024. Available at: https://www.tesla.com/support/transitioning-tesla-vision.

[5] Volkswagen Group. Technical milestone in road safety: experts praise Volkswagen's Car2X technology. *Volkswagen Newsroom*, 2023. Available at: https://www.volkswagen-newsroom.com/en/press-releases/technical-milestone-in-road-safety-experts-praise-volkswagens-car2x-technology-5914.