UC San Diego
JACOBS SCHOOL OF ENGINEERING
GEAR

Near-Intersection Vehicle Trajectory Prediction

Jiawen Xu*, Diego Martinez*
Advisor: Jedrzej Kozerawski
Department of Computer Science and Engineering, University of California, San Diego
*denotes equal distribution

Background

Motivation

Motion planning is important in autonomous vehicle (AV) design. It requires accurate predictions of future motion trajectories for surrounding vehicles, which tend to be more complex near intersections. Understanding the trajectories of cars near intersections would allow us to make AV driving safer.

Problems

Current trajectory prediction models are unaware of intersection locations. Performance metrics only take into account the average performance across an entire citiy

Task

Utilize the positional data in Argoverse (a map dataset for test and experiment) in order to analyze model performance with respect to intersection location and propose solutions for improving the quality of a model's prediction. Using information such as car's distance to an intersection and whether a car has passed through an intersection will allow us to improve motion planning near these areas.

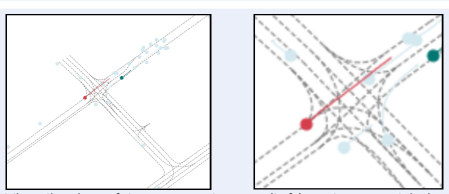

Figure 1: *Visualization of Argoverse dataset (left) and zoomed-in image at intersection (right)*

Experimental Methods

Finding Intersections

- Created map with Argoverse API (a tool that allows us to the visualize positional data of cars and road structures in Miami and Pittsburgh).
- Extracted and labeled coordinate positions (x,y) of every intersection in Miami and Pittsburgh.
- Converted the data into GPS coordinates.

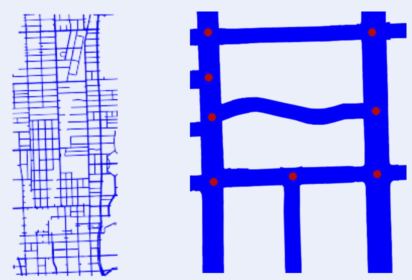

Figure 2: *Map of Miami generated using Argoverse API (left) and a zoomed in patch of the same image with labeled intersections in red (right).*

AV - Intersection Relation

- Determined the distance between the AV and a specified intersection.
- Distinguished 3 Cases:
  a. Moving away from an intersection
  b. Approaching an intersection
  c. Passing through intersection
- Trained Long Short-Term Memory (LSTM) Model on Argoverse Dataset
  - An LSTM is a type of neural network that is suitable for sequential data

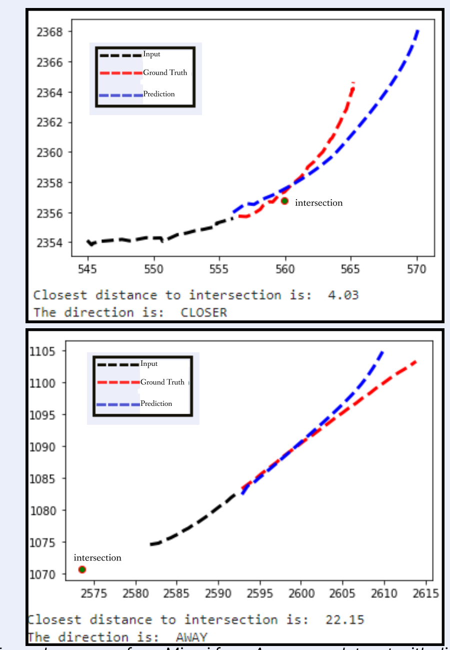

Figure 3: *Exemplary scene from Miami from Argoverse dataset with distance calculation and direction (with respect to the intersection) classification*

Metrics

- *Average Displacement Error* (ADE) is the average of the Euclidean distance between the ground truth (expected output) and the prediction over all the timesteps.
- Metrics for Model Peformance:
  - *Accuracy*
  - *Precision*
  - *Recall*
  - *F-1 Score*

Evaluation and Performance Equations

$$\texttt{accuracy}(y, \hat{y}) = \frac{1}{n_\text{samples}} \sum_{i=0}^{n_\text{samples}-1} 1(\hat{y}_i = y_i)$$

Accuracy is the fraction of correct predictions over $n_{samples}$ is defined above, where $\hat{y}_i$ is the predicted value of the i-th sample and y_i is the corresponding true value, and $1(x)$ is the indicator function

$$\text{precision} = \frac{tp}{tp + fp},$$

$$\text{recall} = \frac{tp}{tp + fn},$$

$$\text{F1 score} = 2\frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}$$

In a binary classification task, the terms "tp" refers to a true positive, "tn" refers to a true negative, "fn" refers to a false negative, and "fp" refers to a false positive. The terms "positive" and "negative" refer to the classifier's prediction, and the terms "true" and "false" refer to whether that prediction corresponds to the ground truth (sometimes known as the "observation").

$$ADE = \frac{\sum_{t=0}^{T} ||\hat{F}_{t+1} - F_{t+1}||_2}{T}$$

T is the number of predicted time steps

$\hat{F}_{t+1}$ is the predicted coordinates of the trajectory

F_{t+1} is the corresponding ground truth coordinates

Results & Discussion

ADE/FDE vs Distance to Intersection

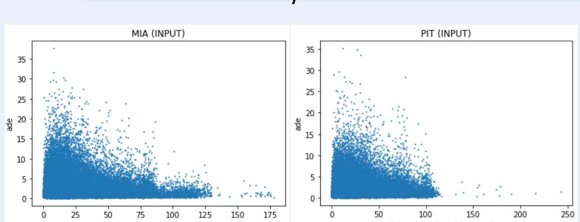

Figure 4: *Average Displacement Error (ADE) vs. distance to intersection for Miami (left) and Pittsburgh (right)*

- We trained an LSTM model for vehicle trajectory predictions in important near-intersection scenarios.
- We calculated ADE with respect to the distance to the nearest intersection represented by the plots in Figure 4.
- Using only average metrics would conceal larger errors in important intersection scenarios.
- Error is higher near intersections.
- Predicting which cars will enter the intersection within a given time frame could provide valuable information to improve the quality of a model's prediciton.

Prediction of a Vehicle Entering Intersection

Method	Accuracy	F-1 Score	Precision	Recall
MLP	0.996	0.951	0.952	0.951
LSTM	0.934	0.919	0.931	0.908

Figure 5: *Performance for the task of predicting whether a vehicle will enter an intersection within T timesteps*

- We used two models: Multi-Layer Perceptron (MLP) and Long Short-Term Memory (LSTM) .
- MLP model has a higher performance than the LSTM model.
- Since we are able to predict whether a car will enter an intersection within a given time, we can estimate the crowdedness (amount of cars at a given time) of an intersection. This information can be useful for motion planning.
- To protect against underreporting or overestimating the amount of cars, we must include Precision and Recall scores.

Future Steps

- Use information about the distance to intersection to improve the quality of trajectory predictions.
- Utilize predicted intersection state (number of cars at an intersection at given time) to improve motion planning.

References

[1]Argoverse: 3D tracking and forecasting with rich maps M.-F. Chang, J. Lambert, P. Sangkloy, J. Singh, S. Bak, A. Hartnett, D. Wang, P. Carr, S. Lucey, D. Ramanan, and J. Hays, "Argoverse: 3D tracking and forecasting with rich maps," in IEEE Conf. on Computer Vision and Pattern Recognition (CVPR), https://arxiv.org/pdf/1911.02620.pdf

[2] Huang, P., Fang, Y., Hu, B., Gao, S. & Li, J. CTP-net for cross-domain trajectory prediction. arXiv.org (2021). Available at: https://arxiv.org/abs/2110.11645. (Accessed: 17th May 2022)

[3] 3.3. metrics and scoring: Quantifying the quality of predictions. scikit Available at: https://scikit-learn.org/stable/modules/model_evaluation.html#accuracy-score. (Accessed: 17th May 2022)