Test Autonomous Vehicles on the Publics Streets

Zhao Ding

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Safety

Energy [Chang, ITSC, 2018]

Security/Privacy [Jia, ITSC, 2017]

Environment

Business/Insurance [Arief, INFORMS, 2018]

Efficient Monotonicity [Huang, ITSC, 2017] — 7

Versatile Kernel [Huang, ACC, 2018] — 8

Experimental Kriging [Zhao, ITSC, 2017] — 5

Accurate Piecewise dist. [Zhao, TITS 2017] — 6

Adaptive Cross-Entropy [Zhao, TITS,2017] — 3

Dynamic Stochastic Optimization, [Zhao, TITS, 2017] — 4

Heuristic Frequentist [Zhao, IAVSD, 2015] — 1

Rigorous Importance Sampling [Zhao, DSCC, 2015] — 2

Safe AI Lab

What We Do

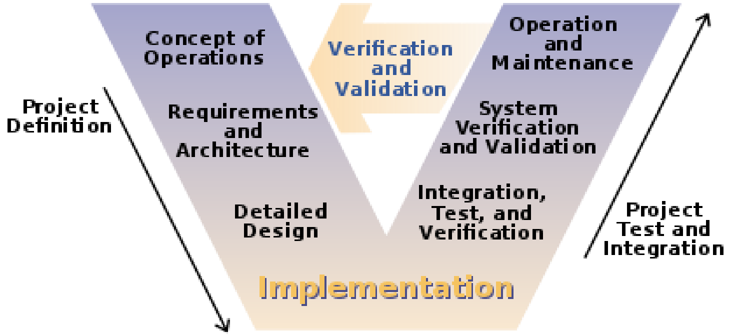
Where We Come From

Where We Go

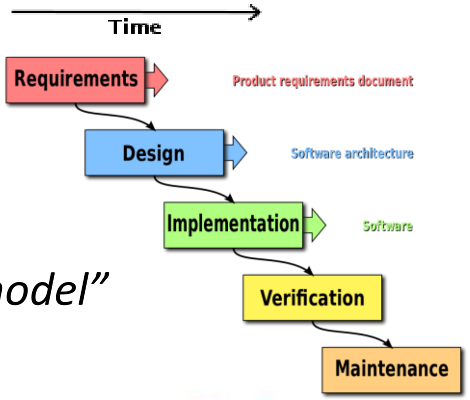
Rare-event learning Understand failures

Model the environment Unsupervised learning

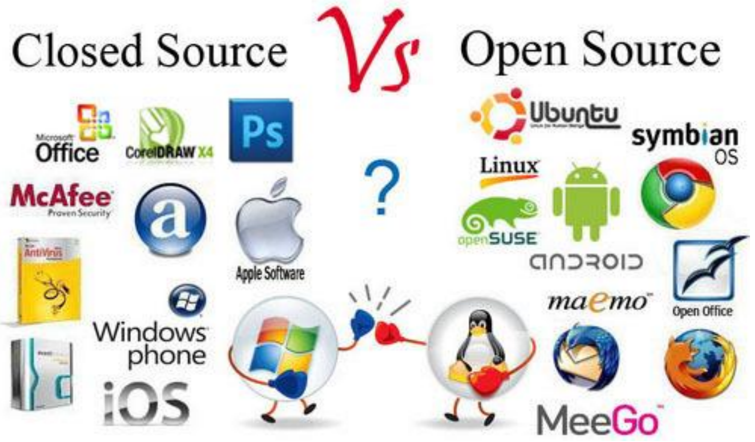
We are on the cusp to revolute the way to make machines



"V process"
Wikipedia



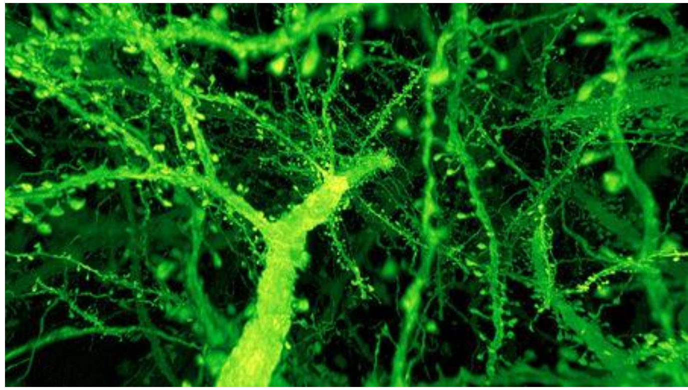
"Waterfall model"



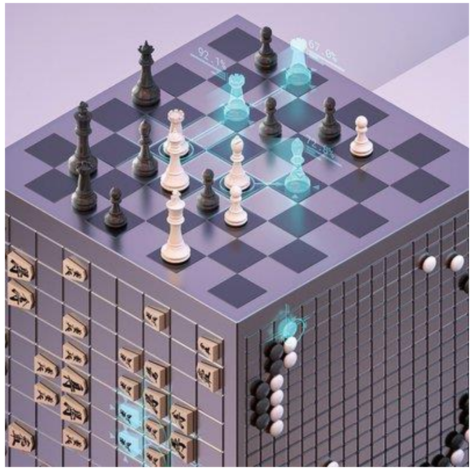
Connecting

Evolving

Sharing



Neural Network
[science, 2019]



Reinforcement Learning
[science, 2018]

Open Code/data
[science, 2017]

How to design safe AI-empowered robots?

\- Mission of *Safe AI Lab* @ CMU

AV seems to be a perfect field to study this!

Tesla
Fatal Crash, May, 2016

Waymo
Accident, May, 2018

Uber
Kill a pedestrian, March, 2018

Things can go wrong
... even for the top companies.

How to design safe technologies

How to safely test the technologies

Two fundamental challenges for AI safety

Describe tasks/Evaluation metrics

⇒Unsupervised learning

Understand failures

⇒Rare-event learning

“To develop **verifiable, explainable, reliable, affordable**, and **good-for-all AI** in the face of the uncertain, dynamic, and possibly human-involved environment by bridging statistics and cybernetics.

- Mission of *Safe AI Lab* @ CMU

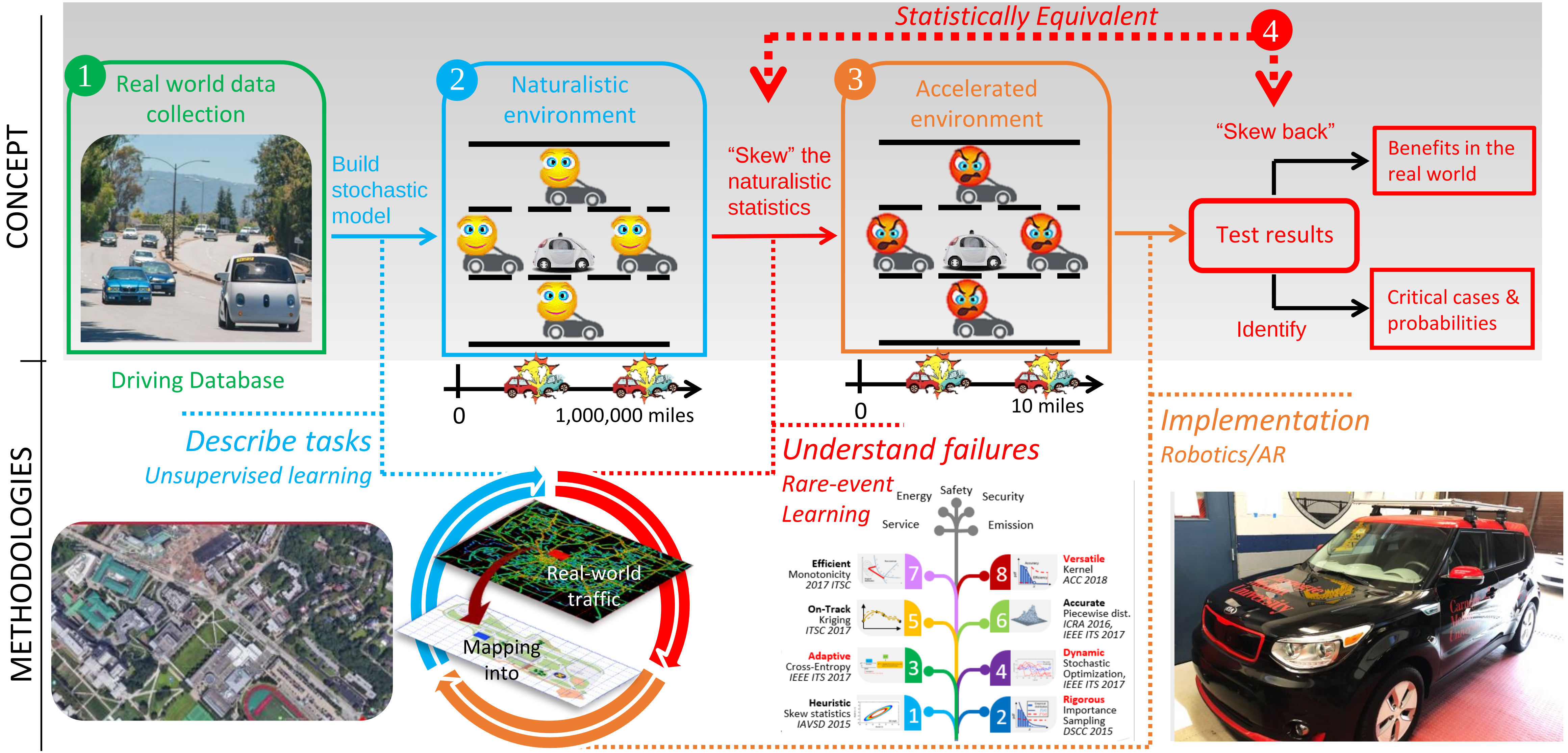
11 billion miles

To prove an AV is safer than human drivers

Rare event analysis

[Nidhi Kalra, Susan M. Paddock, "How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability? RAND report 2016]

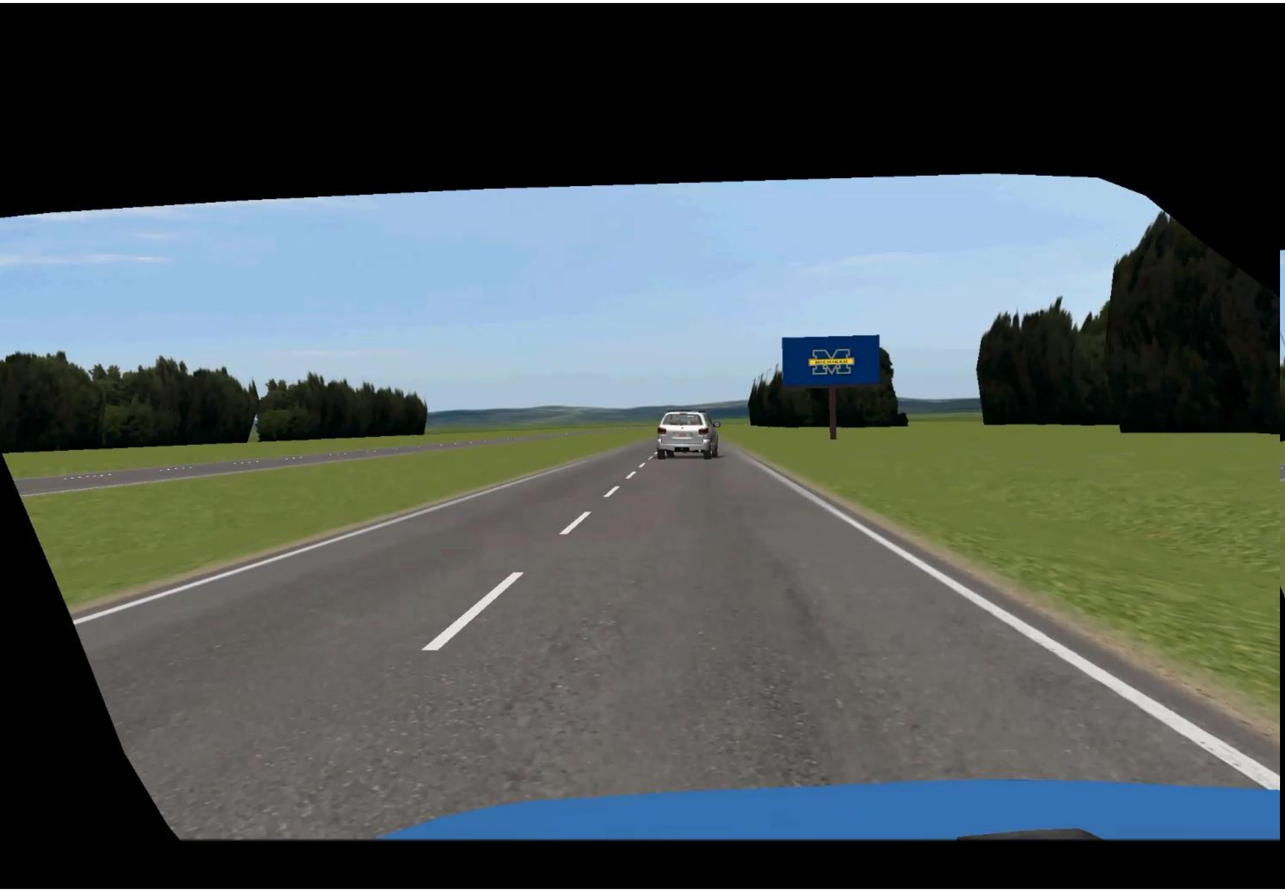
Unsupervised learning + Rare-event learning



[Zhao, et al, ''Accelerated Evaluation of Automated Vehicles Safety in Lane-Change Scenarios Based on Importance Sampling Techniques", IEEE ITS, 2017.]

Naturalistic Environment *vs* Accelerated Environment

Naturalistic Environment



Accelerated Environment

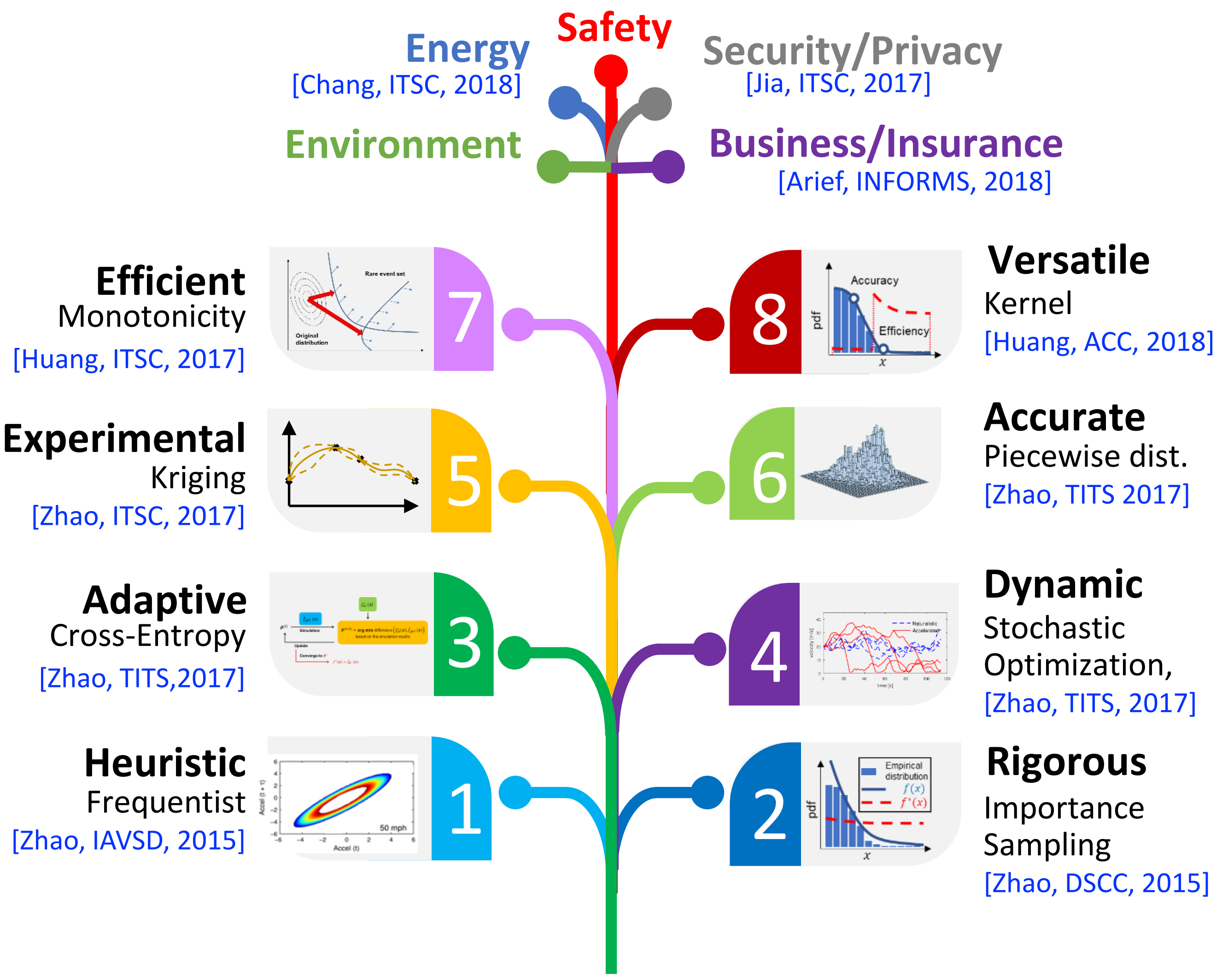
Accelerated Evaluation

Ongoing projects:

"Development of provable autonomous vehicle **evaluation approaches** with efficient data collection, unsupervised analysis, and high-dimensional stochastic models of on-road driving environment" (Uber, PI)

"Development of efficient multi-model **annotation and checking tools** based on synthesized learning methods" (Bosch, PI)

"Development of a "primary other **test vehicle**" for the testing and evaluation of high-level automated vehicles" (Toyota, Co-PI)

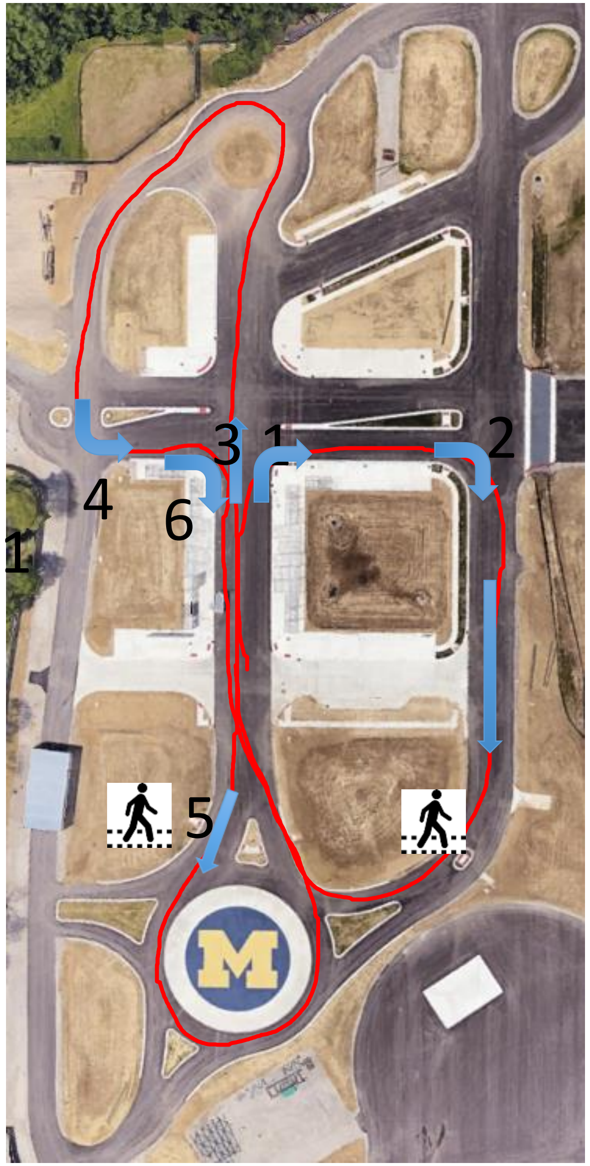


Uber BOSCH TOYOTA RESEARCH INSTITUTE Ford SAIC 上汽集团 SAIC MOTOR M city UNIVERSITY OF MICHIGAN

AV Testing

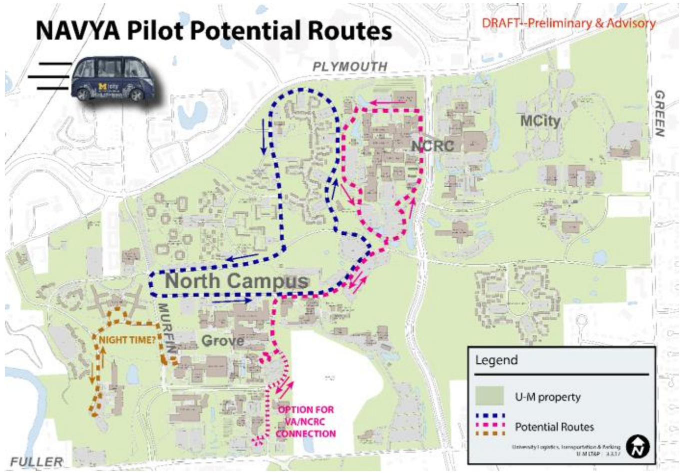
CARLA: An open-source simulator for AV research

Carla



Mcity test track

Mcity



Driverless shuttle deployment

Michigan

Fully driverless permit

The Verge

Mcity
UNIVERSITY OF MICHIGAN

From the Lab to the Street: *Solving the Challenge of Accelerating Automated Vehicle Testing*

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Director, Mcity
Roger L. McCarthy Professor
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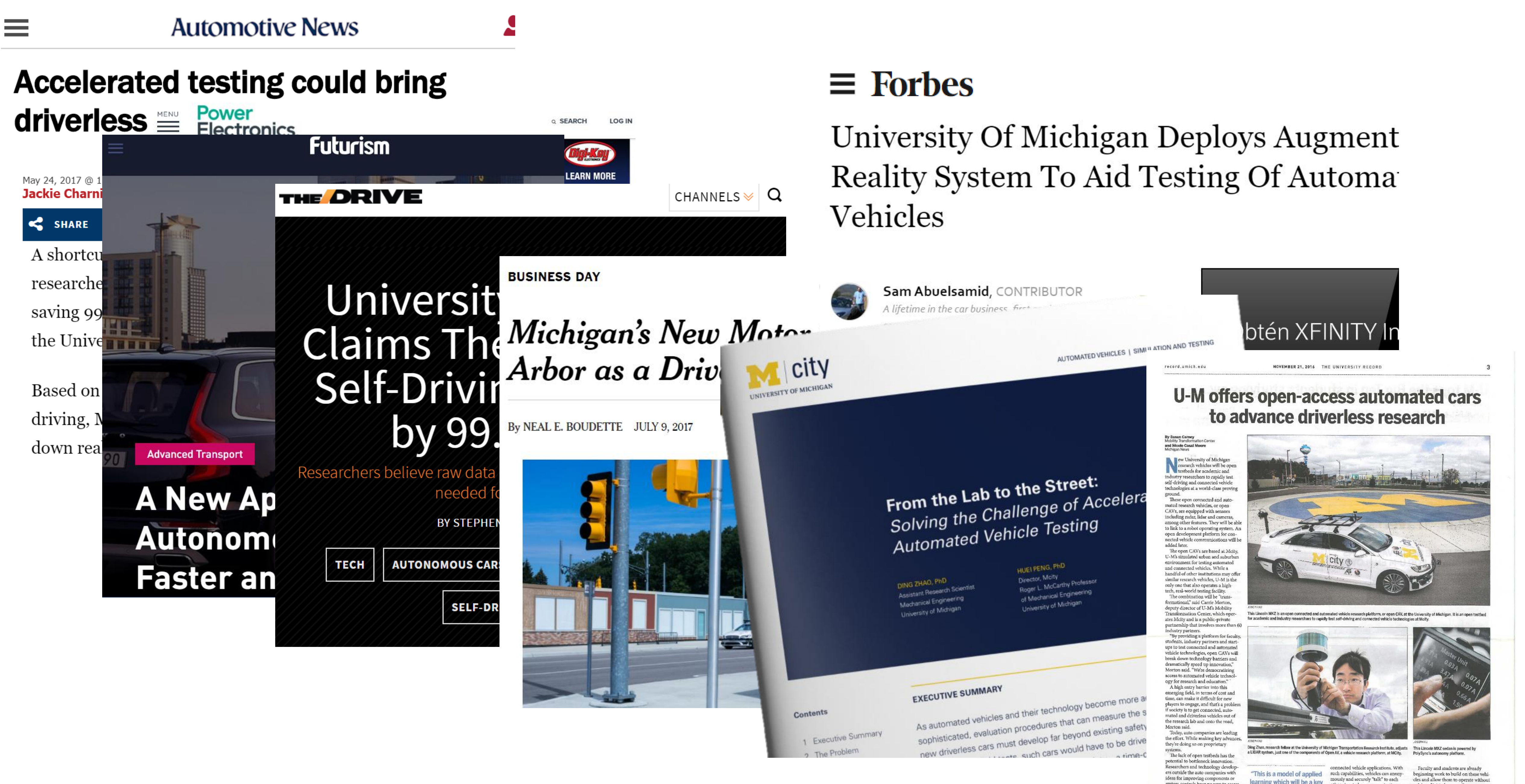
University of Michigan

EXECUTIVE SUMMARY

...icles and their technology become more advanced and technically
...easure the safety and reliability of these
...accurate

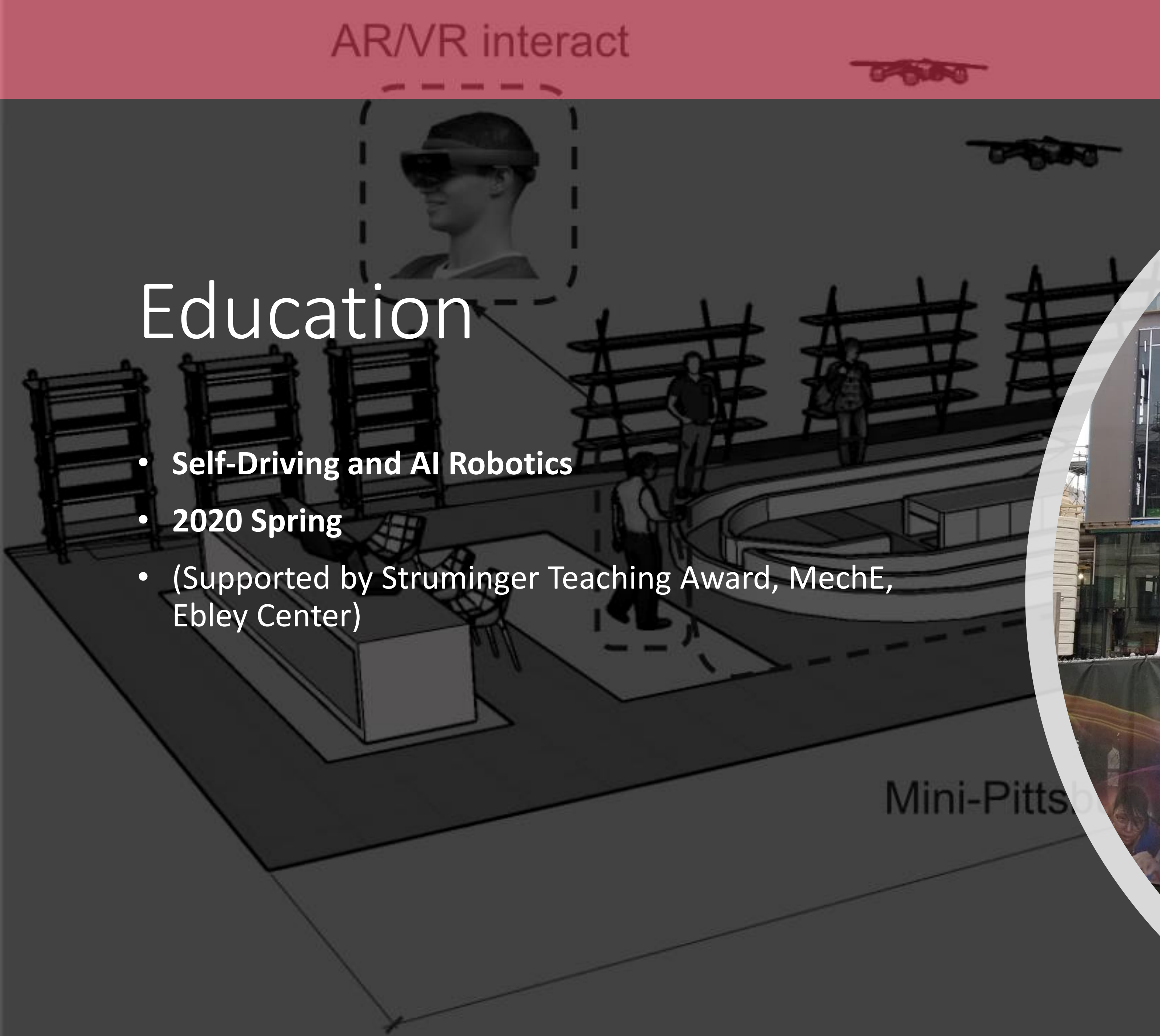
Contents

Media Coverage



Education

- **Self-Driving and AI Robotics**
- **2020 Spring**
- (Supported by Struminger Teaching Award, MechE, Ebley Center)



800 Hours

Needed to analyze 1 hour video data

Unsupervised learning

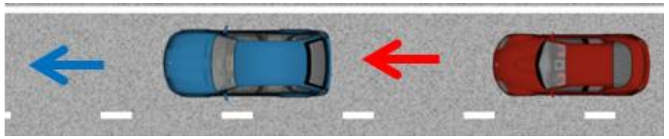
[Carol Reiley, CEO of Open.drive, 2017]

The Autonomous Vehicle Datasets

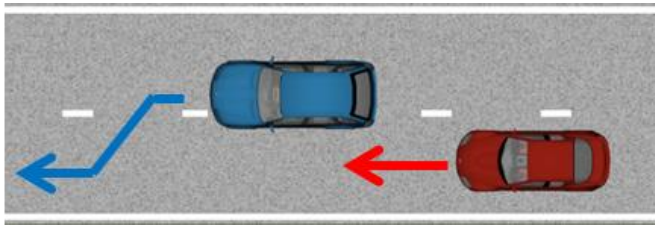
Name	Size	Information (Benchmark)	Format
KITTI [1]	>180GB	Vision, Lidar, GPS, IMU	txt, png
Berkeley Deep Drive [2]	>1100 Hour	Vision	video, image
Oxford Robotcar[3]	>1000KM	Vision, Lidar, GPS, IMU, VO	Bin, csv, png
Apollo[4]	>156GB (Raw data)	Vision, GPS,IMU, Dynamic	Rosbag
Udacity[5]	>8 Hour, 286 GB	Vision, Lidar, GPS,Dynamic	Rosbag

Extensions to Other Scenarios

Car-following



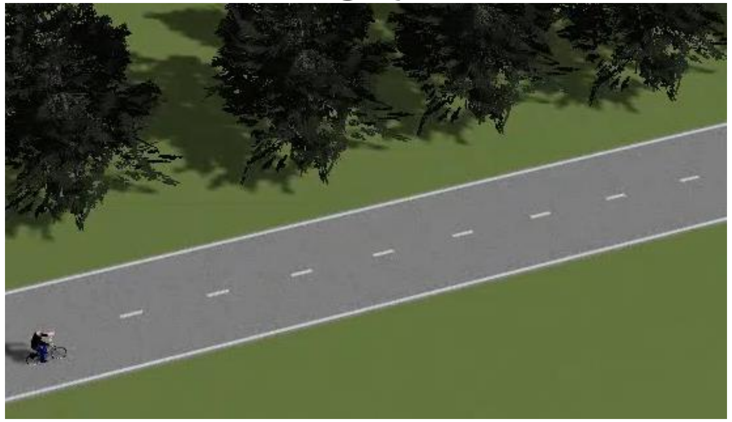
Lane change



Left turn

Pedestrian crossing

Passing cyclists

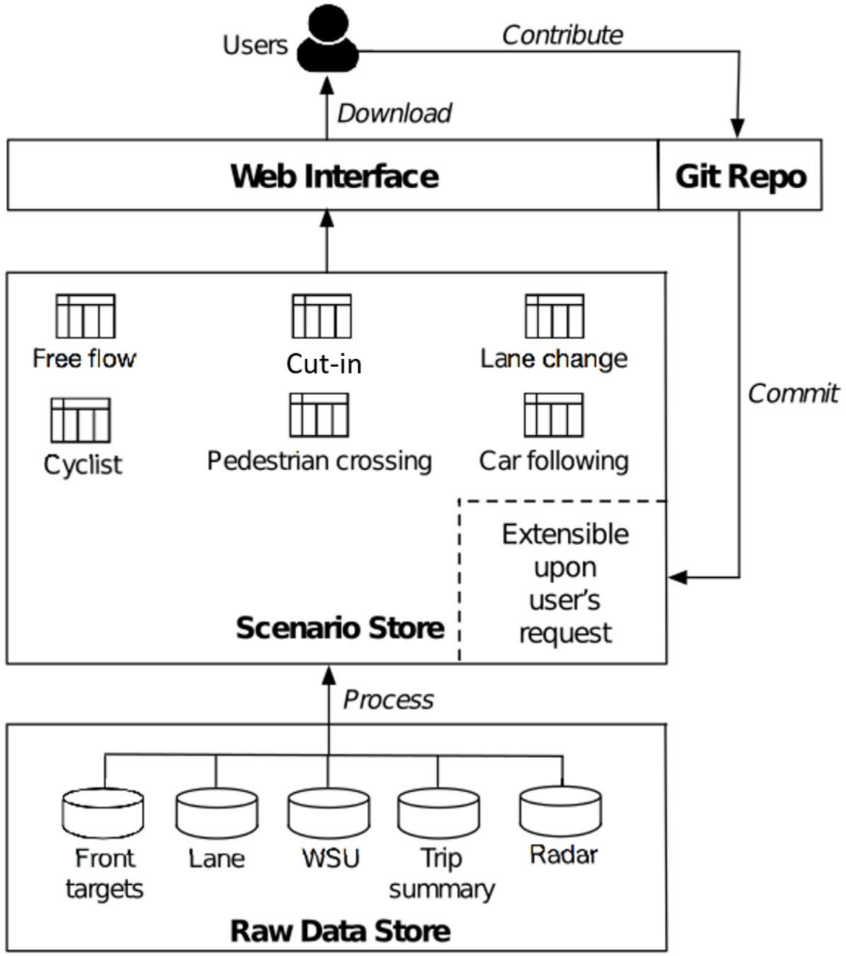


B. Chen, D. Zhao, H. Peng, D. LeBlanc, "Analysis and Modeling of Unprotected Intersection Left-Turn Conflicts based on Naturalistic Driving Data, " IEEE Intelligent Vehicle Symposium, 2017

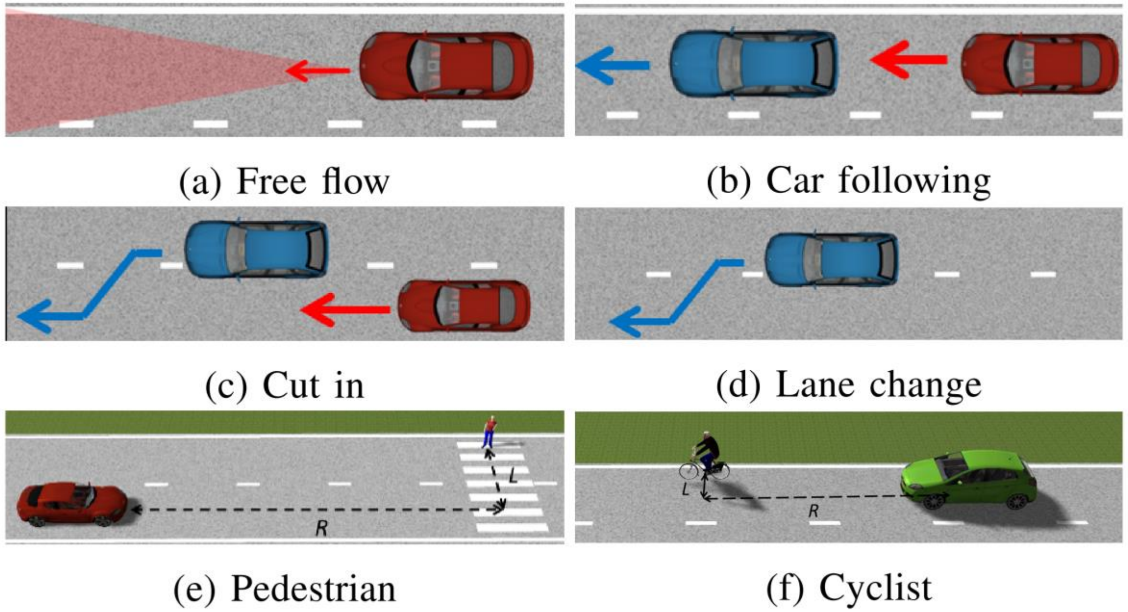
B. Chen, D. Zhao, H. Peng, "Evaluation of Automated Vehicles Encountering Pedestrians at Unsignalized Crossings," IEEE Intelligent Vehicle Symposium, 2017.

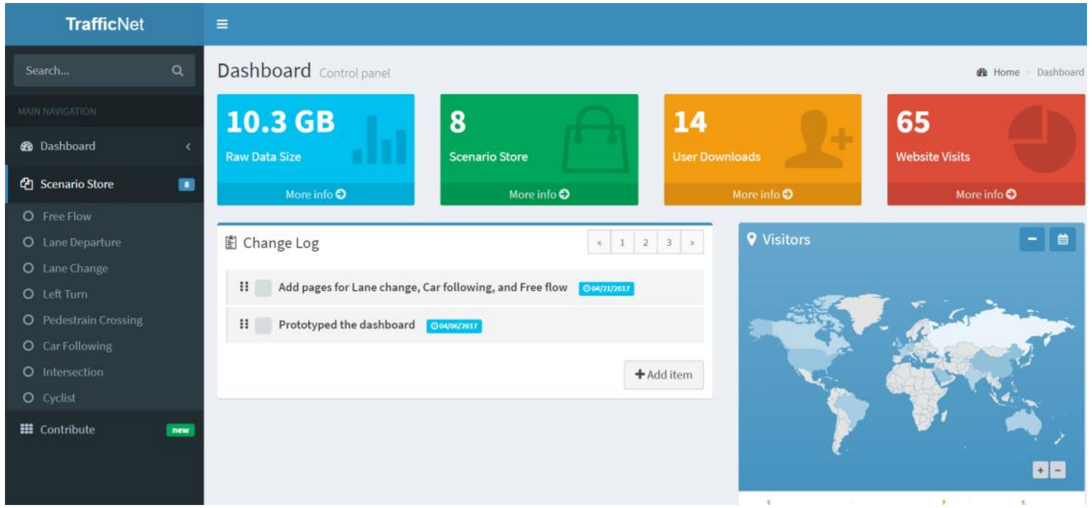
Y. Guo, Z. Mo, D. Zhao, "Approaching and Passing Cyclists - A learning Based Approach", under preparation.

TrafficNet.org: An Open Naturalistic Driving Scenario



Framework of TrafficNet



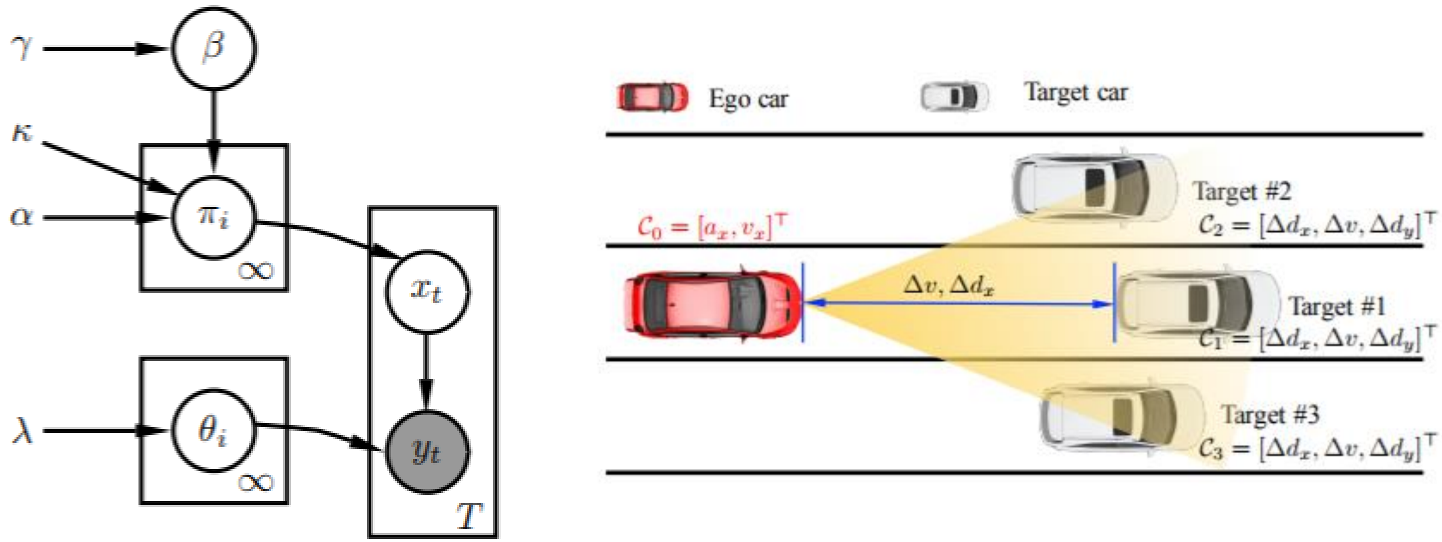


[Zhao, Guo, Jia, TrafficNet: An Open Naturalistic Driving Scenario Library ITSC, 2017]

Extracting Traffic Primitives using Unsupervised

Toyota (**PI**) “Extracting **Traffic Primitives** from Millions of Naturalistic Driving Encounters -- A Synthesized Method based on Nonparametric Bayesian and Deep Unsupervised Learning”

Traffic primitive is referred to the representation of fundamental building blocks of the traffic environment in spatiotemporal space.



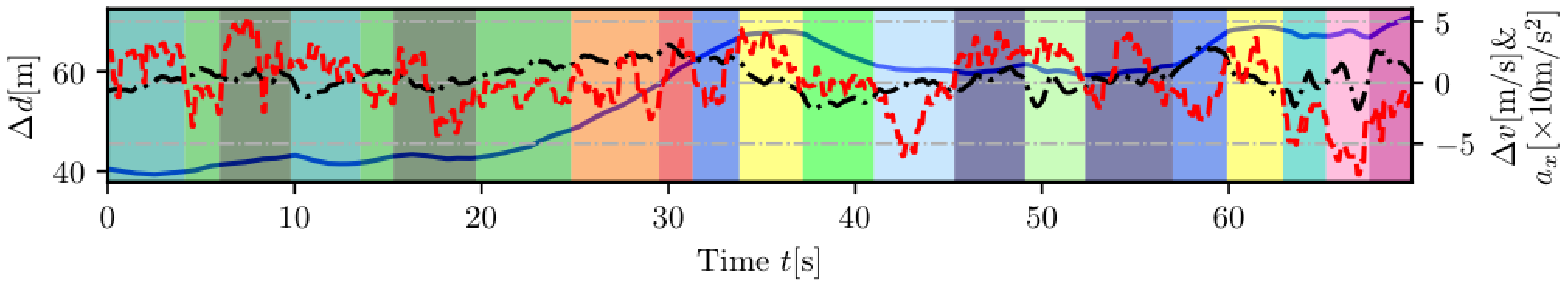
Previous methods:

- **Subjectively-selected scenarios**

Traffic Primitive:

- Segment/cluster similar traffic scenes automatically using unsupervised learning

- Objectively-selected scenarios

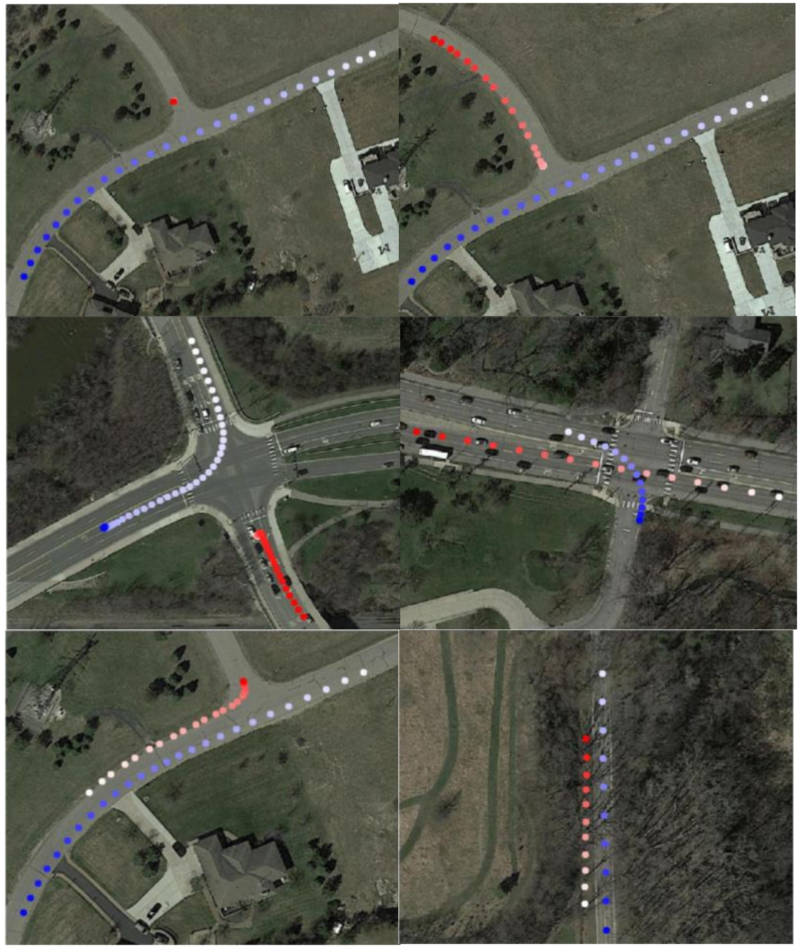


[Wang, Zhao, 'Extracting Traffic Primitives Directly from Naturalistically Logged Data for Self-Driving Applications, ICRA, 2018]

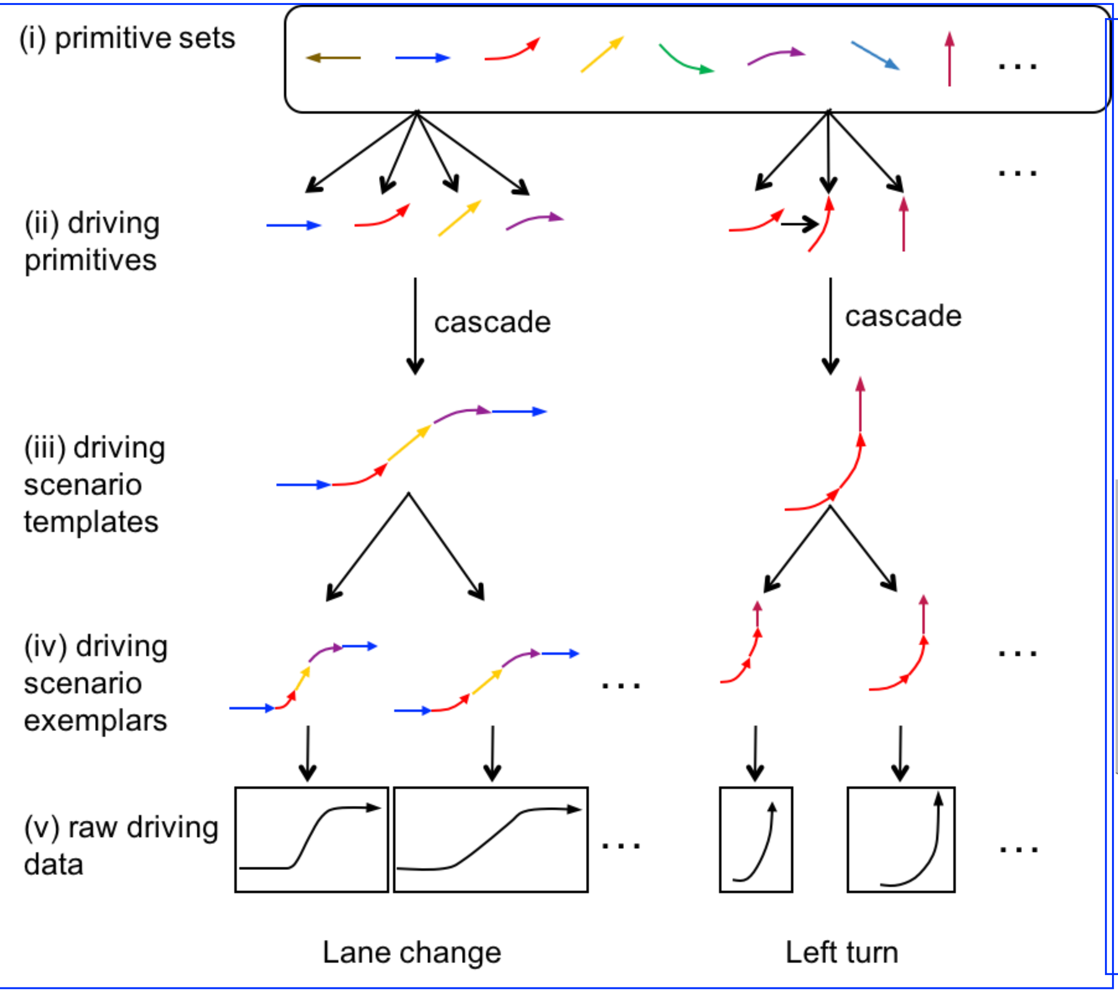
Driving encounters collection

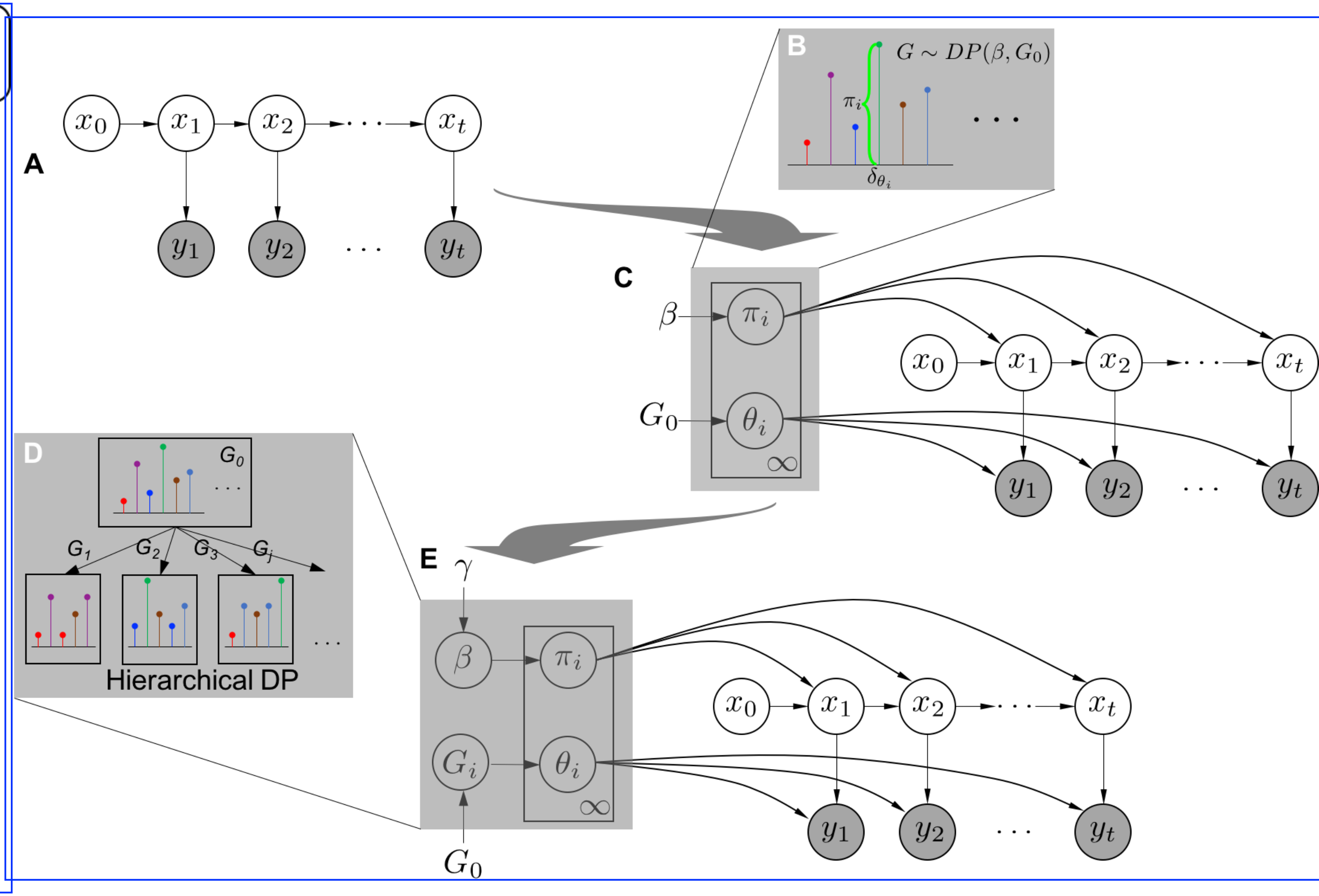
- Naturalistic driving encounters

1600~2800 vehicles
5+ years
1 million encounters



Primitive Extraction & Analysis



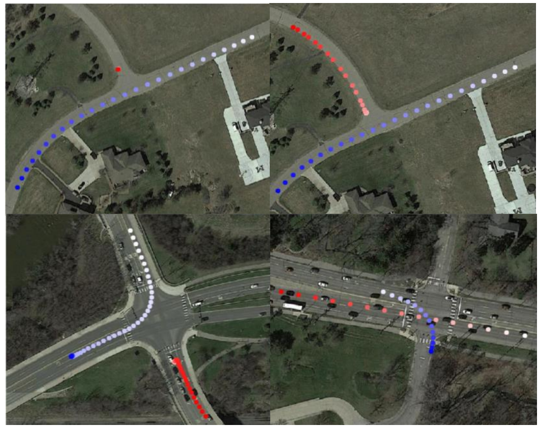


Extracting driving primitives

Nonparametric Bayesian learning

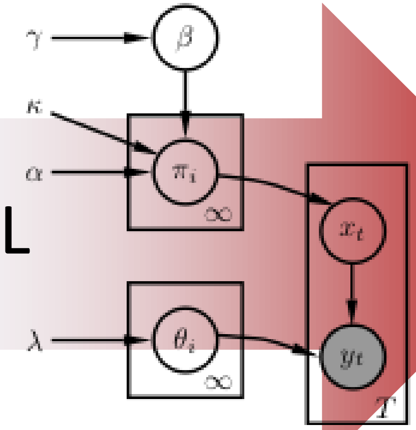
[Wang, Zhang, Zhao, 'Understanding V2V Driving Scenarios through Traffic Primitives', under review, 2018]

Nonparametric Bayesian Learning

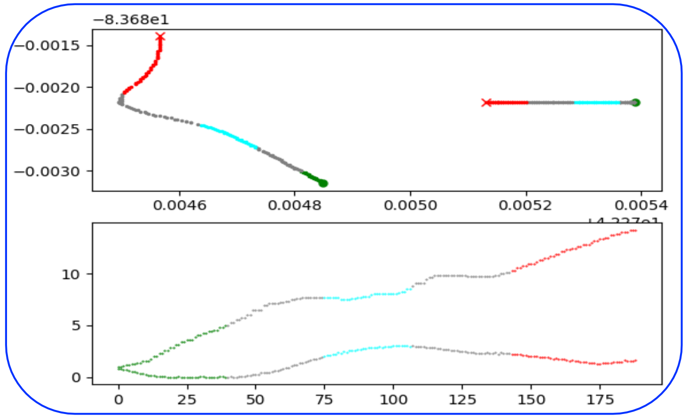


Raw encountering data

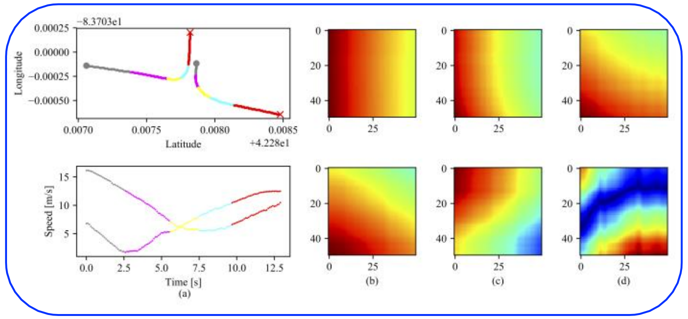
NPBL



Primitives



DTW



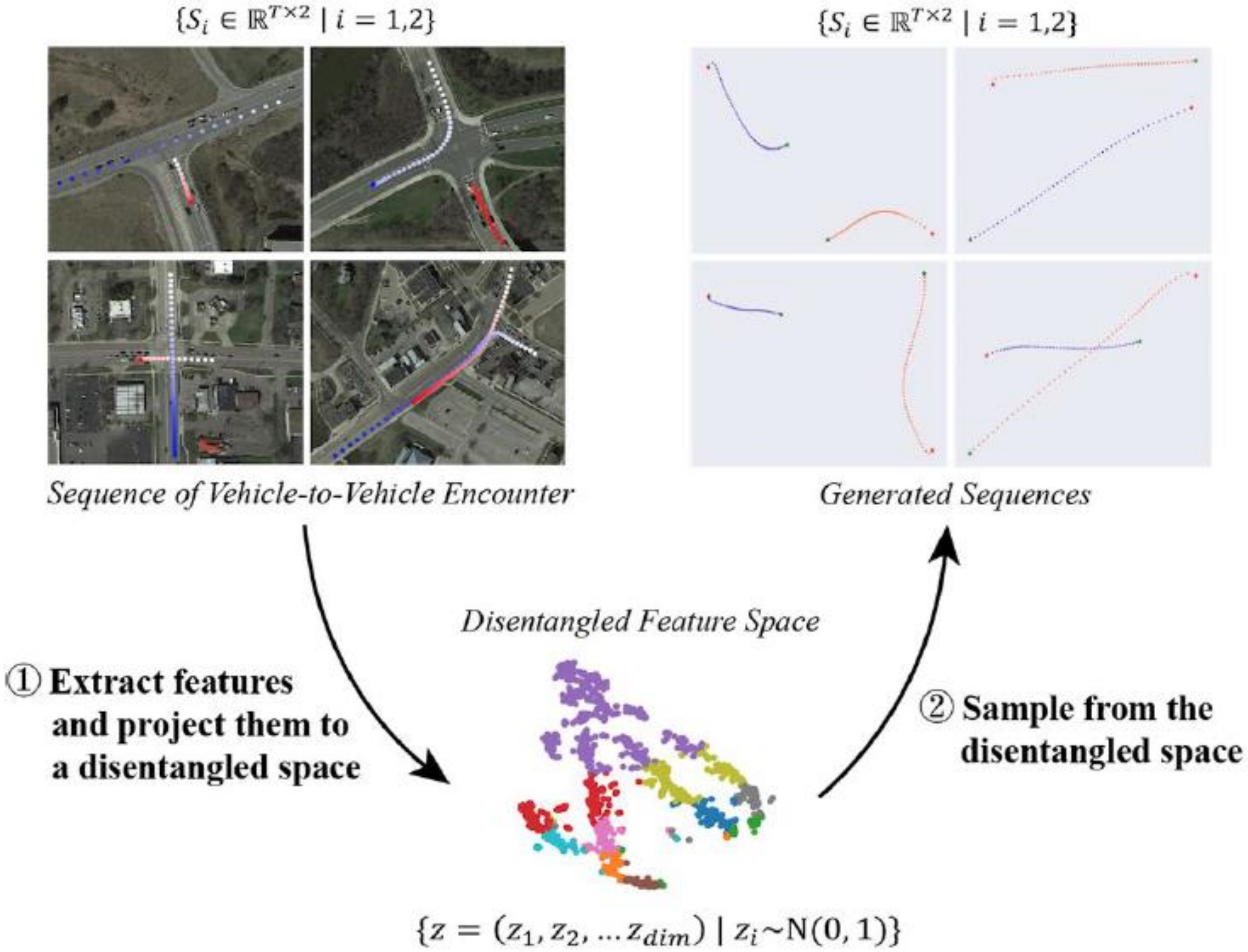
Feature representations

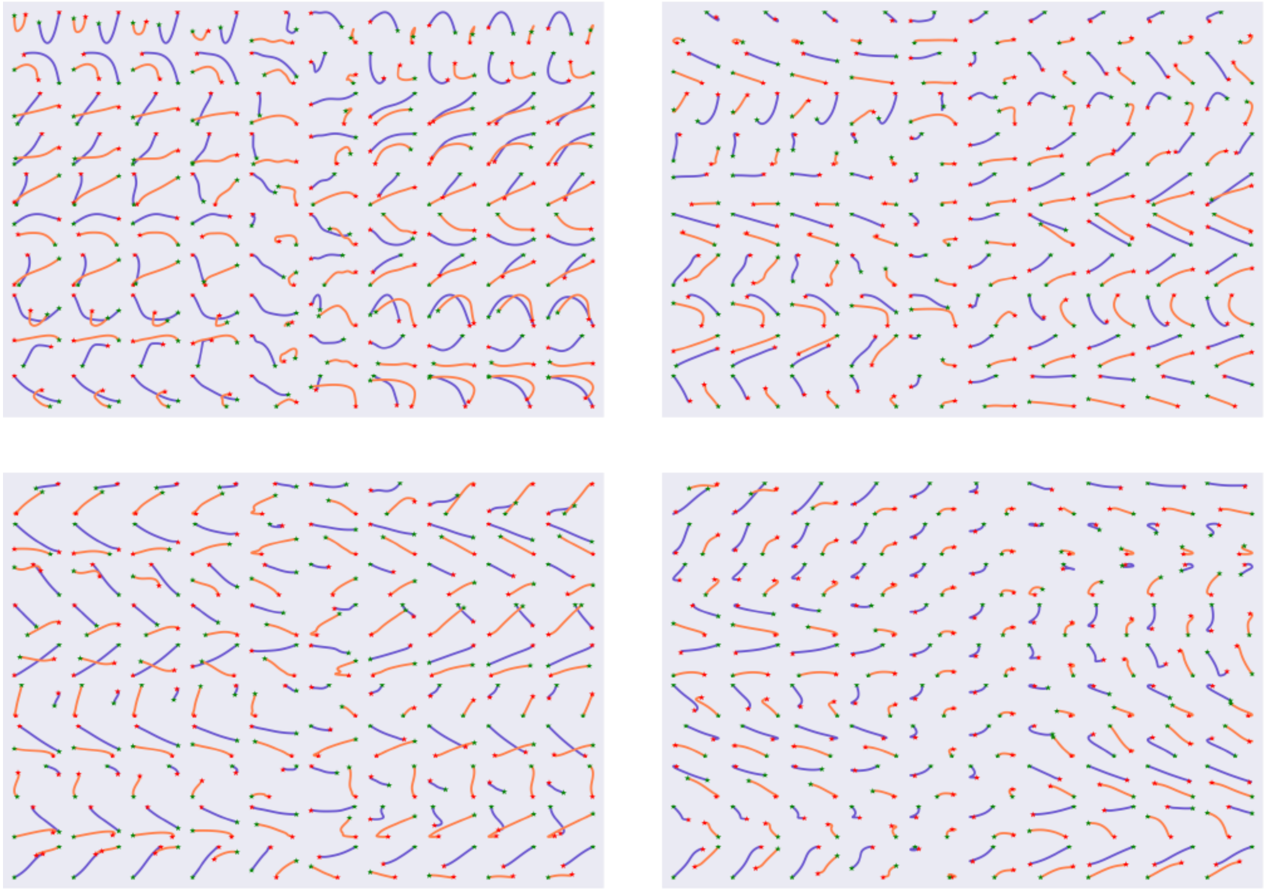
Clustering

Primitive clusters

[Wang, Zhang, Zhao, 'Understanding V2V Driving Scenarios through Traffic Primitives', under review, 2018.]

Driving Encounter Generation

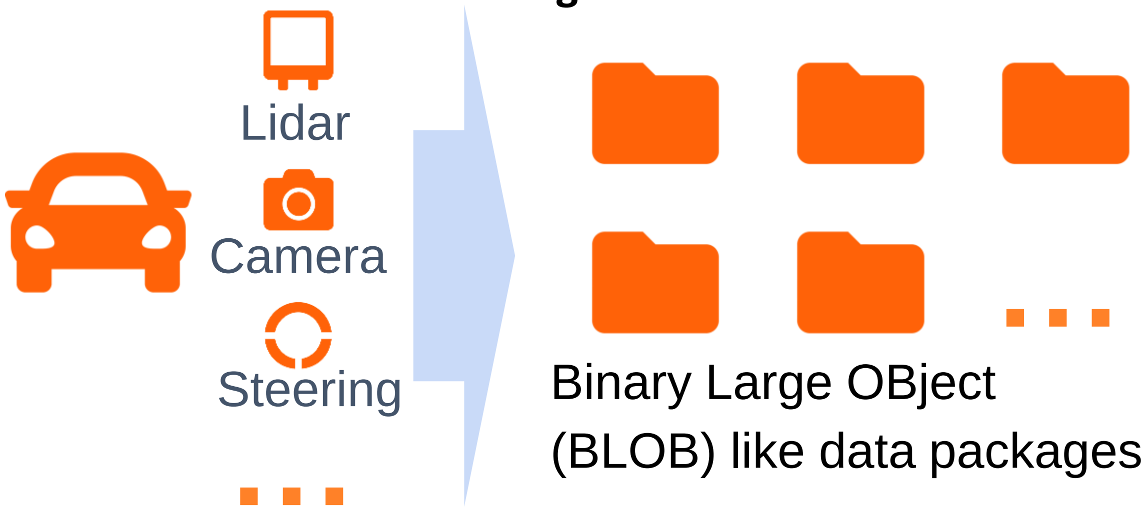




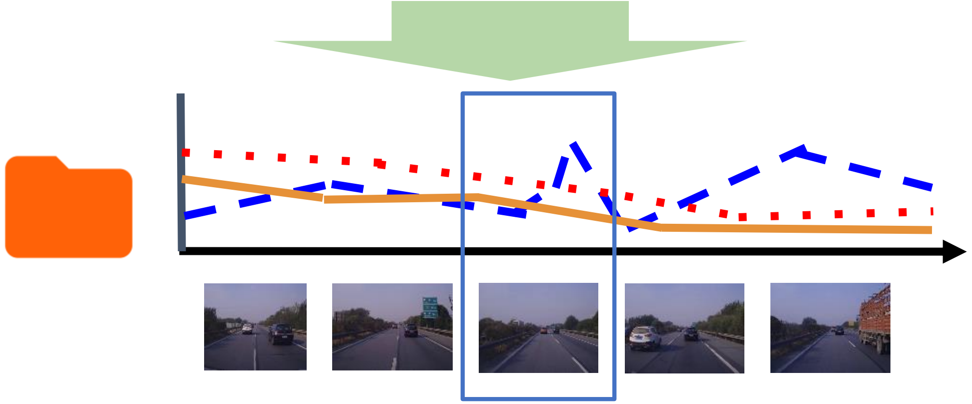
Ding, Wang, Zhao, 'Multi-Vehicle Trajectories Generation for Vehicle-to-Vehicle Encounters', IEEE IRCA, under review, 2018.

Unified Autonomous Vehicle Data Integration

Traditional Autonomous Vehicle Data Storing Method

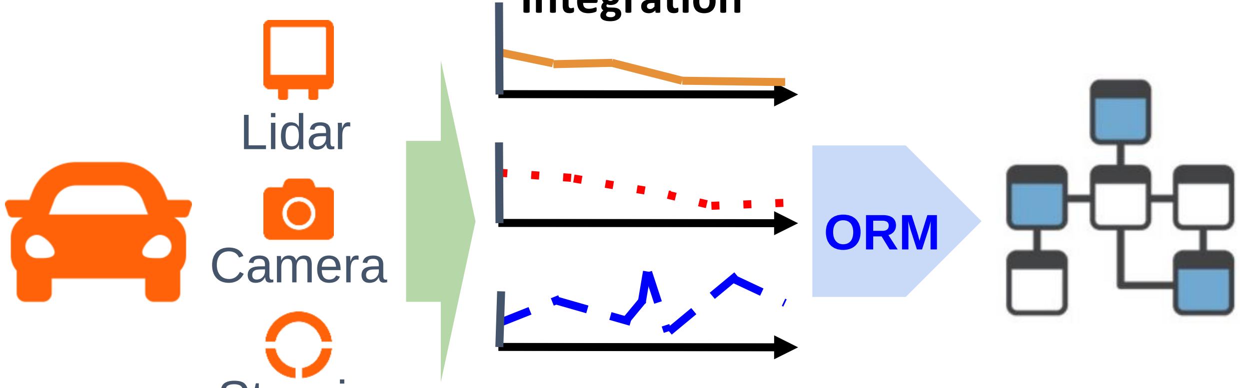


Binary Large OBject (BLOB) like data packages

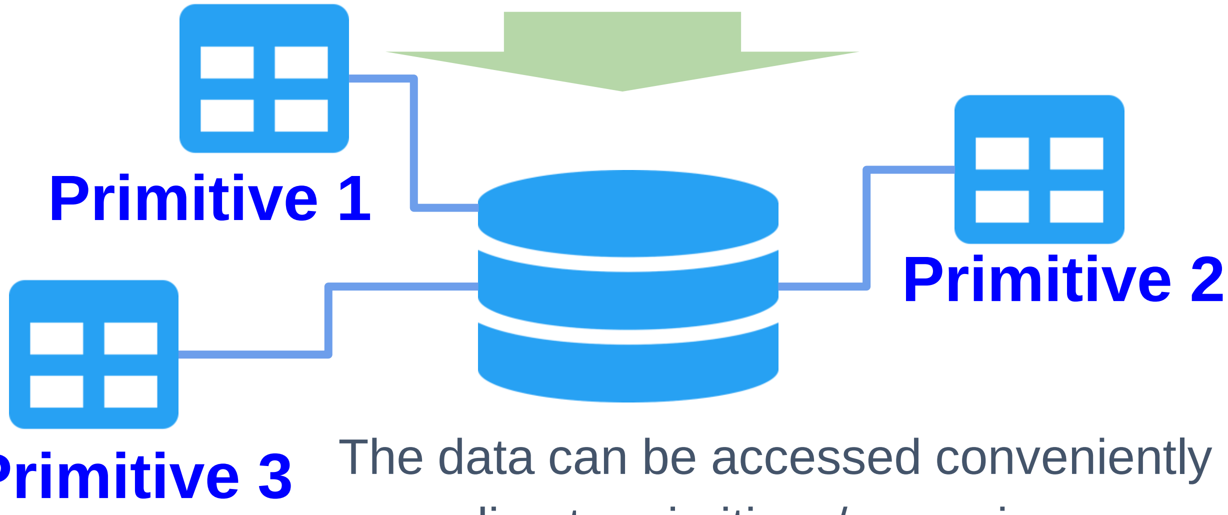


The whole data package need to be traversed to investigate specific data

Unified Autonomous Vehicle Data Integration



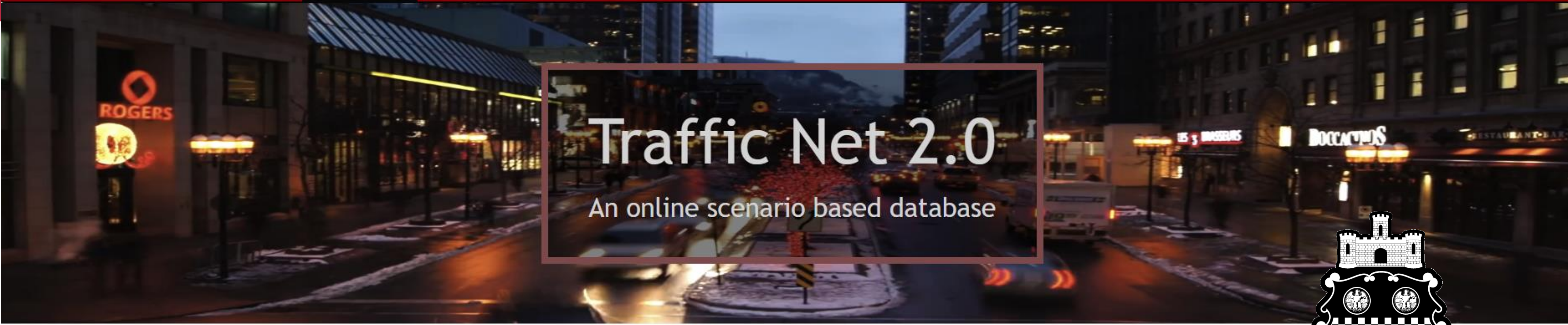
Different kinds of data are integrated into a relational database respectively



The data can be accessed conveniently according to primitives/scenarios

[Zhu, Wang, Zhao, Integrating Heterogeneous Driving data For Autonomous Vehicles , ITSC, 2018]

TRAFFICNET2.0 | **HOME** | DATASETS | DOCUMENTATION | TERMS | CITATION | CONTACT



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- Data Format
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Last updated: 09-04-2019 05:28:01 PM EST

Datasets

Our data set is a multitude of publicly-available driving datasets and data platforms have been raised

Use “Traffic Primitives” to define driving scenarios

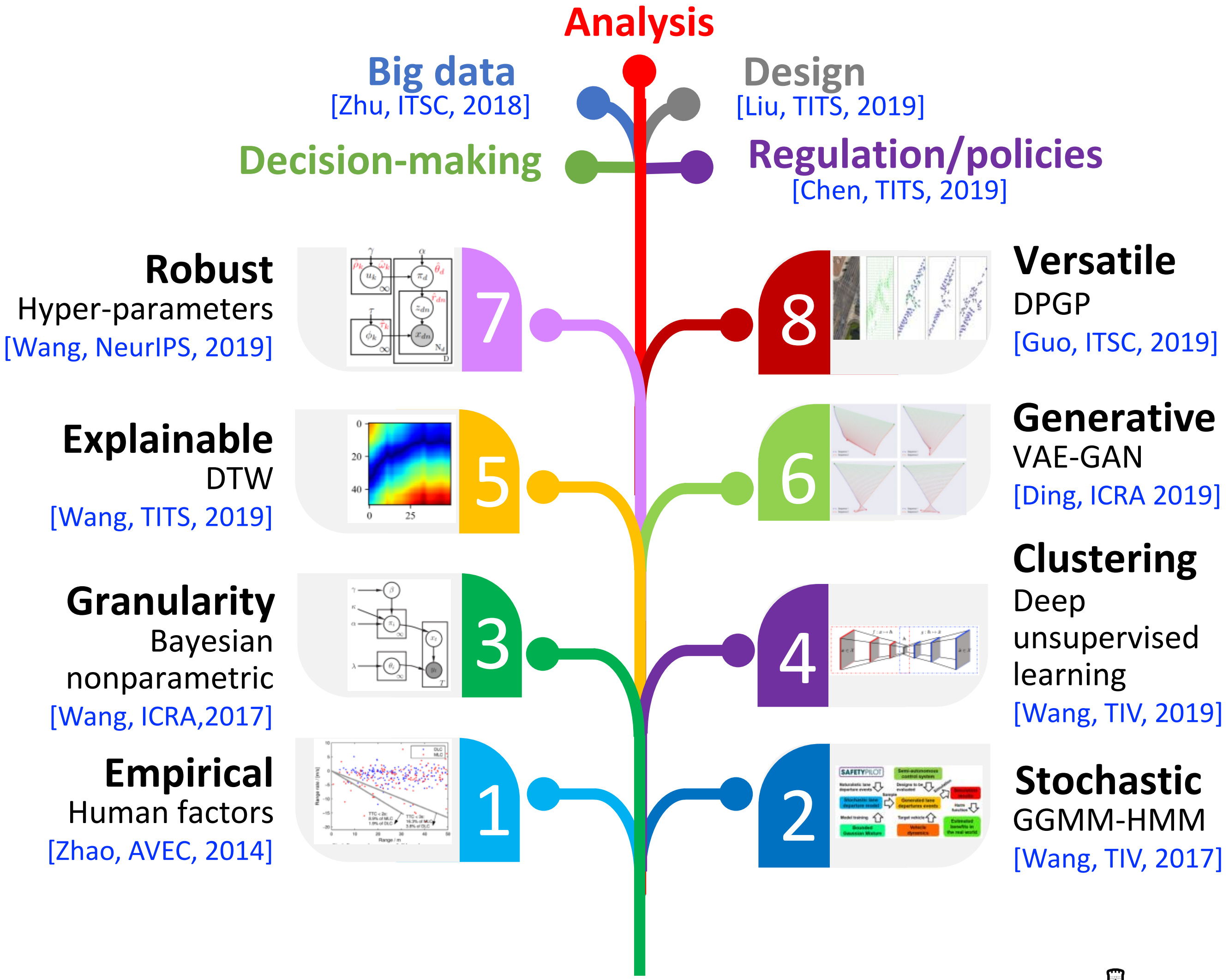
Ongoing projects:

“A scenario-based **database** for connected and autonomous driving in A smart city” (Traffic21, PI)

“**Labeling roads** with different types of functional automated driving requirements using machine learning” (Mobility21, PI)

“Extracting **traffic primitives** from millions of naturalistic driving encounters -- A synthesized method based on nonparametric Bayesian and deep unsupervised learning” (Toyota, PI)

“A unified, auto-checking, and self-analyzing **data platform** for intelligent driving applications” (Denso, PI)



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“To develop **verifiable, explainable, reliable, affordable**, and **good-for-all AI** in the face of the uncertain, dynamic, and possibly human-involved environment by bridging statistics and cybernetics.

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