Automatically Learning Driver Behaviors for Safe Autonomous Vehicle Navigation

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If you are driving, which driver will you pay attention to?

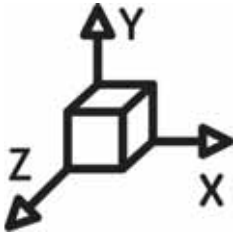
Identifying Driving behavior allows autonomous systems to:

Pay extra "attention"

Avoid getting close to them

Re-run perception algorithms at higher resolution for those area

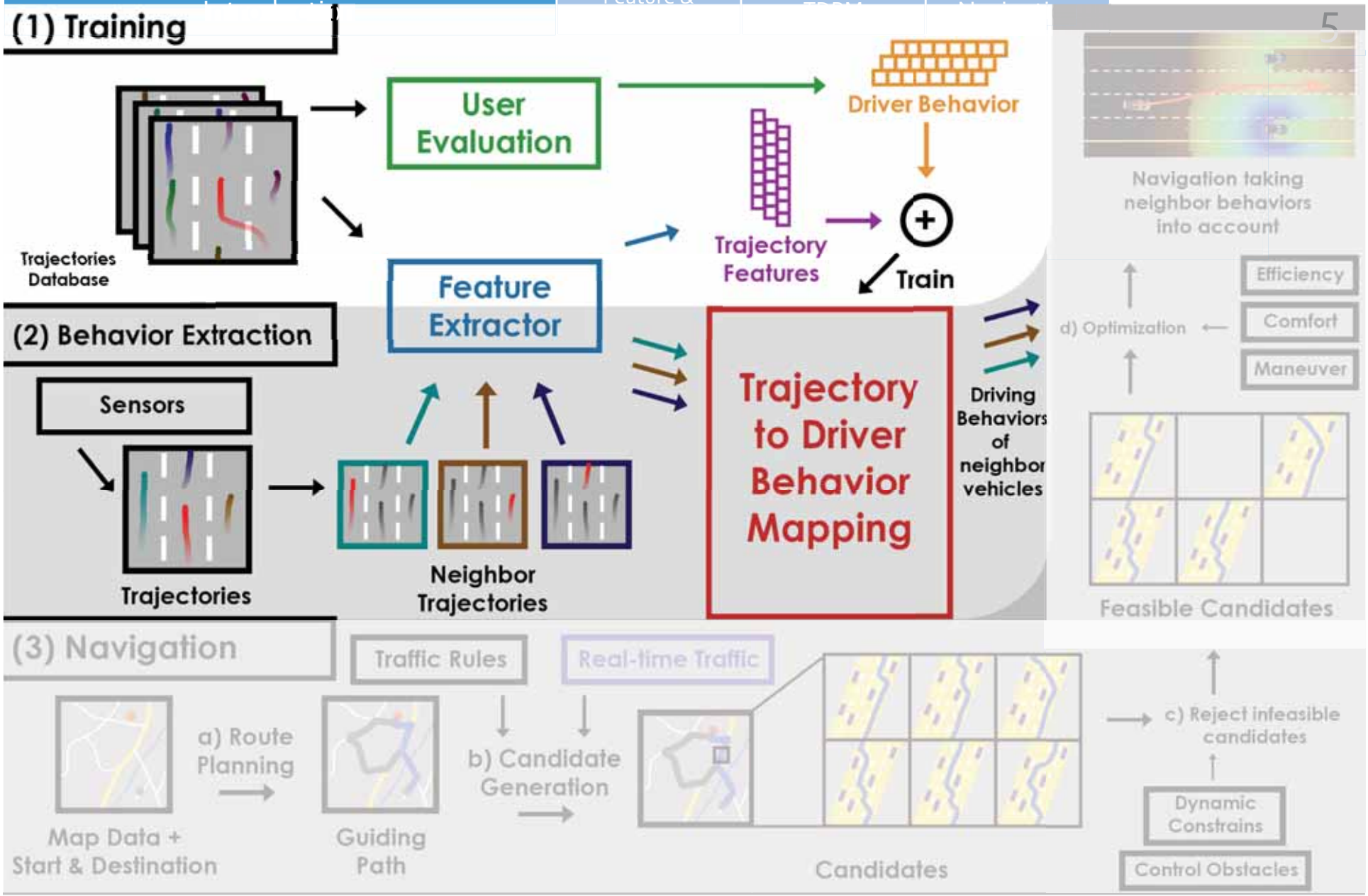
Main contributions



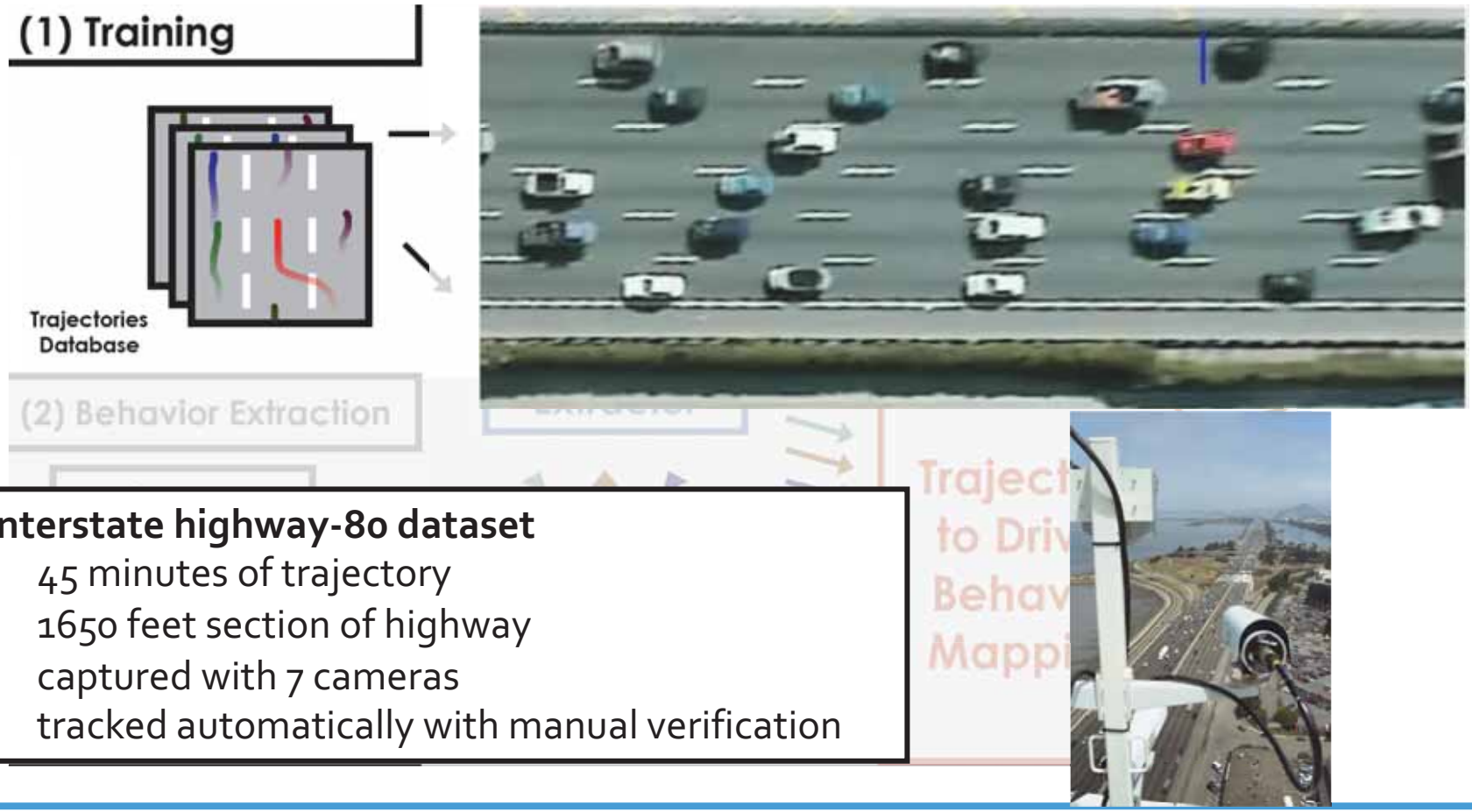
Feature extraction from trajectories in real-time

Trajectory to Driver Behavior Mapping

Improved Real-time Navigation



Trajectory Database



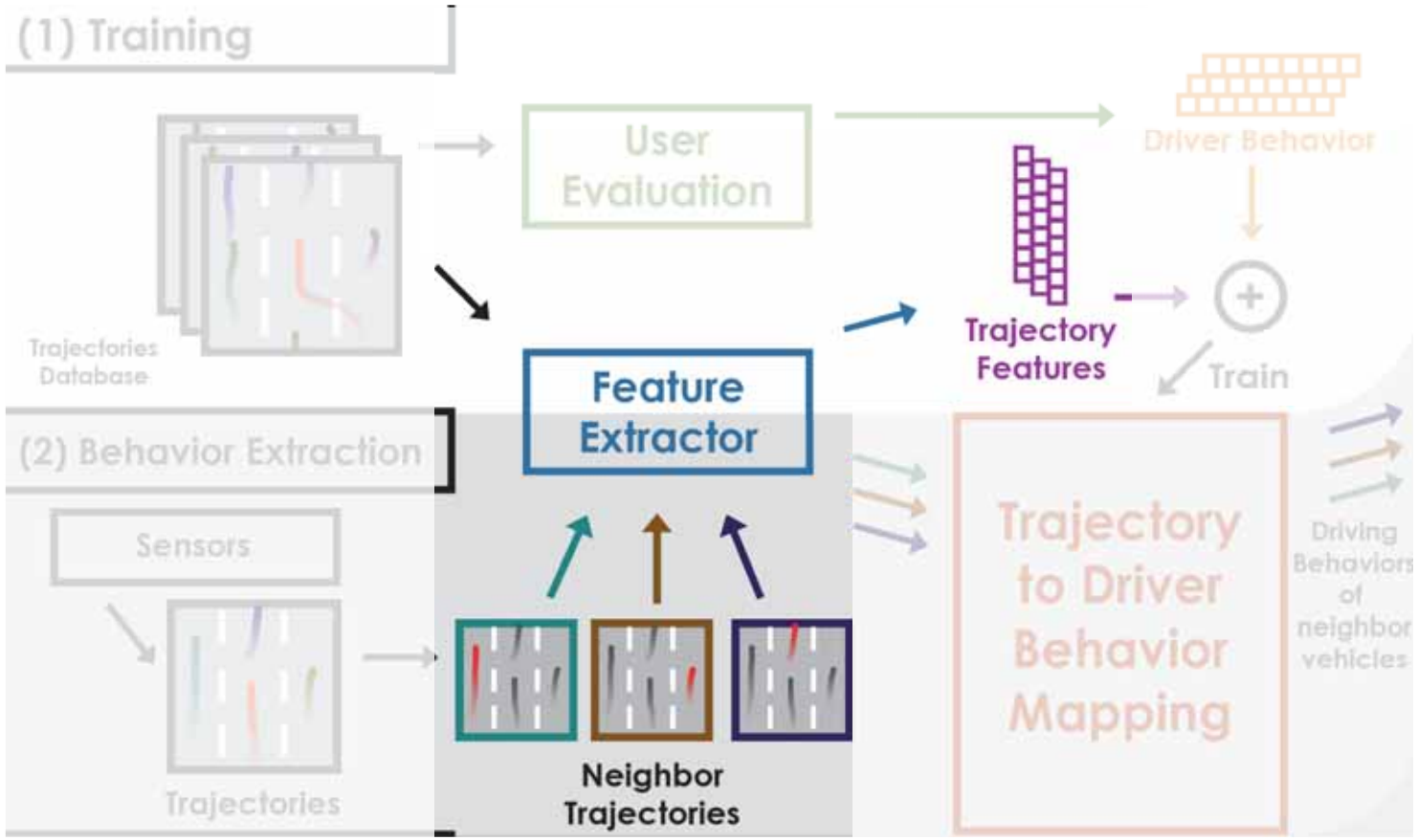
Interstate highway-80 dataset

- 45 minutes of trajectory
- 1650 feet section of highway
- captured with 7 cameras
- tracked automatically with manual verification

User Evaluation

Symbol	Description	Symbol	Level of Attention when
b_0	Aggressive	b_6	following the target
b_1	Reckless	b_7	preceding the target
b_2	Threatening	b_8	driving next to the target
b_3	Careful	b_9	far from the target
b_4	Cautious		
b_5	Timid		

Feature Extraction



Feature Extraction

Symbol	Notation	Description
f_0	v_{front}	Average relative speed to the car in front
f_1	v_{back}	Average relative speed to the car in the back
f_2	v_{left}	Average relative speed to cars in the left lane
f_3	v_{right}	Average relative speed to cars in the right lane
f_4	v_{nei}	Relative speed to neighbors
f_5	v_{avg}	Average velocity
f_6	s_{front}	Distance with front car
f_7	j_l	Longitudinal jerk
f_8	j_p	Progressive jerk
f_9	s_{center}	Lane following metric

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Relative Speed

- Previous works: using average speed to the car in front / back / adjacent lane
- Problems:
  i) features missing when there is no car in relative positions,
  ii) driving slow may not imply carefully, and
  iii) driving faster than an immediate neighbor is more aggressive

$$v_{nei} = \int \sum_{n \in N} \max(0, \frac{v(t) - v_n(t)}{dist(x(t), x_n(t))}) dt$$

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Lane following metric

- This metric captures the 'drifting' behavior of typical careless drivers:

$$s_{center} = \int |s_C(t)| \left[\mu + \int_{t-\tau}^{t} |s'_{\emptyset}(t)| dt \right] dt$$

$$s_C(t) = \begin{cases} 0, & \text{if } \exists t \in C \text{ s.t. } t \in [t-k, t+k], \\ y(t) - y_l, & \text{otherwise.} \end{cases}$$

- where C = {t_1, t_2, ...} with a set of lane changing events, y(t) and y_l are the longitudinal position of a car and the center of the lane respectively, and
  μ and τ are parameters to this metric

Lane following metric

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i) distance between center
ii) rate of change of (i) in the past τ (parameter) seconds
iii) weight (parameter) for driving off-center constantly

Lane following metric

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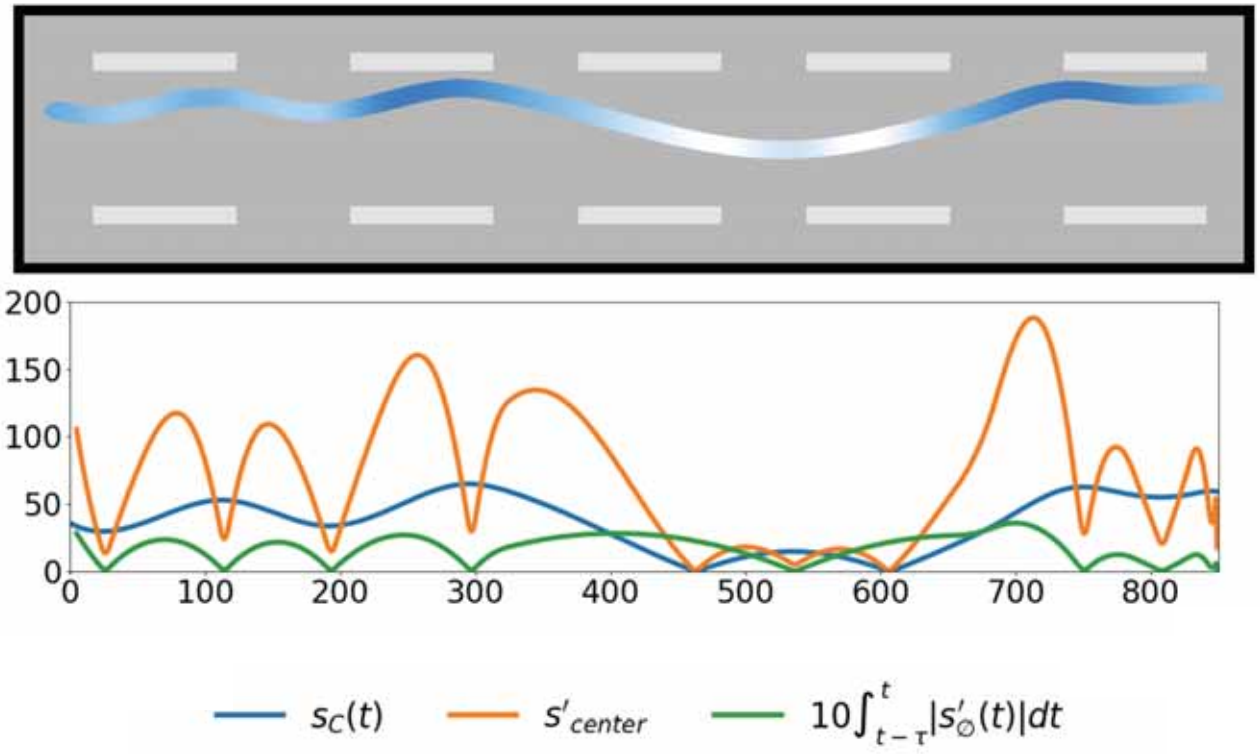

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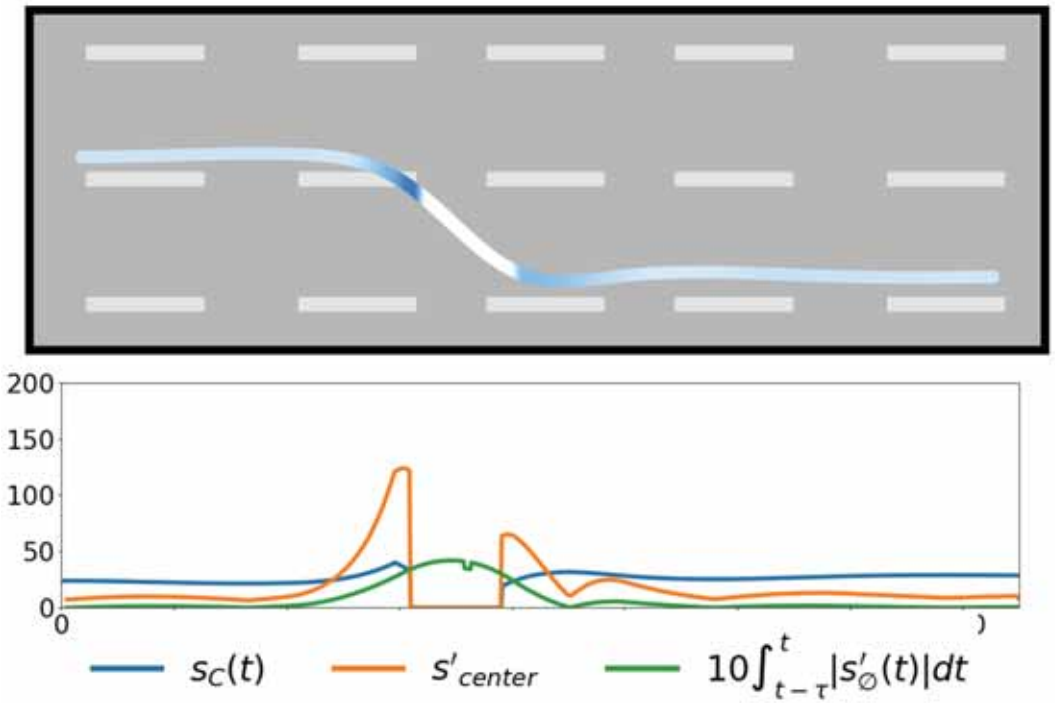
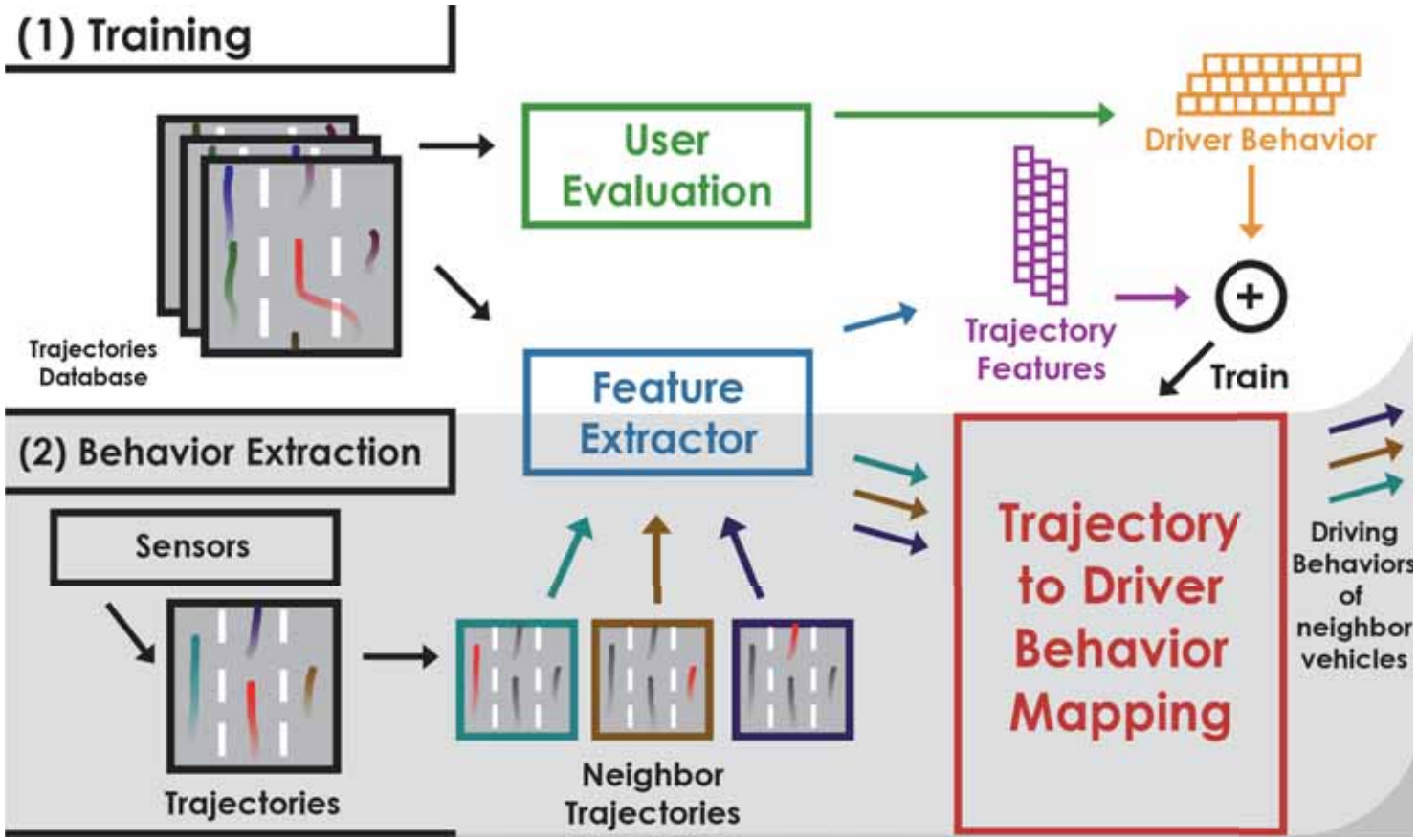


Trajectory to Driver Behavior Mapping



Feature selection

- 5 features that are most favorable in regression analysis are selected

	v_{front}	v_{left}	v_{right}	v_{back}	v_{nei}	v_{avg}	s_{front}	j_l	j_p	s_{center}
Aggressive	-2.7	-2.08	-2.12	-1.78	-2.2	-0.65	-0.62	-1.45	-1.72	-2.05
Reckless	-2.7	-1.62	-3.55	-2.22	-1.35	-1.85	-1.38	-1.7	-3.0	-0.38
Threatening	-1.78	-1.92	-1.92	-2.92	-1.5	-1.72	-2.1	-2.1	-2.4	-0.45
Careful	-1.82	-2.52	-1.92	-2.92	-1.35	-2.58	-2.02	-2.2	-2.48	-0.45
Cautious	-2.05	-2.8	-2.2	-3.05	-1.48	-2.55	-2.0	-2.17	-2.95	-0.52
Timid	-2.17	-1.95	-2.4	-2.55	-1.52	-2.02	-2.0	-2.05	-2.85	-0.52
$Attention_{back}$	-3.35	-1.62	-2.8	-1.88	-1.58	-1.72	-1.88	-2.2	-2.9	-0.52
$Attention_{front}$	-2.62	-3.32	-2.75	-4.5	-1.78	-2.12	-2.33	-2.1	-2.48	-0.75
$Attention_{adj}$	-2.02	-2.12	-3.52	-2.35	-1.78	-1.32	-2.15	-2.5	-2.22	-1.08
$Attention_{far}$	-1.98	-2.4	-3.72	-2.45	-1.75	-1.78	-2.2	-2.48	-2.65	-0.9
Behavior Average	-2.2	-2.15	-2.35	-2.58	-1.57	-1.9	-1.69	-1.95	-2.57	-0.73
Attention Average	-2.49	-2.37	-3.2	-2.79	-1.72	-1.74	-2.14	-2.32	-2.56	-0.81
Overall Average	-2.32	-2.24	-2.69	-2.66	-1.63	-1.83	-1.87	-2.1	-2.56	-0.76

Mapping Validation

- The mapping between the features and the behavior / attention metric is validated using cross-validation. The average error is:

b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9
0.75	0.94	0.78	0.7	0.6	0.89	0.2	0.49	0.38	0.23

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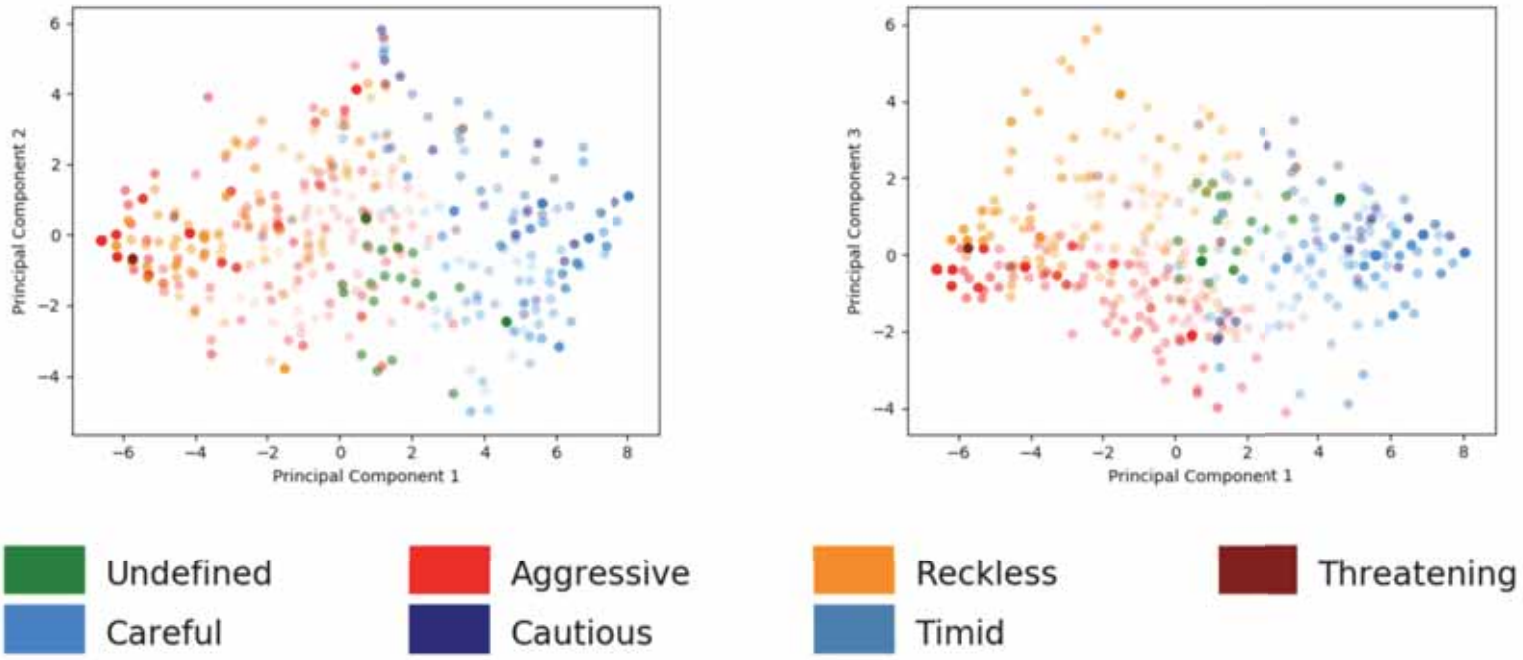
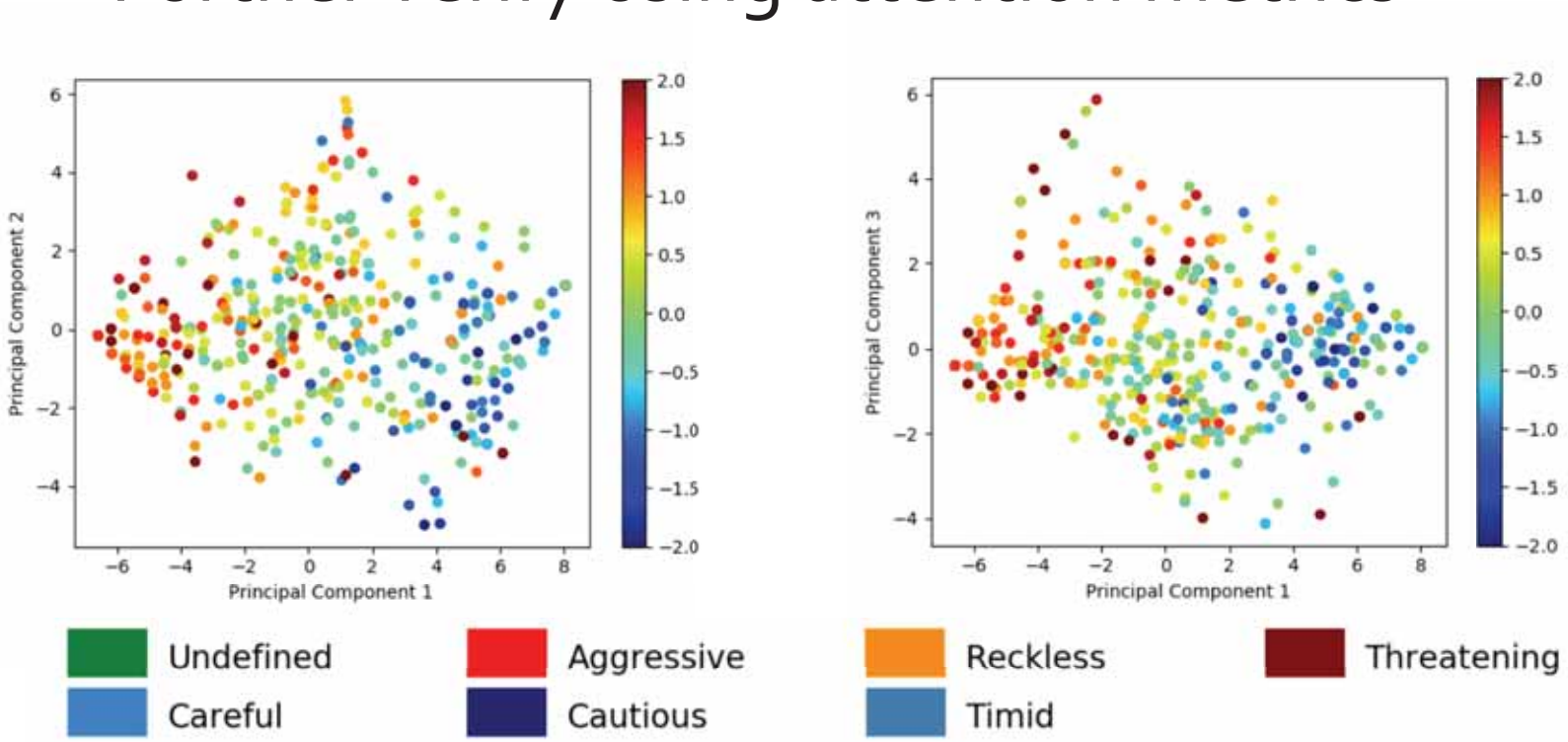
Trajectory to Driver Behavior Mapping

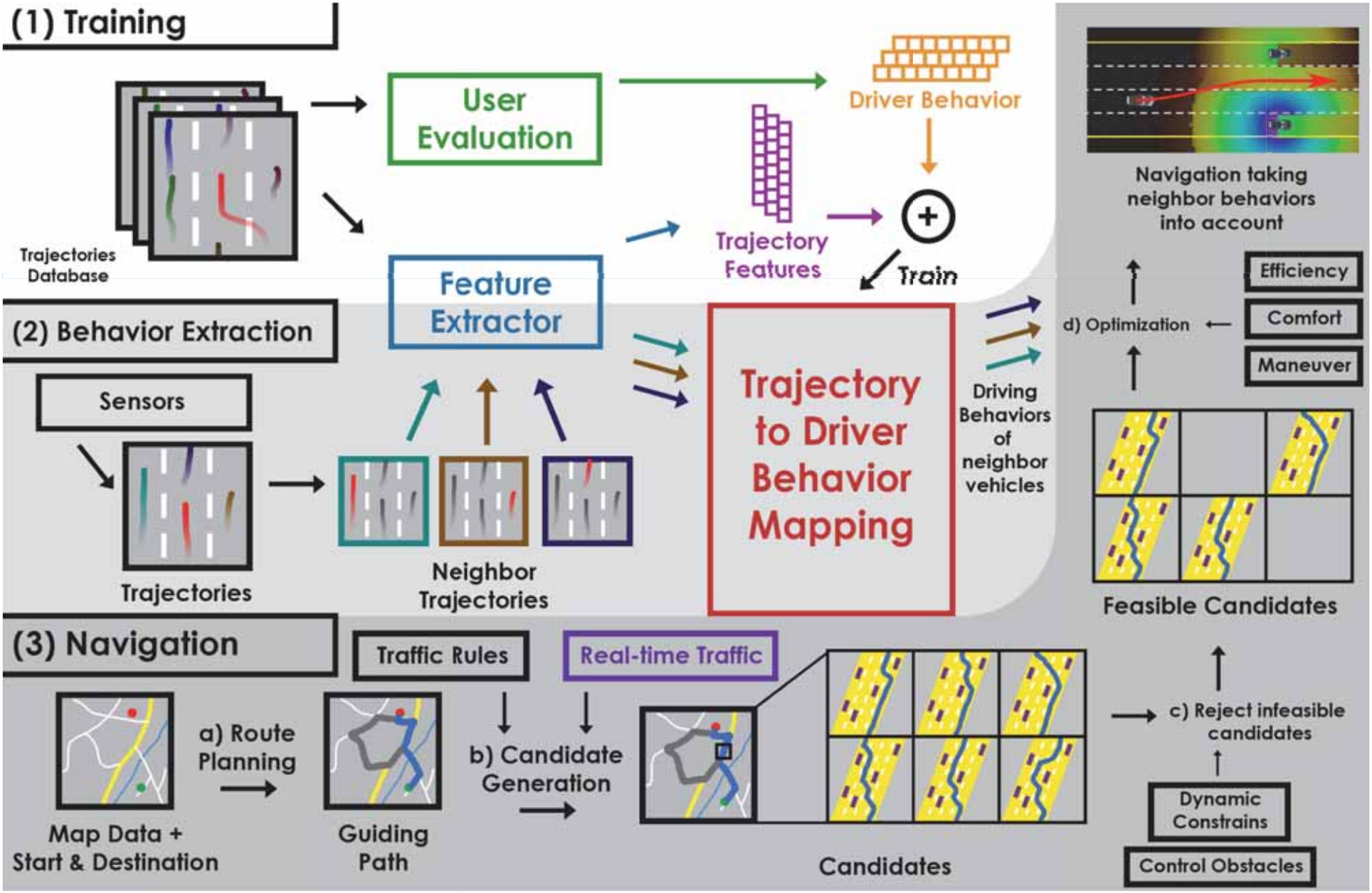
- If we perform PCA on the six behaviors



Trajectory to Driver Behavior Mapping

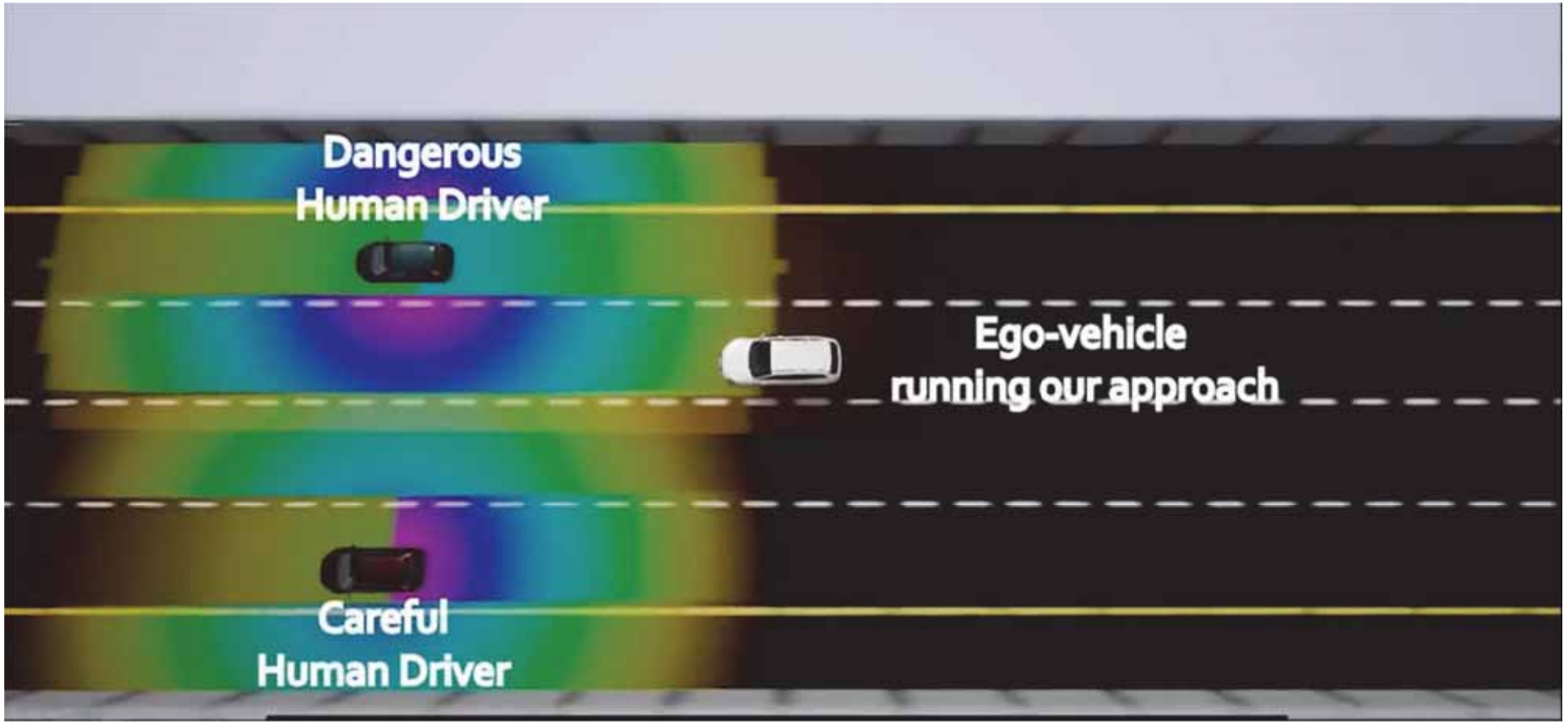
- Further verify using attention metrics





AutonoVi: Autonomous Vehicle Planning with Dynamic Maneuvers and Traffic Constraints, Best et. al (http://gamma.cs.unc.edu/AutonoVi/)

Navigation improvements



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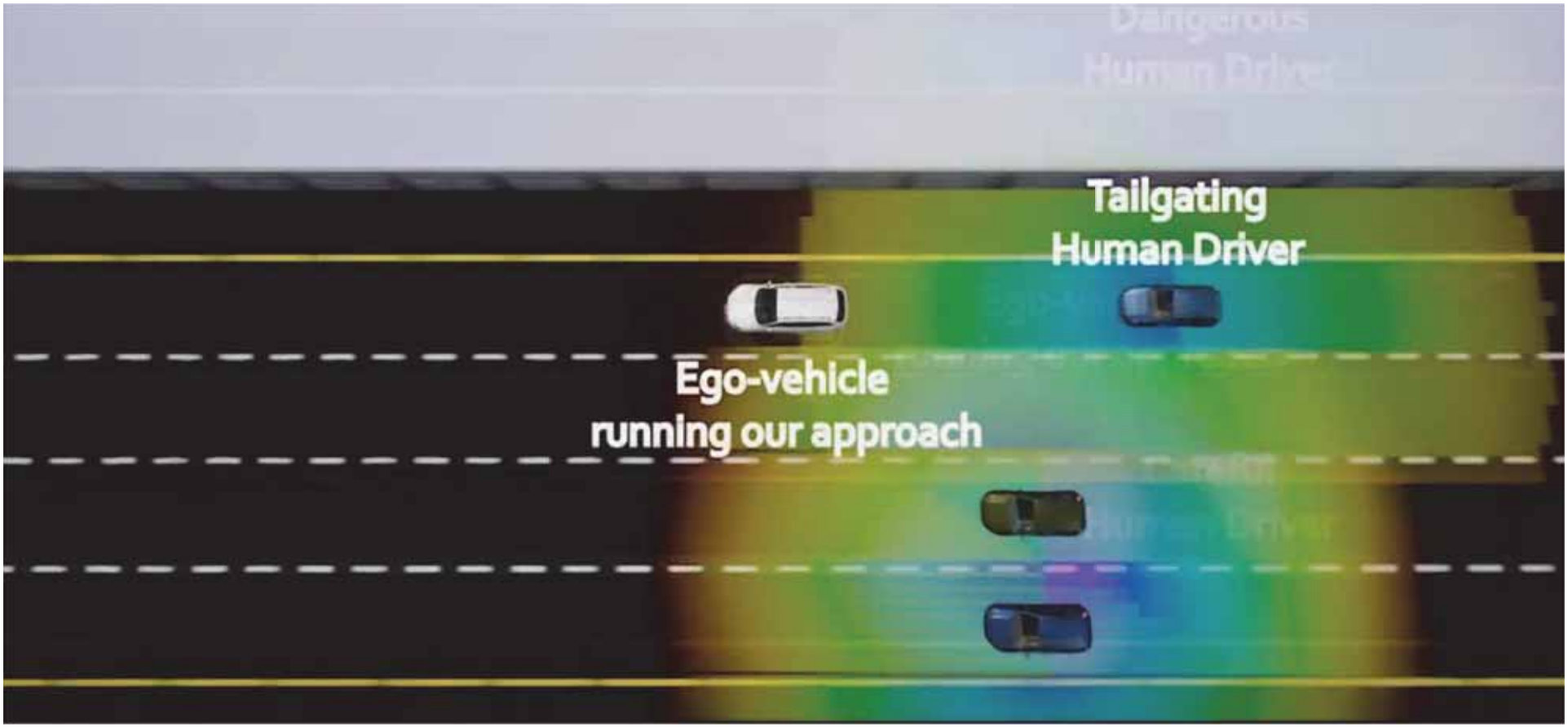

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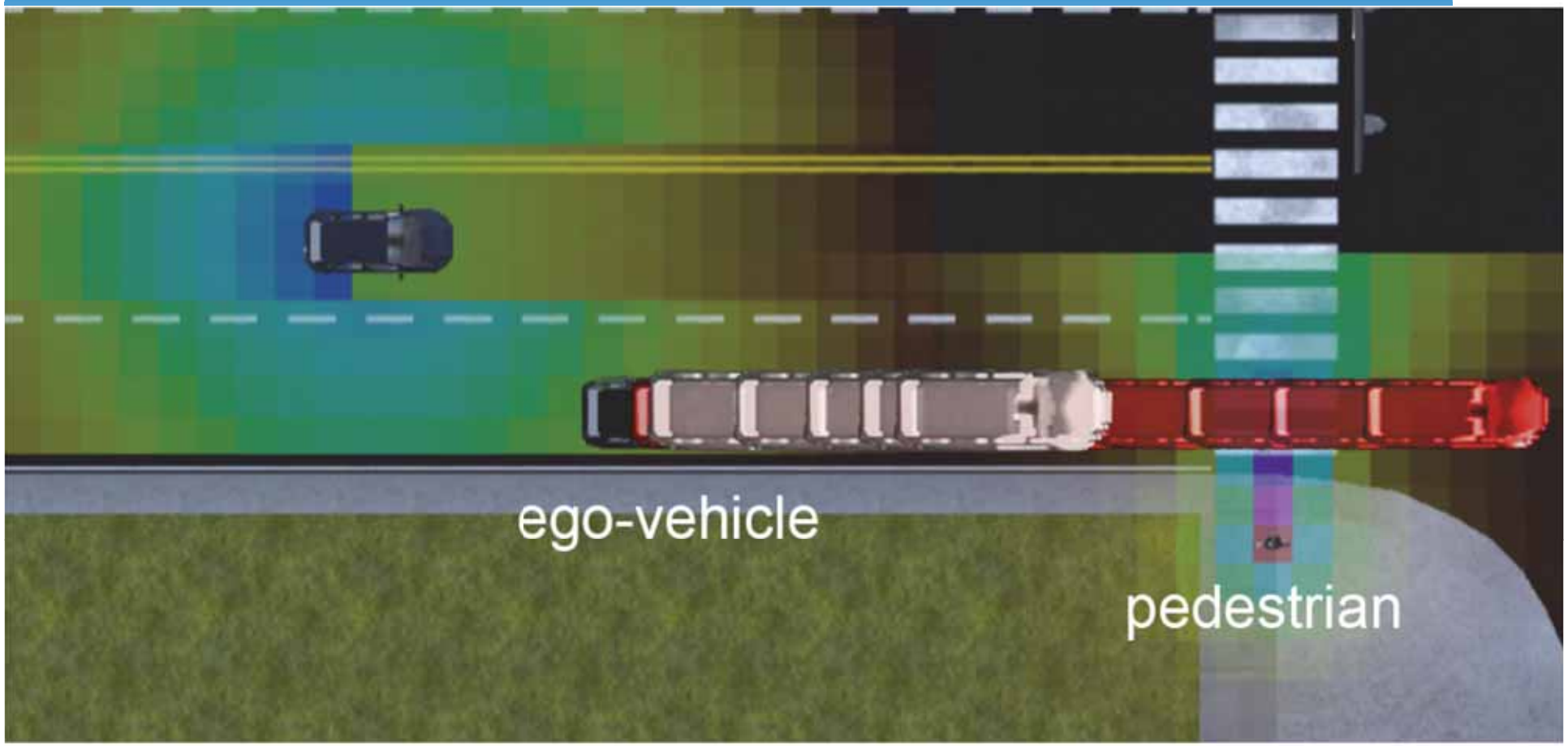

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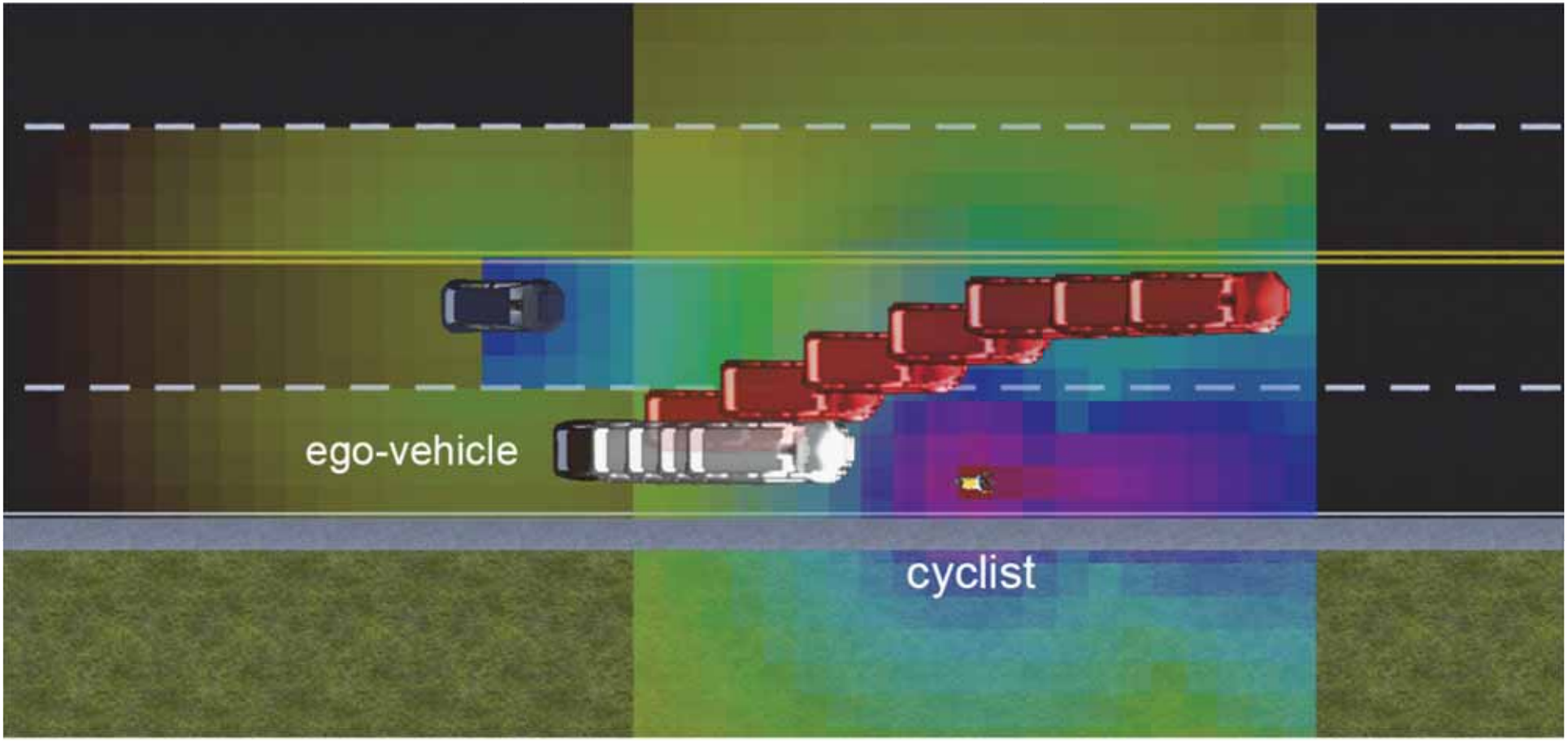

WeBTS7 Regular session, Room 2.L3	Wednesday 11:45
Autonomous Vehicles I