RUTGERS
Center for Advanced Infrastructure and Transportation

A Vehicle Trajectory Stitching and Reconstruction Method for Digital Twin Applications with High-Resolution Roadside LiDAR Data

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verizon iteris

OUSTER Velodyne Lidar

MIDDLESEX COUNTY • NJ

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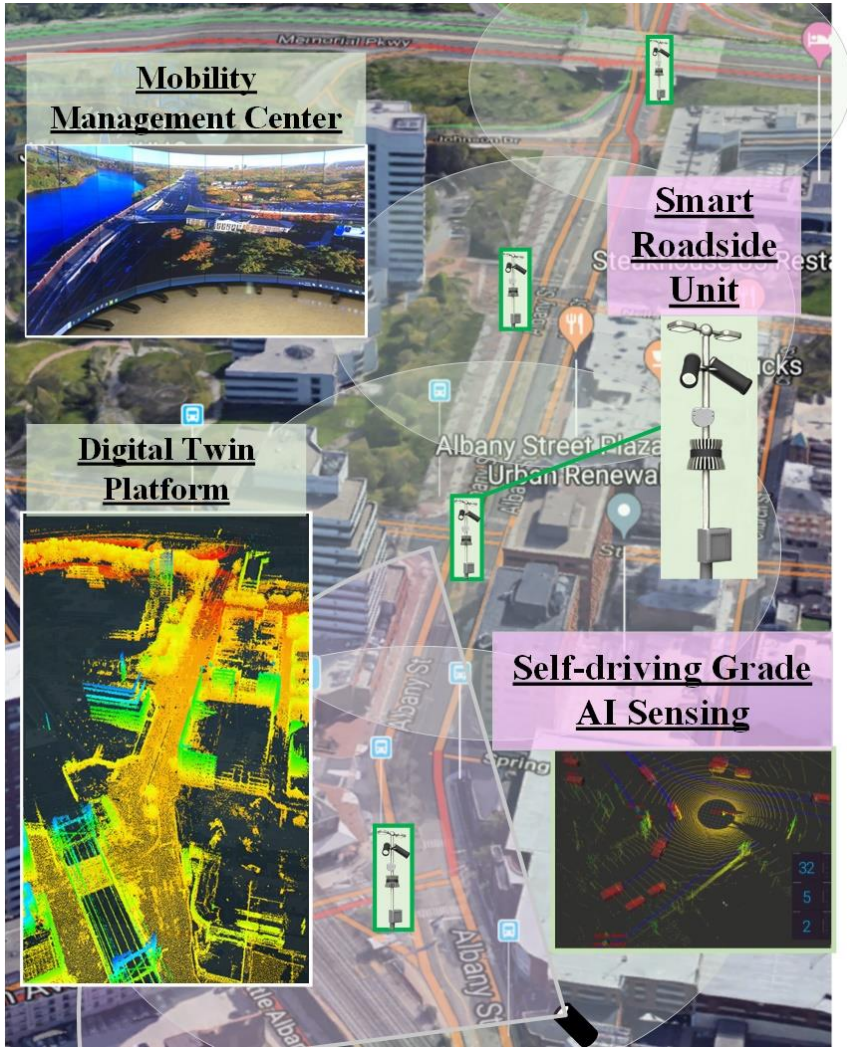
Background

DataCity Smart Mobility Testing Ground Project

- **Self-Driving-Grade Roadside** Sensing and Computing Infrastructure
- **Smart Mobility Management Center**
- **Digital Twin** platform to support early-stage R&D
- V2X Smartphone-based **Community Mobility Applications**



- Smart Mobility **Data Hub Application**
- Technology **Testing and Certification Center**
- Mobility Technology **Breeding Ground**

Background - Self-Driving-Grade Roadside Sensor

Sensor:

Velodyne Alpha Prime VLS-128 Beam

Edge Compute:

NVIDIA Jetson Xavier: LiDAR Analytics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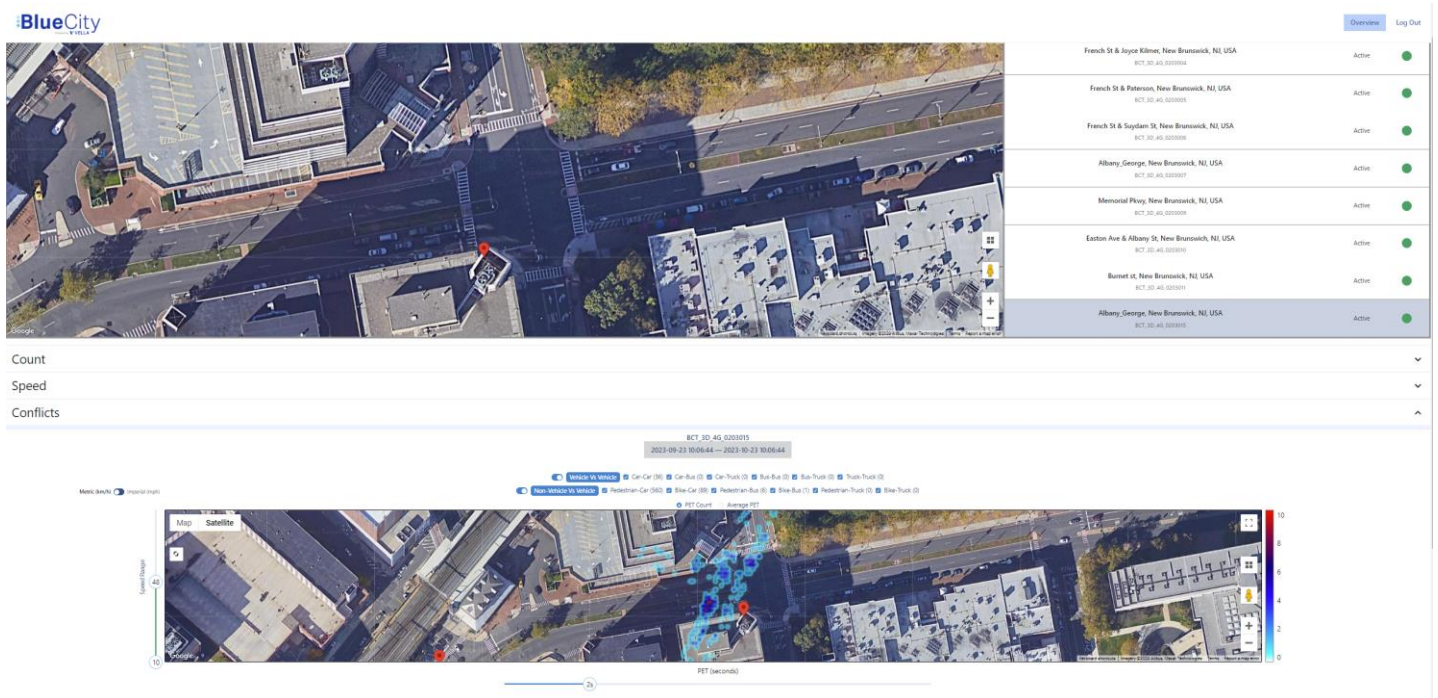
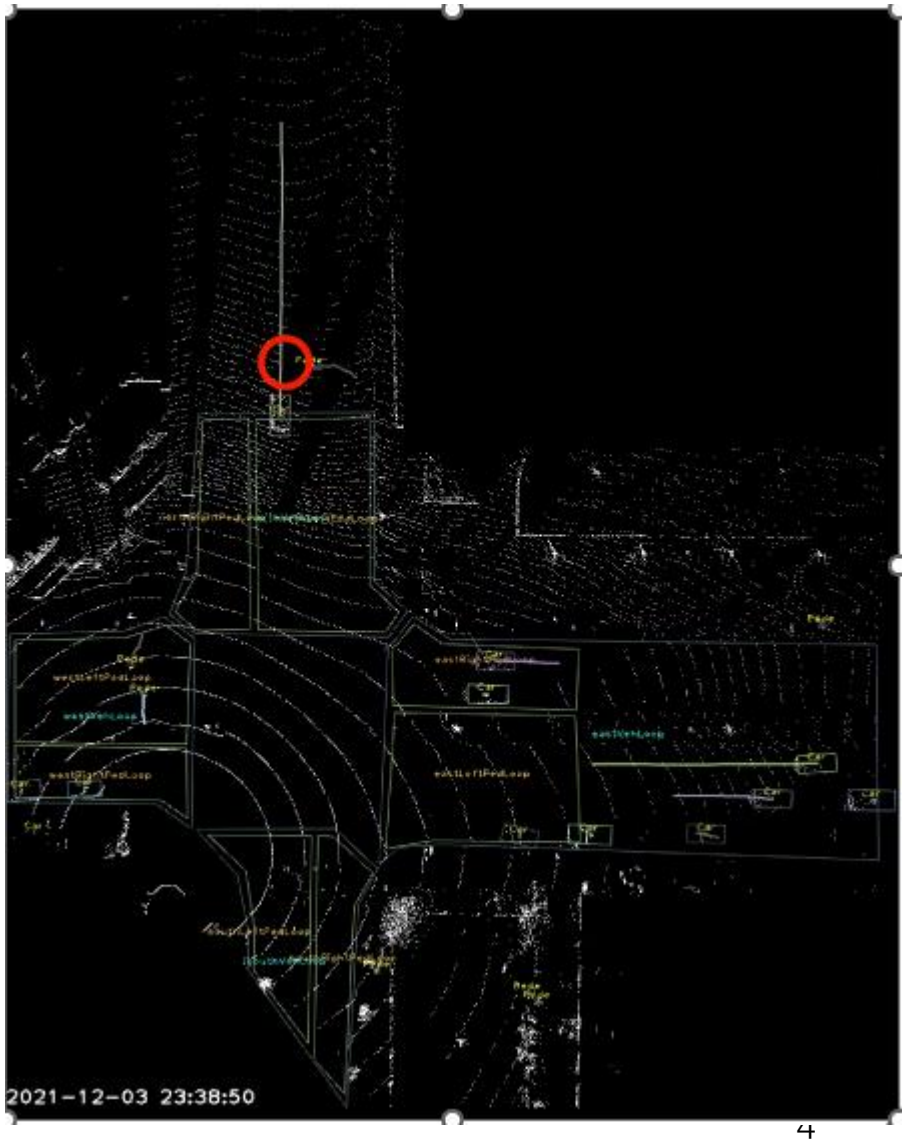
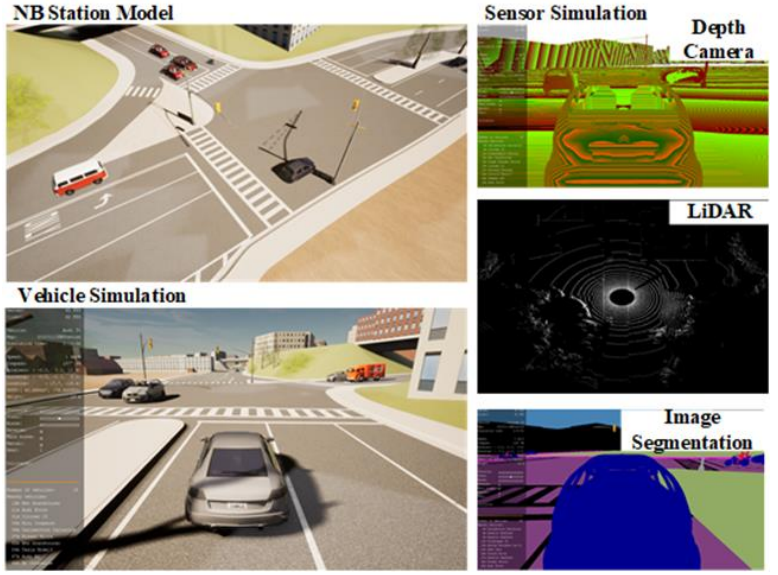
Background - Self-Driving-Grade Roadside Sensor





Background - Digital Twin platform

- **Traffic Digital Twin Model**: 3D virtual replications of the vehicle, pedestrian, infrastructure, and environmental dynamics of real-world transportation systems
- **CARLA Emulator:** Open-source simulation platform supports of sensor suites, environmental conditions, full control of all static and dynamic actors, maps generation
- **Digital Twin Input:** Virtual world static assets, High quality traffic data
- **Potential Application**: Automated Technology, Drive Behavior



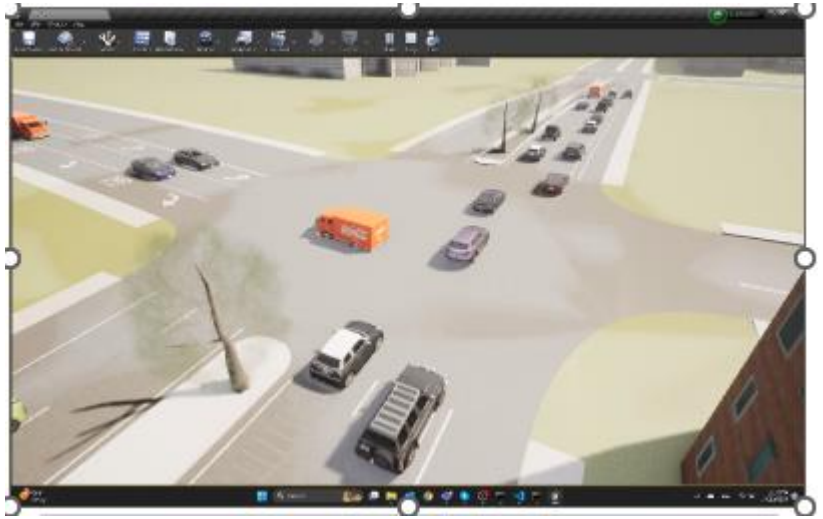
Research Problem

Trajectory Data Quality Issues:

- Blind Spot
- Unstable Frames
- Inconsistent Headings
- Missing trajectory segments

Issues Reflected in the Digital Twin

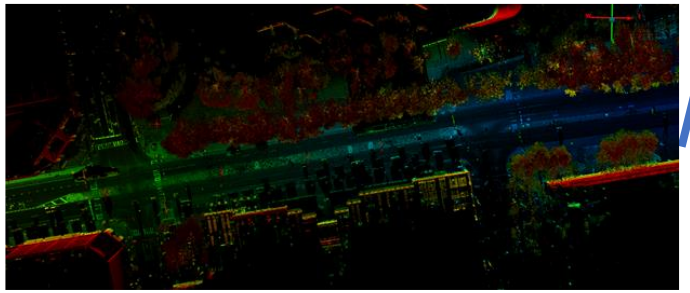
- Vehicles not facing correct travel directions
- Disappearing, or switching appearances
- Potential Safety issue when deploying CAV



Methodology - Static

LiDAR location and orientation

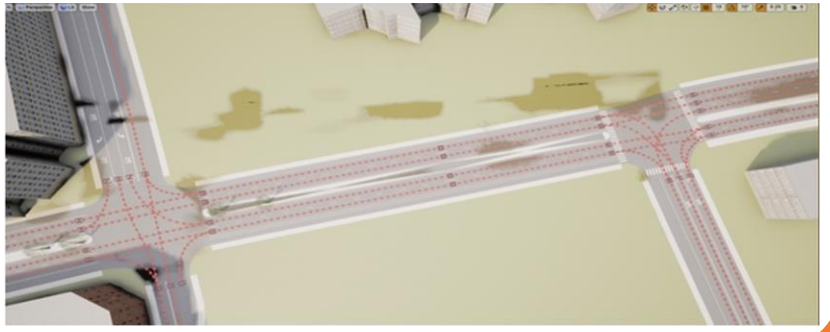
LiDAR scanning File
(Dr. Gong's group contribution)



Infrastructure and road network reconstruction

Centerline points of roadway network

3D virtual world



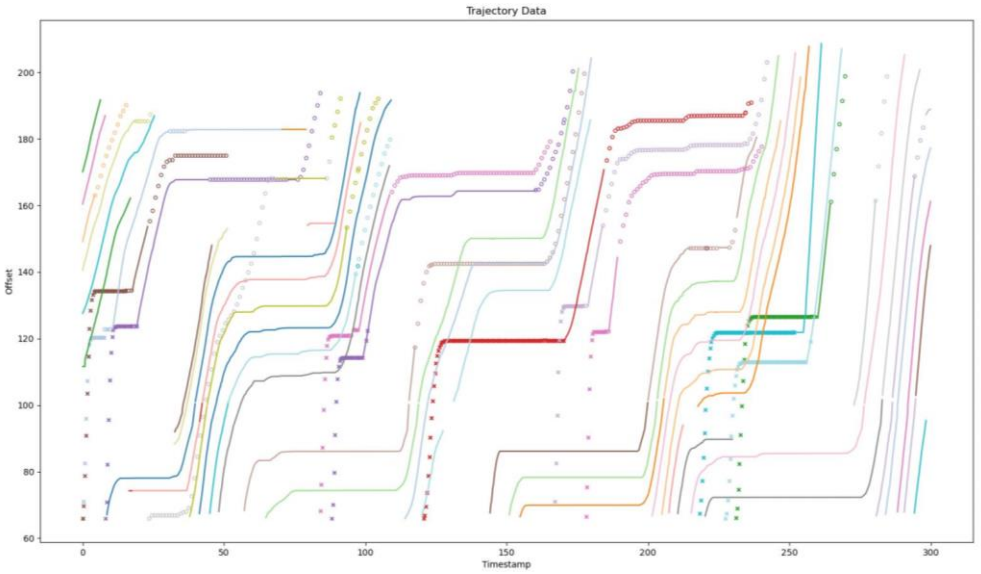
Methodology - Trajectory

STEP ONE: Waypoints in the Centerline Map

STEP TWO: Vehicle Trajectory Point Projection

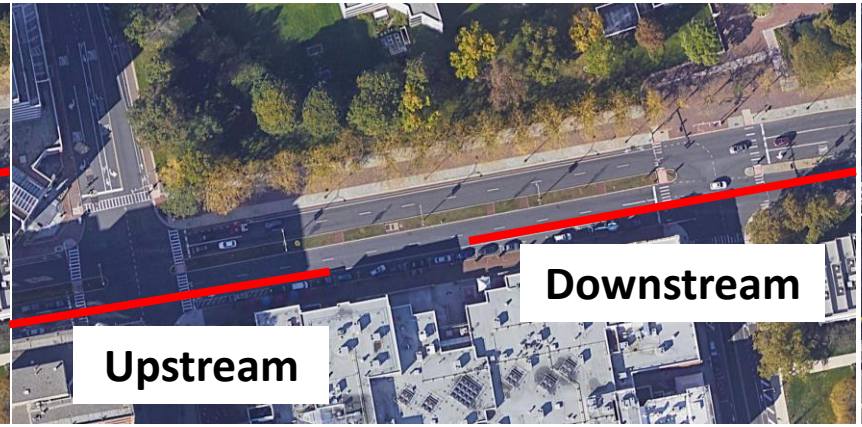
$$\text{Trajectory Point}(x, y, t) \rightarrow \text{Trajectory Point}(S, t, \text{lane information})$$

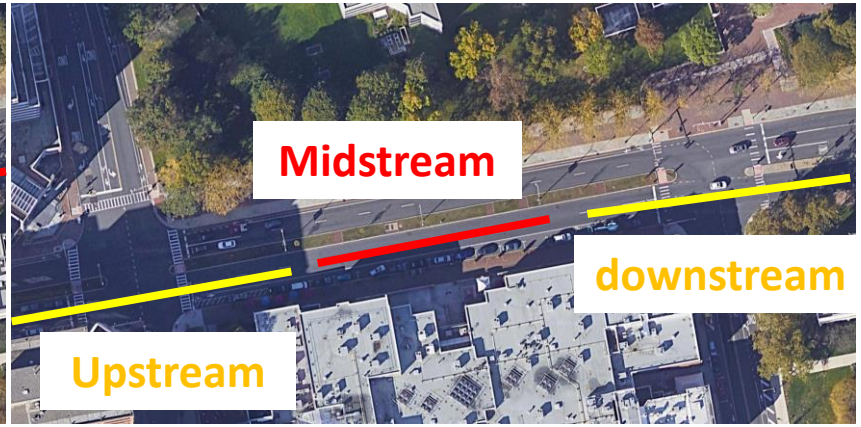
Methodology - Trajectory



STEP THREE: Vehicle Trajectory Stitching and Reconstruction

- **Complete Trajectory**
- **Upstream Trajectory**
- **Downstream Trajectory**
- **Midstream Trajectory**



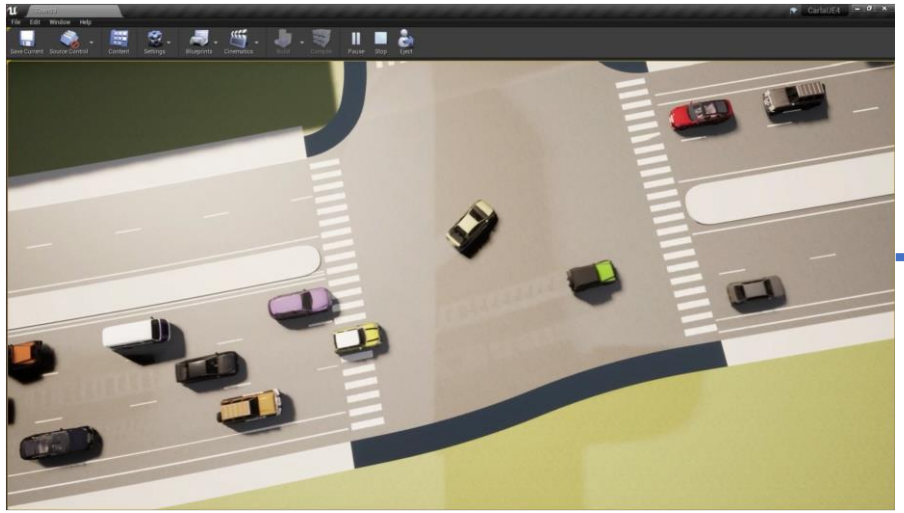


Trajectory Stitching, Reconstruction, Interpolation:
Small time interval Predication based on timestamp gaps, offset gaps, instantaneous velocity

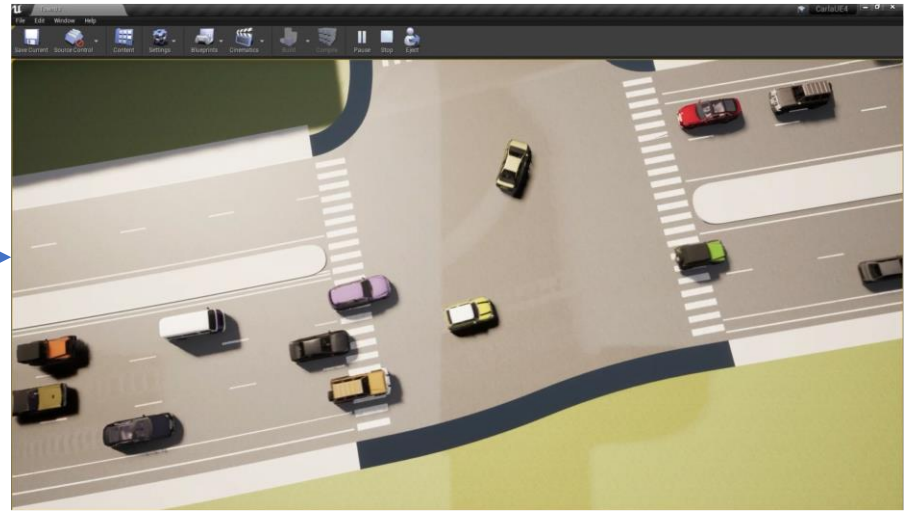
Methodology - Control

STEP FOUR: Vehicle Dynamic Control Method

For each time frame in Digital Twin Model, update the spatial information of each vehicle object



Time: N

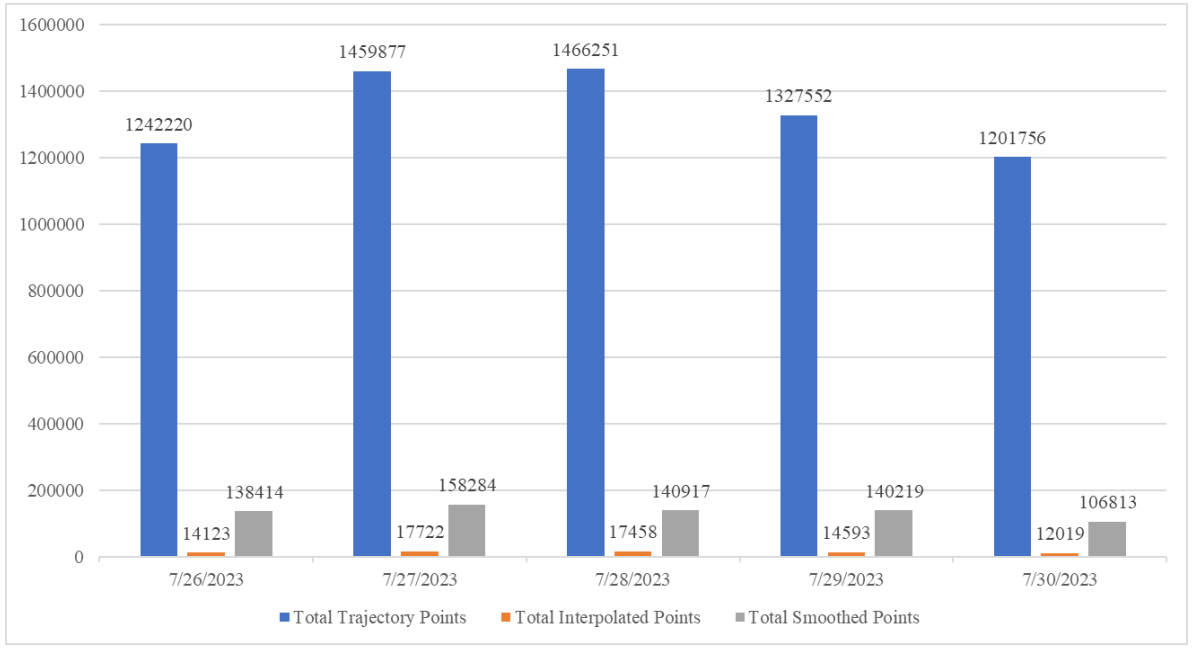


Time: N+0.1

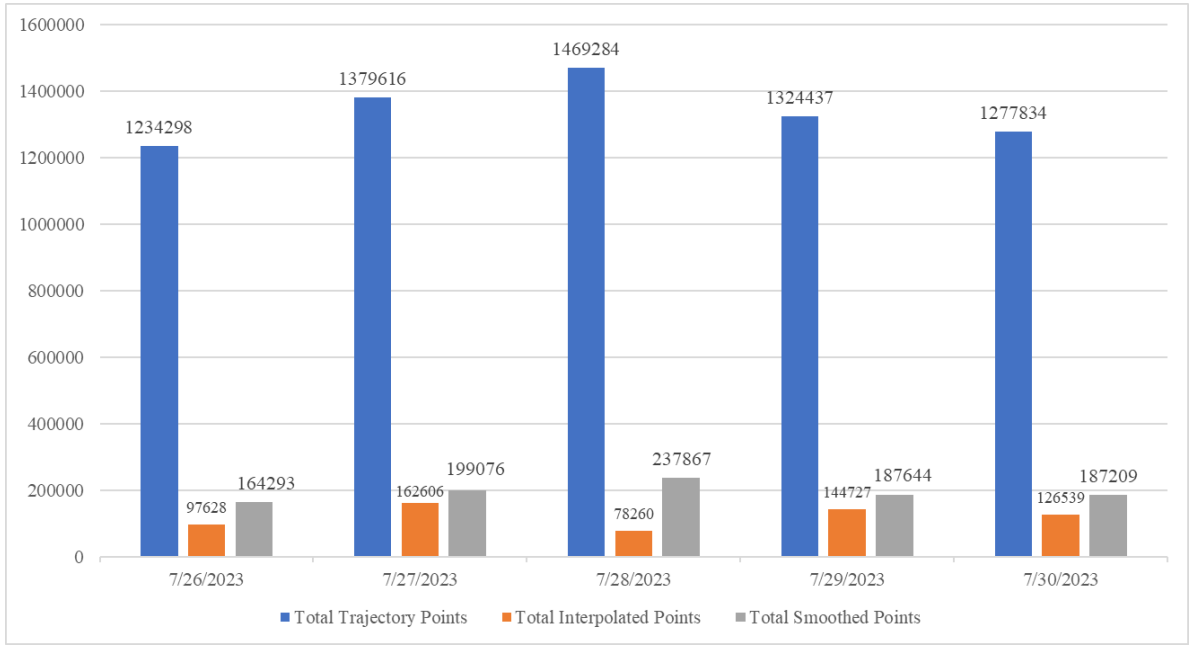
Trajectory Point Processing Percentage

Interpolation: Missing/Disappearing trajectory point caused lost frame and mis-tracking

Smooth: Speed distortion (unreasonable sudden change) and incorrect position (back-and-forth wiggling detection of stop vehicle)



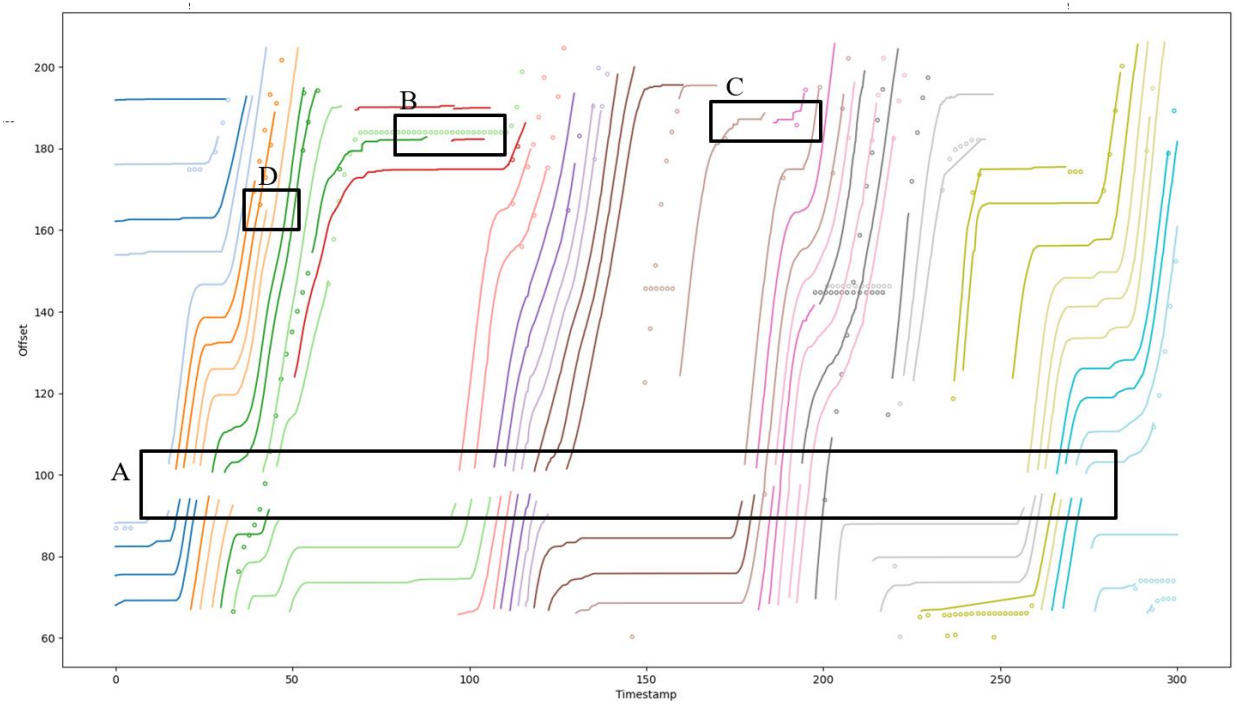
Albany @ George Intersection



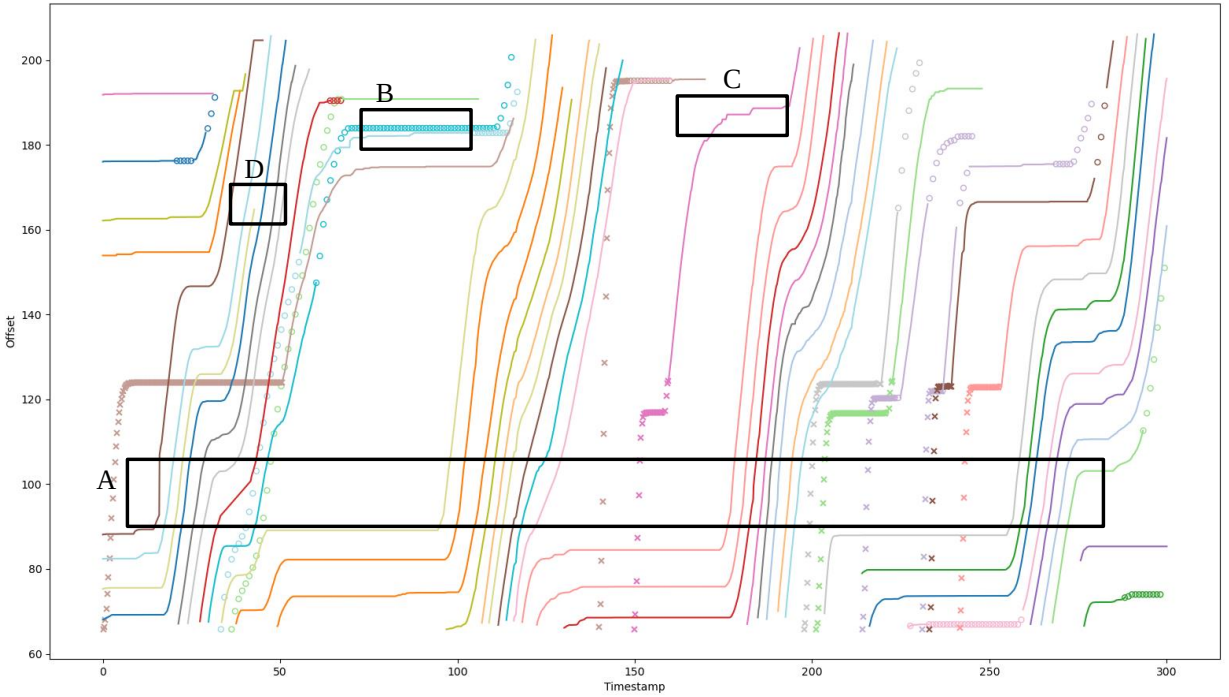
Albany @ Neilson Intersection

Trajectory Stitching and Reconstruction

Trajectory Spatial-temporal Diagram (One lane)

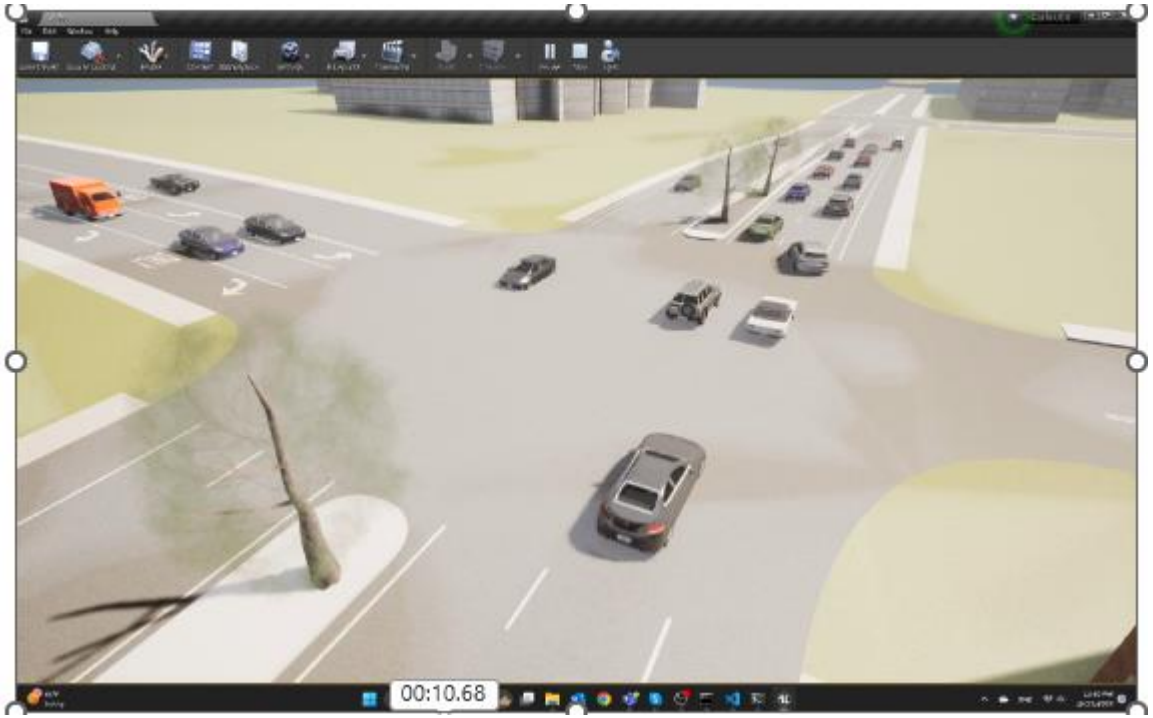


Before Processed



After Processed

Trajectory Stitching and Reconstruction



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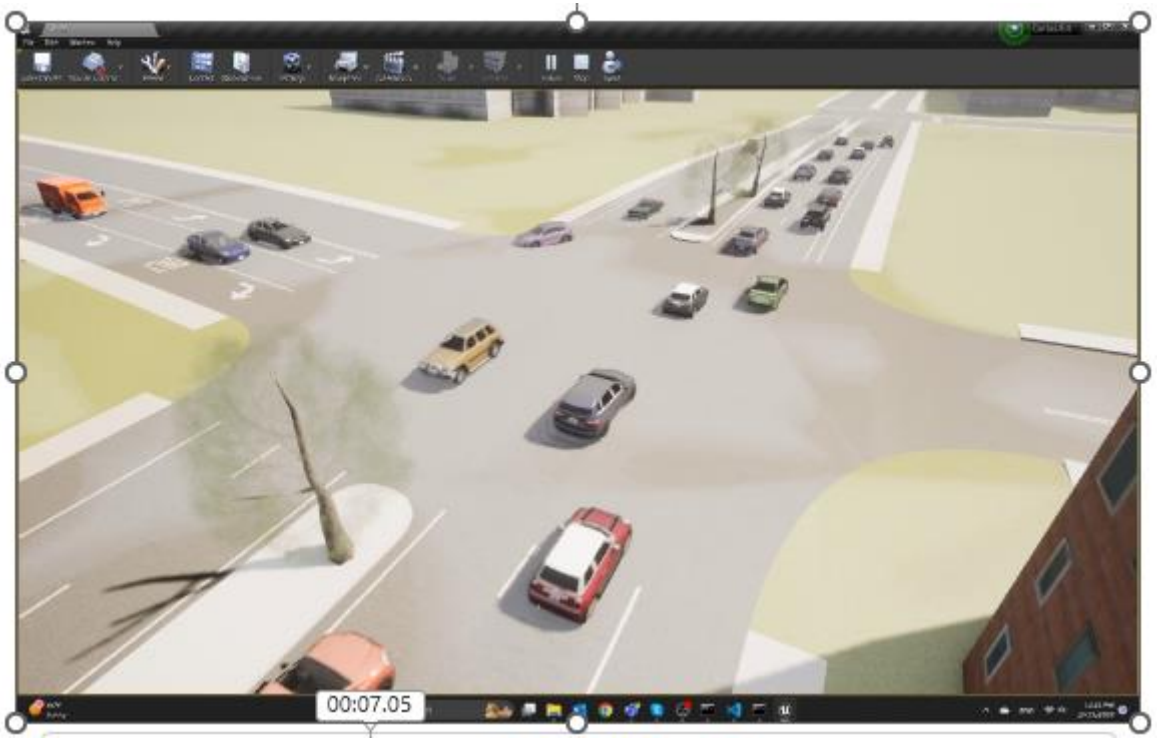


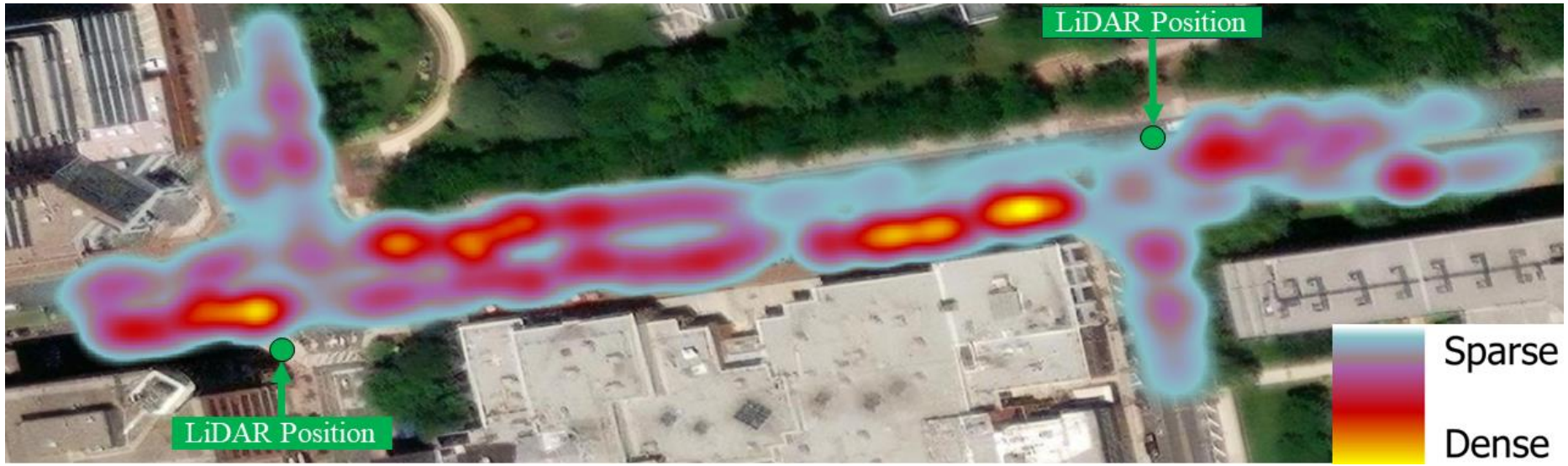
After Processed

Trajectory Stitching Result Analysis

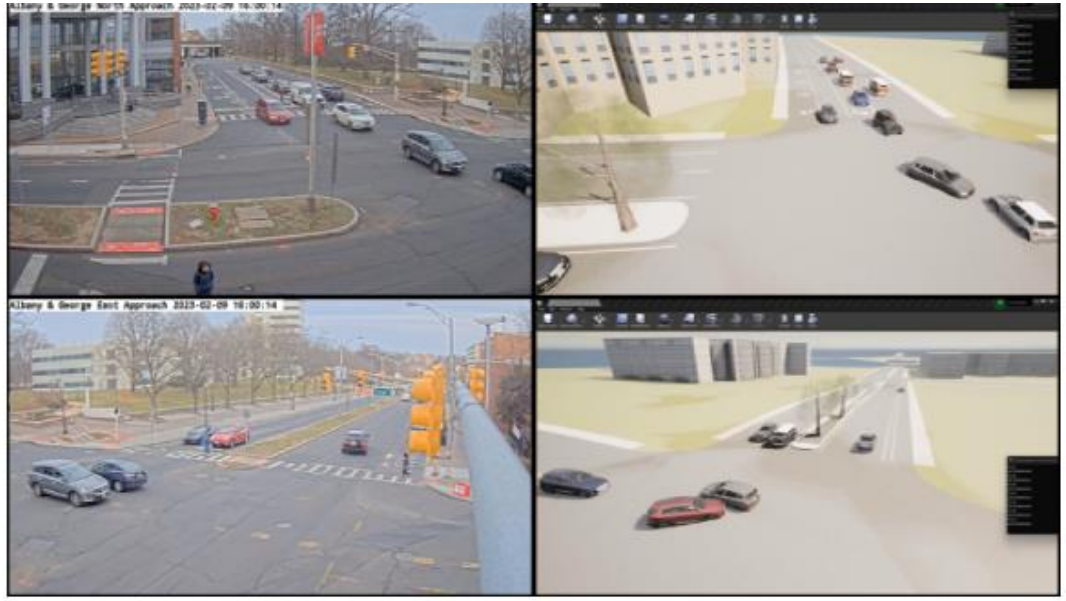
Rapid ID switching count: an evaluation index for detecting broken trajectories

ID Switching Count Before and After Processing at Two Intersections

Intersection		06/26/23	06/27/23	06/28/23	06/29/23	06/30/23	Average
Albany@ George	Before	2578	2804	3035	2916	2566	2780
	After	162	136	240	178	126	168
	Reduction	93.7%	95.1%	92.1%	93.9%	95.1%	94.0%
Albany@ Neilson	Before	4129	4780	4547	4706	4729	4578
	After	266	324	327	312	320	310
	Reduction	93.6%	93.2%	92.8%	93.4%	93.2%	93.2%



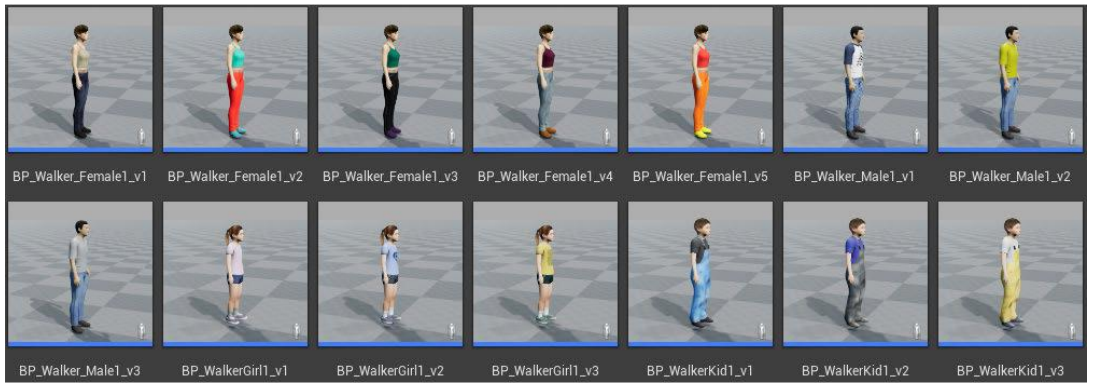
Digital Twin Model Demonstration



Remaining Works

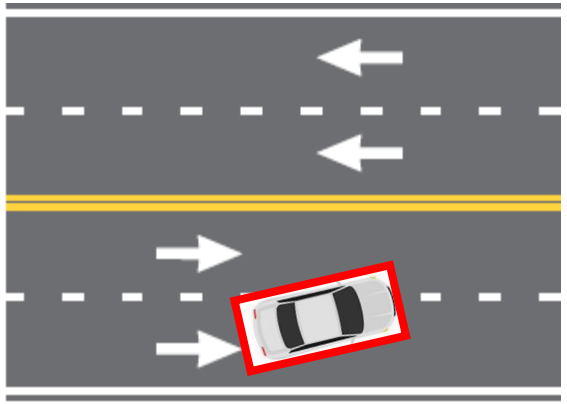
Pedestrian in Digital Twin Model

- Same issue as Vehicle, but more complicated
- 3D modeling, such as using skateboard, Scooter



More Accurate Lane Projection

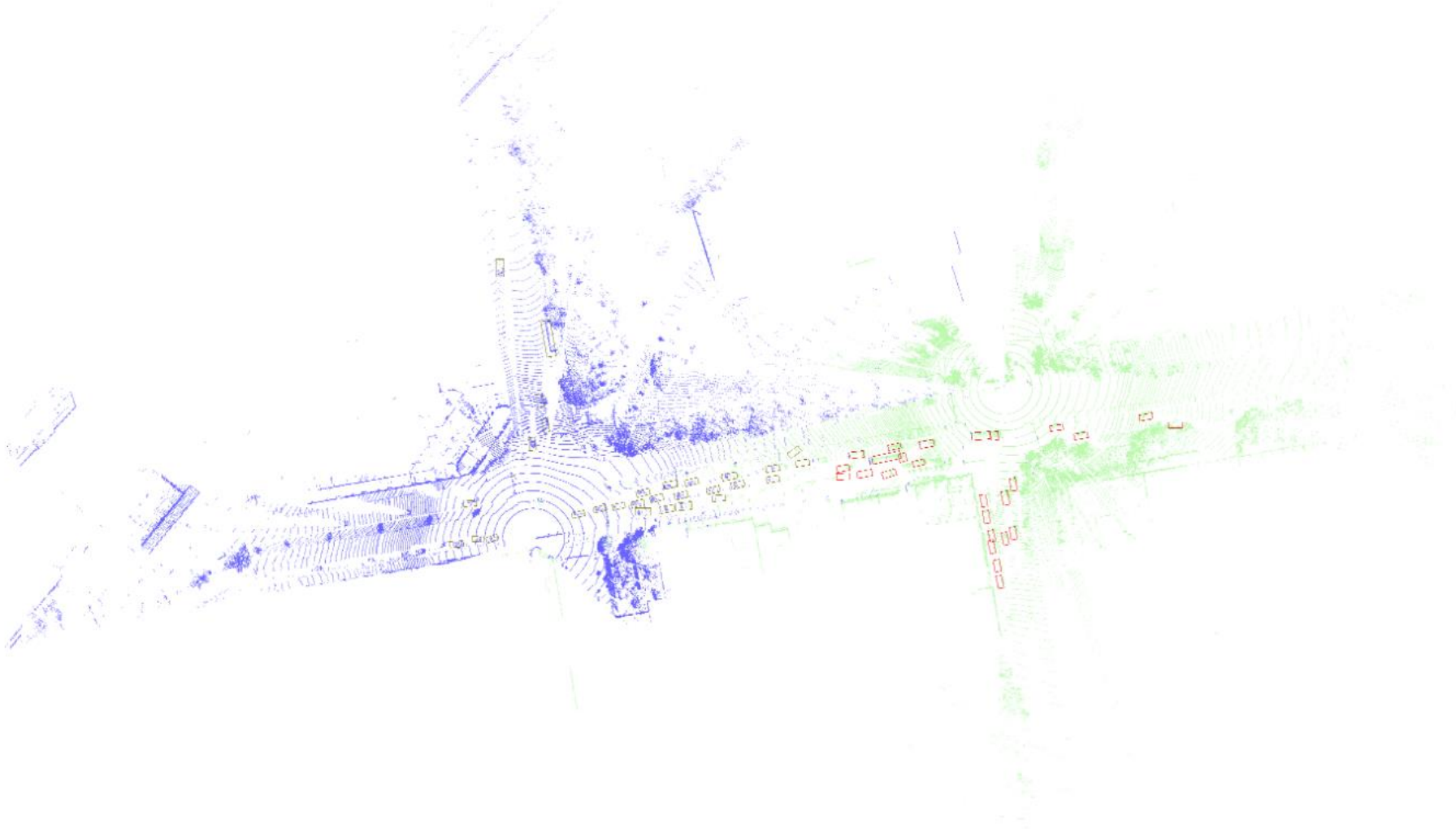
- More powerful on lane changing behavior detection
- More flexible for arterial streets



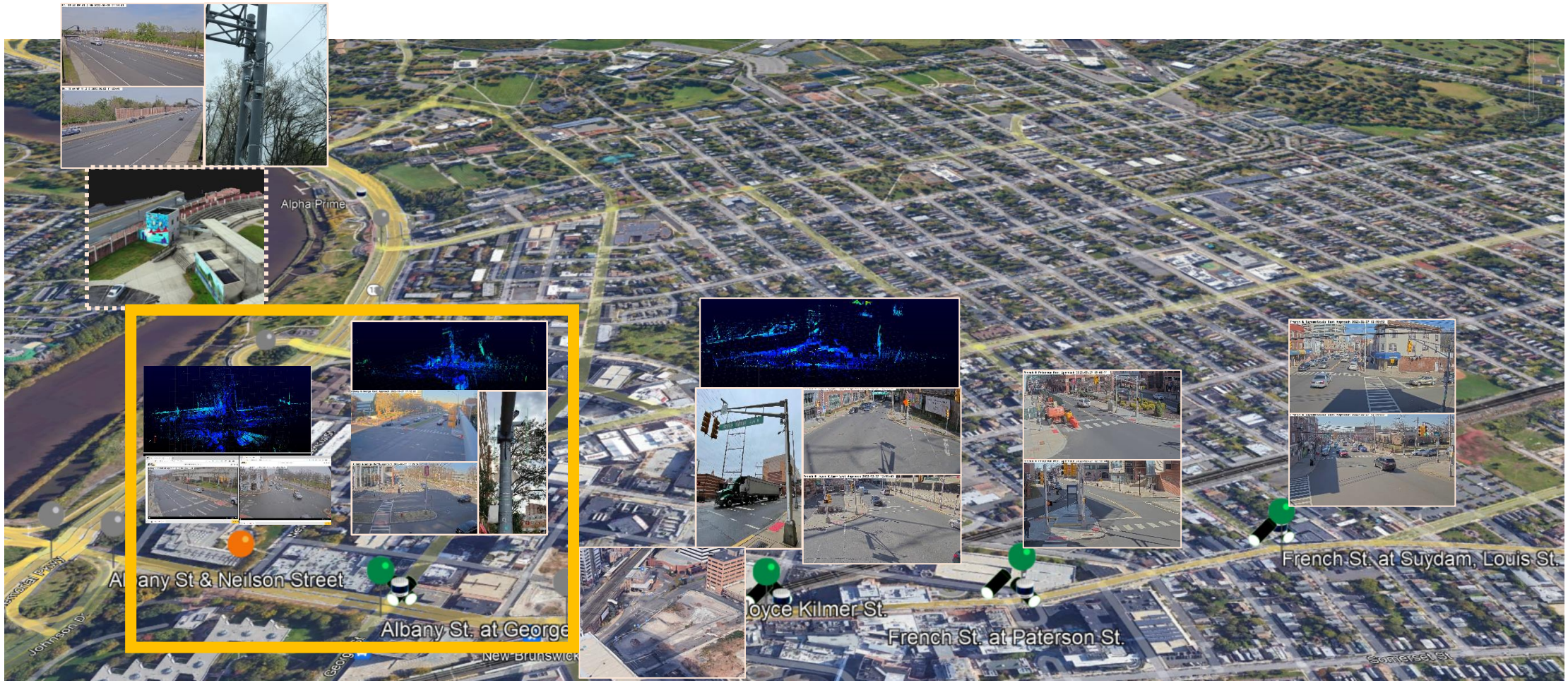
Optimization the latency in Digital Twin Model

- High Hardware Requirement
- GPU Consuming

Future Work



Future Work


Alpha Prime
Albany St & Neilson Street
Albany St. at George
French St. at Paterson St.
French St. at Suydam, Louis St.

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THANK YOU!

Q&A