Vehicle Motion Prediction and Safety Assurance using GNN and Path Optimization – Project Proposal

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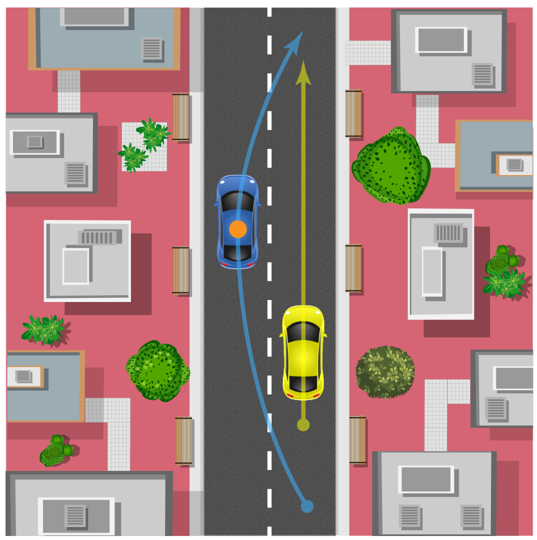

Figure 1: A human driven vehicle (blue) making a dangerous overtake maneuver. Blue line depicts the entire length of the trajectory $\xi_{\mathcal{HB}}$ from time-step $t = 0$ to $t = T$. The second human driven car (yellow) follows a consistent trajectory from $t = 0$ to time-step $t = T$. We aim to identify the critical time-step $t + 1$ (shown with orange dot) that allows us to predict the motion of the blue car from that time-step until the end of the trajectory.

Abstract

Prediction of driving behavior can help improve traffic safety in the real world. The research of the project mainly studies the relationship between vehicles, vehicles and traffic environment to predicts the movement of vehicles, and gives corresponding collision avoidance strategies to improve driving safety. Using graph neural networks (GNN), we aim to predict human-driven car movements, identify potentially unsafe behaviors. Then we validate our model with the INTERACTION dataset. Specifically, the project proposal describes in detail the contributions of each team member, clarifies the research questions in detail, and finally gives our milestone plan.

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1 Team members & Tasks

Collectively we have identified major tasks of this project. Every task in this project will have a primary (i.e., lead) and at least one secondary in charge of it. We expect that everybody will write at least one section of the final paper and will develop multiple slides for the presentation. The tasks of this project are: Literature Review, Methodology, Developing the algorithm, Running the experiments, Review and edit of the final presentation.

1.1 Lang Zhang

Lang Zhang is a first year PhD student in Computer Science & Application department. His research includes multi-source information fusion and multimodal learning. He had done works in EEG signal classification for safety-driving (e.g., Evidence theory) and products recommendation (e.g., Graph neural network). He will use PyTorch to develop the framework of model. His main contribution in this projects lies in:

- Methodology (primary)
- Developing algorithm (primary)
- Literature review (secondary)
- Review and edit of the final manuscript (secondary)

1.2 Shahabedin Sagheb

Shahab is a second year PhD student in the Mechanical Engineering department's Collaborative Robotics Lab. In his research he explores learning algorithms that can influence humans. He has worked with control (e.g., MPC) and Deep Learning (e.g., Behavior Cloning) algorithms. He develops his work using Python and PyTorch. Given his experience he will contribute in this project in the following areas:

- Data Analysis (primary)
- Methodology (secondary)
- Development of the algorithms (secondary)
- Review and edit of the final manuscript (primary)

1.3 Michael Shi

Michael is a first year Masters of Engineering student in the Computer Science department. While he doesn't have as much experience in PyTorch as some other members of the group, he does have prior experience with Python. Given his experience he will contribute the following:

- Review and edit of the final presentation (primary)
- Literature Review (secondary)
- Development of the algorithms (secondary)
- Running the experiments (secondary)

1.4 Trent Greer

Trent is a second year M.Eng Student in the Computer Science Department. He has experience with a variety of machine learning projects, but most notably those that include natural language processing and image recognition. He is proficient in Python, C++, OpenCV, Pytorch, and Scikit.

- Literature Review (Primary)
- Methodology (Secondary)
- Data Analysis (Secondary)
- Running the Algorithm (Secondary)

1.5 Yulong Zhong

Yulong is a first-year M.Eng Student in the Computer Science Department. He has experience with Python, Java, and R and has done projects about VT baseball player performance dashboards and NFL prediction for class. With his expertise, he is expected to make contributions in these fields:

- Running the experiments (primary)
- Data Analysis (secondary)
- Review and edit of the final manuscript (secondary)
- Review and edit of the final presentation (secondary)

2 Problem Statement

Driving is a complex task, and humans may exhibit unexpected behaviors. Therefore, if the vehicle ground motion trajectory in traffic can be predicted based on previous driving behaviors, road safety will be greatly improved [5]. In general, scholars mainly study the motion trajectory of a single vehicle or rely on the connection between the motion trajectory of multiple vehicles to make predictions [1]. But in fact, driving routes are not only influenced by other cars, it is also highly dependent on traffic rules and road conditions, such as congestion conditions and road types [7]. **Our research problem** is to build a machine learning model to characterize the relationship between cars and cars and the relationship between cars and the road environment, so as to achieve more accurate trajectory prediction, then a safer driving trajectory can be formulated. The ability to anticipate driving decisions and react accordingly can go a long way toward reducing accidents [9]. Our intuition is to use the graph neural network to solve the human driver motion prediction problem [8]. As a progress-based extension, we want to use the most advanced path optimization to provide drivers with information about the best route action [2]. **Importance:** The driving behavior of cars is multimodal. While we consider the impact between cars, we also have to consider the impact of environmental factors [3]. **No-trivial:** We need to take into account the complex relationships between vehicles and their interactions with the road environment, and the challenge is to deal with dynamic situations where multiple factors intersect [4].

High-level problem formula In our project, given the temporal set of vehicle control features (e.g., acceleration, heading, position) and the environment features (e.g., road type, surrounding traffic) up to a certain point in time (i.e, $0, \cdots, t$), we aim to predict the vehicle motion in the next time steps (i.e., $t+1, \cdots, T$) where T is the time horizon of a given trajectory ξ. In specific, we aim to explore whether a vehicle's past motions will lead to unsafe behavior such as near-collision or minor accidents. Fig. 1 shows a brief use case of our problem. Similar to existing literature in this domain (e.g., [6]), we will use the INTERACTION Dataset [10] to test our algorithm. This will allow us to compare our results with the existing solutions.

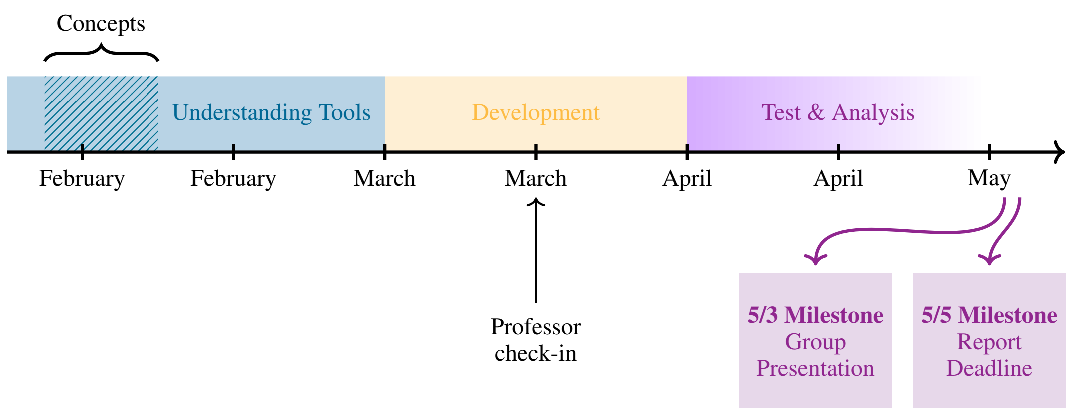
A possible extension If the project time allows, using the predicted motion we will identify the potential unsafe trajectories. We then use path optimization to find a safe trajectory for the human driver. The optimized trajectory can be used as a communication method to real human drivers on the road. Although we will not implement such communication we will provide recommendations for designers.

Our contributions are:

- Developing a forecasting model based on the features and relationships between each driver (agent) on the road.
- As a possible extension, developing an optimization algorithm that provides the safest path for two agents in the interaction.

3 Preliminary Plan

Our plan for project development is shown below[1]:



- Milestone 1 (02/01 – 02/15): Read the literature and determine the use-case environment for the research problem. Filter the appropriate data set based on the specific problem.
- Milestone 2 (02/15 – 02/28): Process the data and learn the relevant tools according to the needs of the model.
- Milestone 3 (03/01 – 03/20): Develop model and test simple use cases.
- Milestone 4 (03/21 – 04/15): Do experiments and evaluate.
- Milestone 5 (04/16 – 05/05): Project report writing and presentation.

We will meet as a team every two weeks to discuss recent development and find solutions to challenges.

[1]Source of the graphic style is Timeline.

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