Nagoya University COI
Mobility Innovation Center

A Risk-index based Sampling Method to Generate Scenarios for the Evaluation of Automated Driving Vehicle Safety

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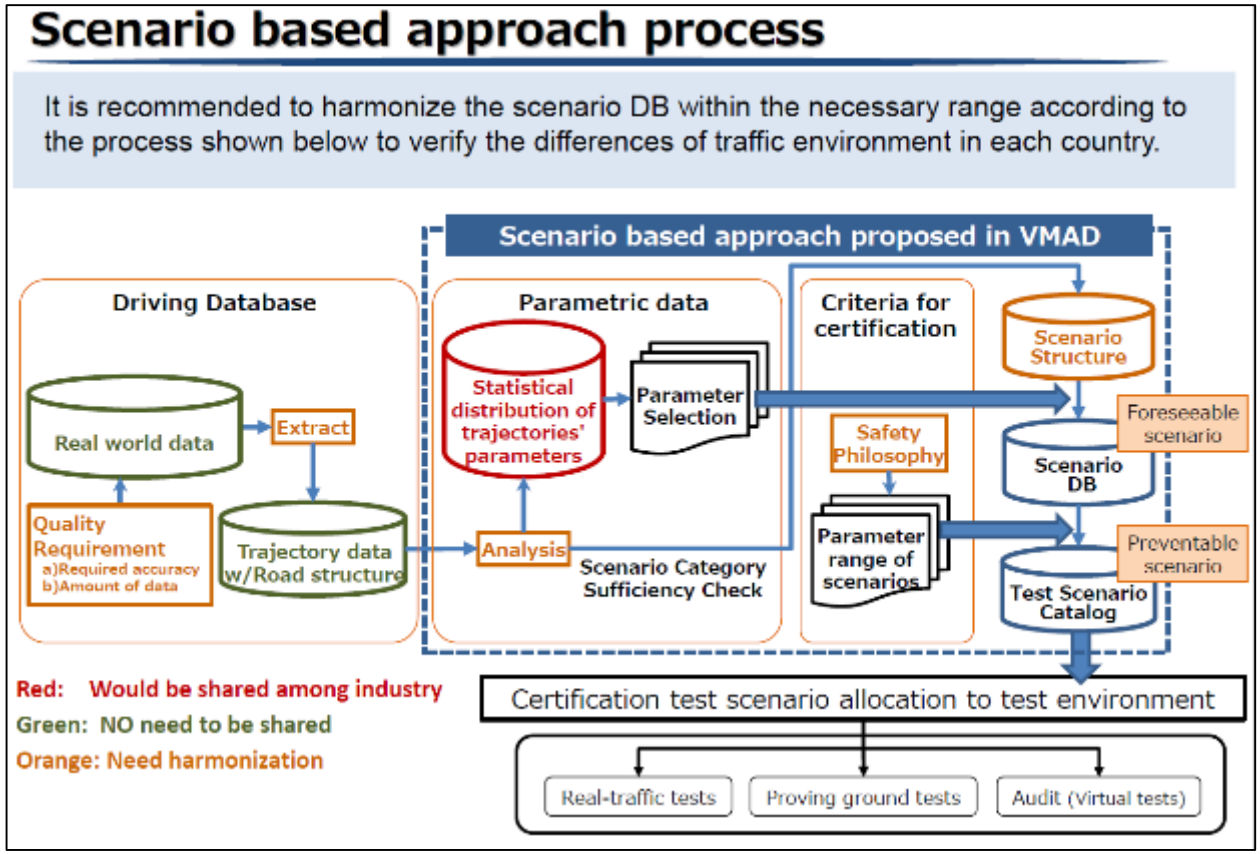
Background

Safety evaluation and validation of automated driving systems



Validation Method for Automated Driving（VMAD） VMAD IWG 4th session

Safety Criteria Study on Innovative Safety Validation Methods of Automated Driving System

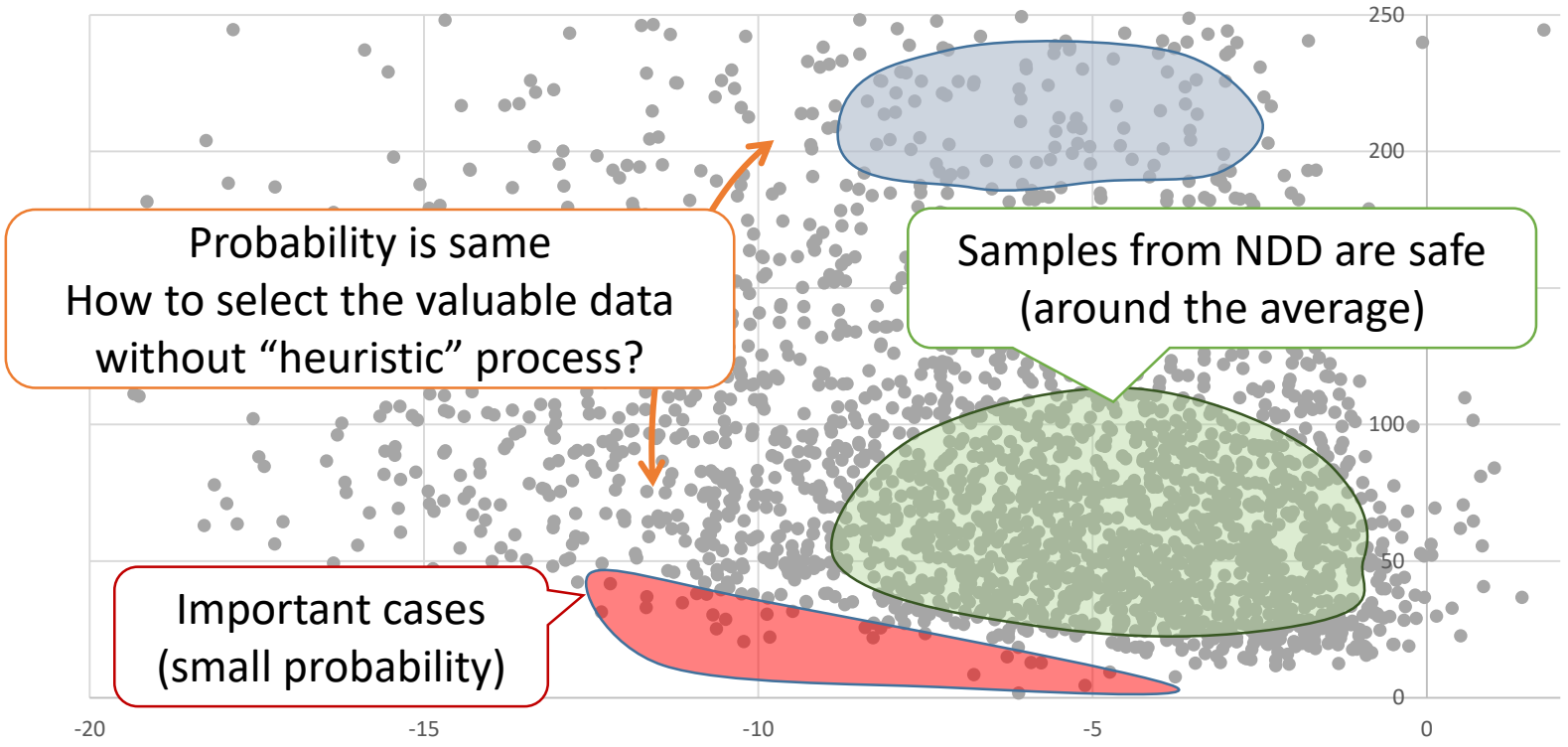
https://globalautoregs.com/meetings/1424-vmad-session-4-16-17-oct-2019

Problems

Human driving is (basically) safe

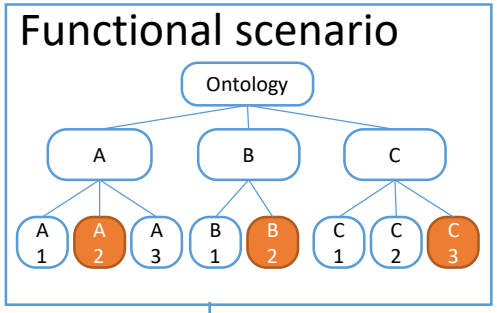
Hazardous situations are needed for the test scenarios.

How to extract risky behavior from naturalistic driving data?

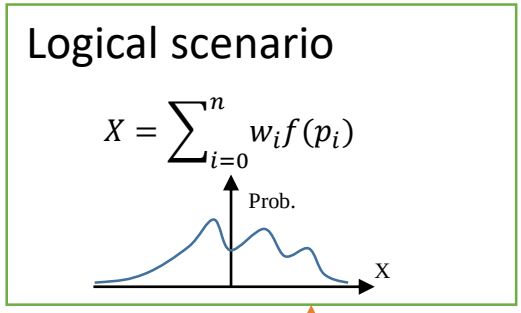


Framework of test scenario generation

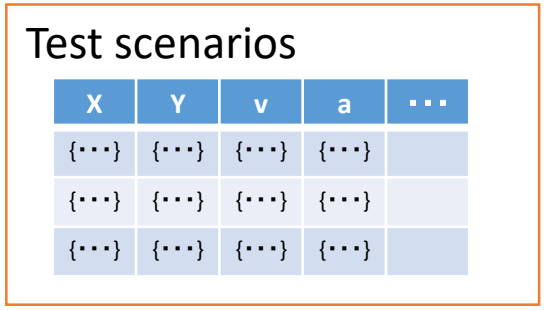
We propose a method to parameter sampling method for test scenarios based on the relationship between the driving parameters and a risk index.



Search

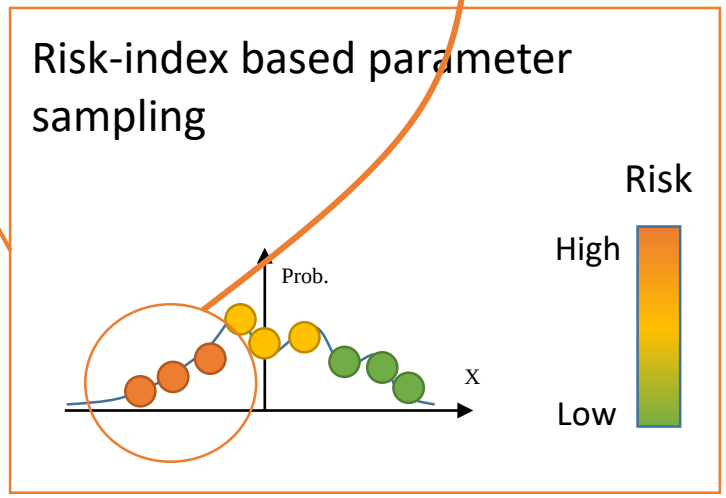


parameter estimation



ID	A	B	C	X	Y	v	a	···
1	1	1	1	{···}	{···}	{···}	{···}	
2	2	2	3	{···}	{···}	{···}	{···}	
3	2	1	2	{···}	{···}	{···}	{···}	
4	2	2	3	{···}	{···}	{···}	{···}	
5	3	1	3	{···}	{···}	{···}	{···}	
⋮								

Naturalistic driving data



Parameter modeling

Parameter model for logical scenarios

Gaussian mixture model （GMM）

$$GMM(P) = \sum_{i=0}^{k} w_i Gauss(P, \mu_i, \Sigma_i)$$

$$Gauss(P, \mu_i, \Sigma_i) = \frac{1}{(\sqrt{2\pi})^k \sqrt{|\Sigma|}} exp\left(-\frac{1}{2}(P-\mu_i)^T \Sigma^{-1}(P-\mu_i)\right)$$

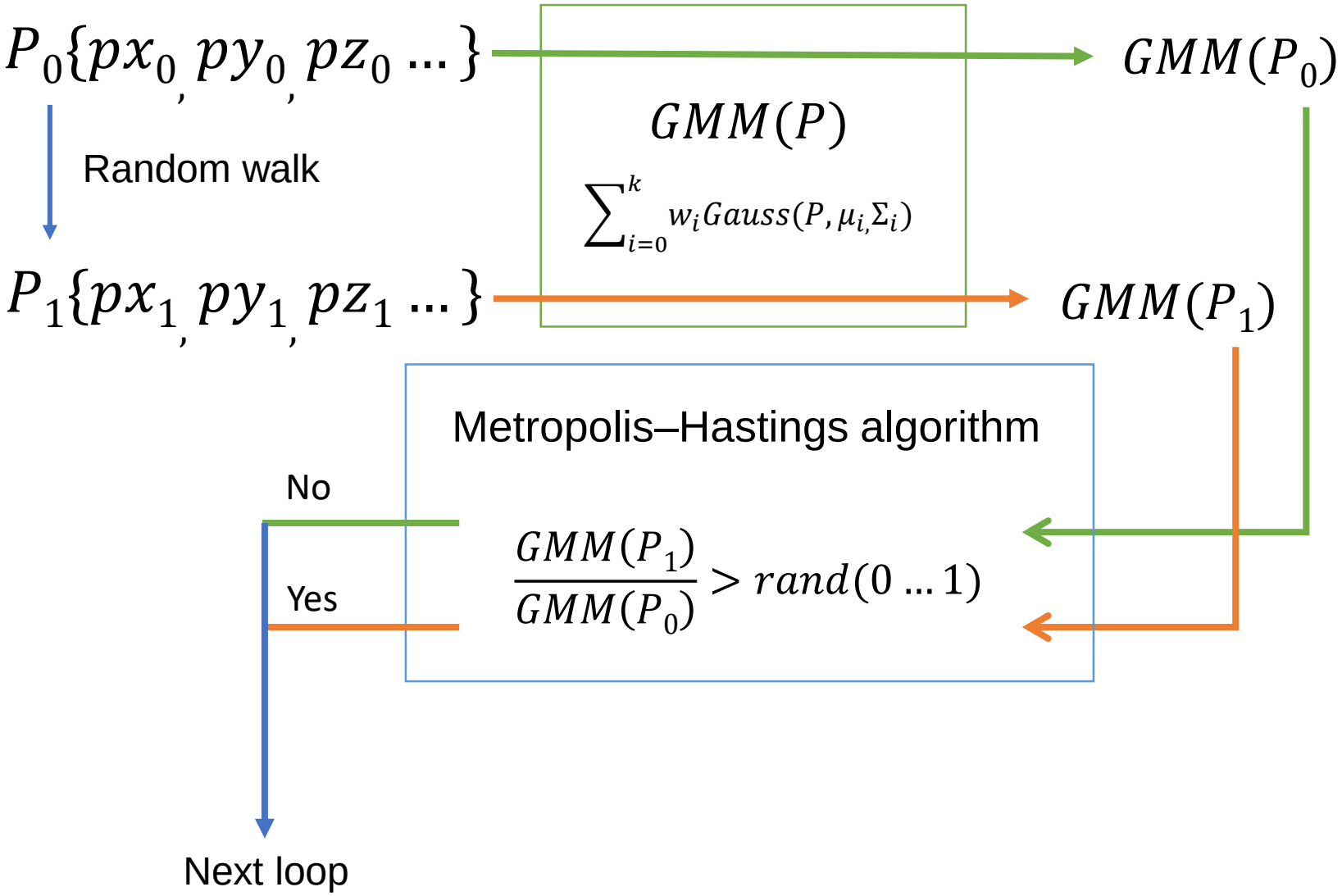
Markov chain Monte Carlo（MCMC) sampling

Risk index based constraint

Efficient test scenarios

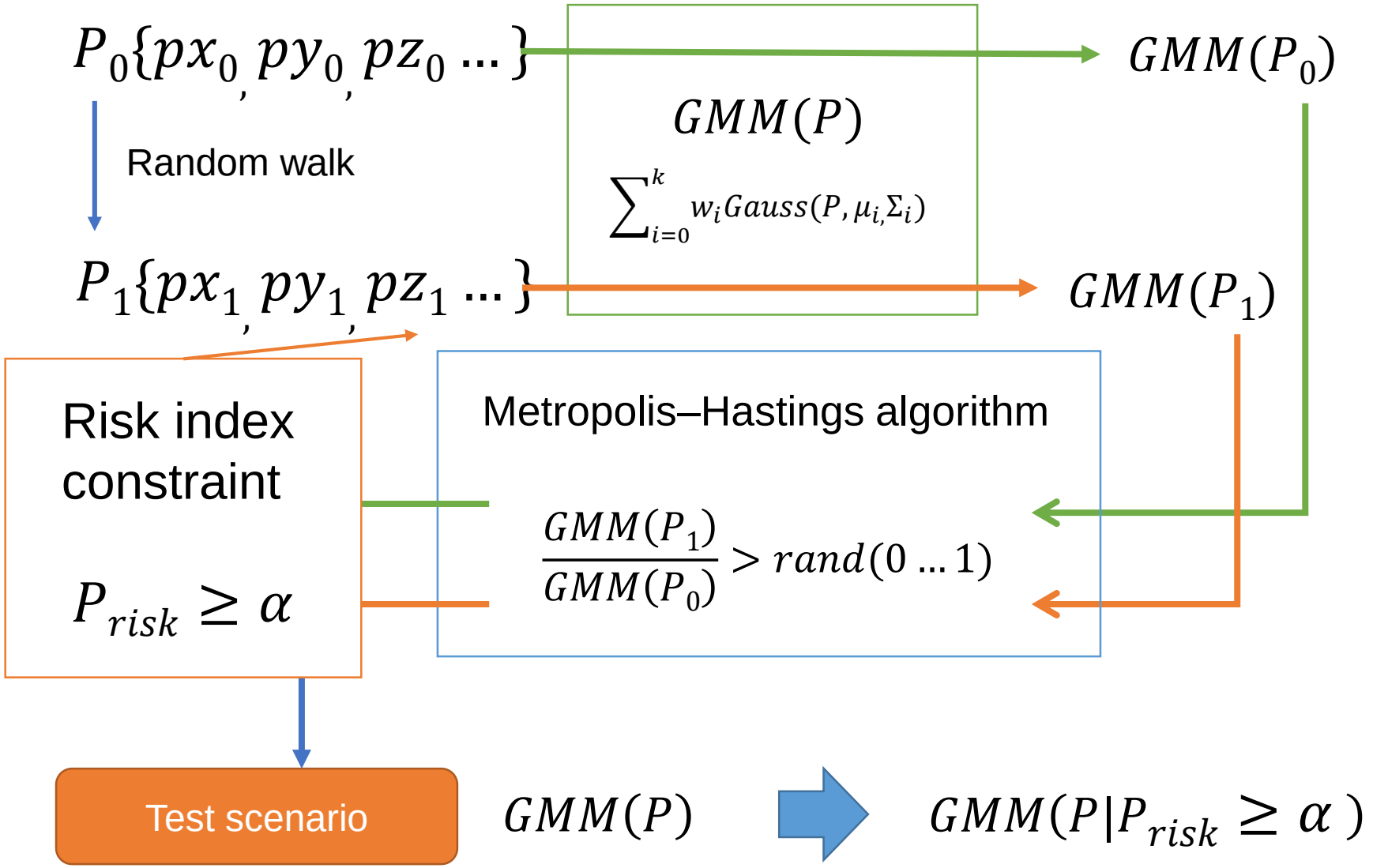
Risk index dependent parameter sampling

Markov chain Monte Carlo（MCMC) sampling



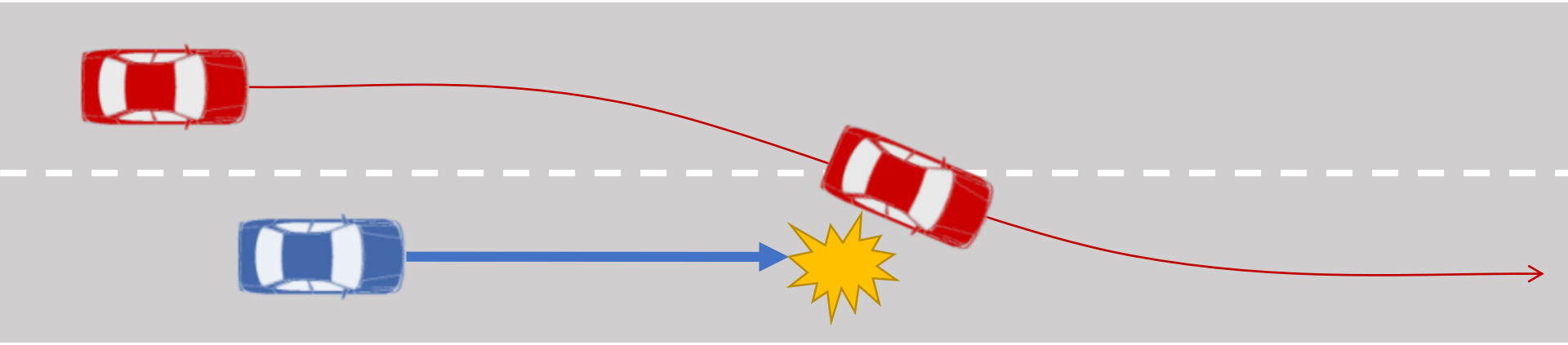
Risk index dependent parameter sampling

Markov chain Monte Carlo（MCMC) sampling



Use case: Cut-in scenario on a highway

A simple scenario is selected to evaluate the proposed framework.
(however, parameter sampling methods should be generic.)



Analysis and modeling of cut-in maneuvers form naturalistic driving data (NDD)

Experimental evaluation

To evaluate the efficiency of the proposed test scenario generation (parameter sampling) by using NDD

DATA1: 462 cut-in data from JARI driving behavior dataset

- Naturalistic driving data of 1200 hours at Japanese Highways.
- Data are collected on-board sensors.
- Lane change maneuvers are detected by Mobileye.

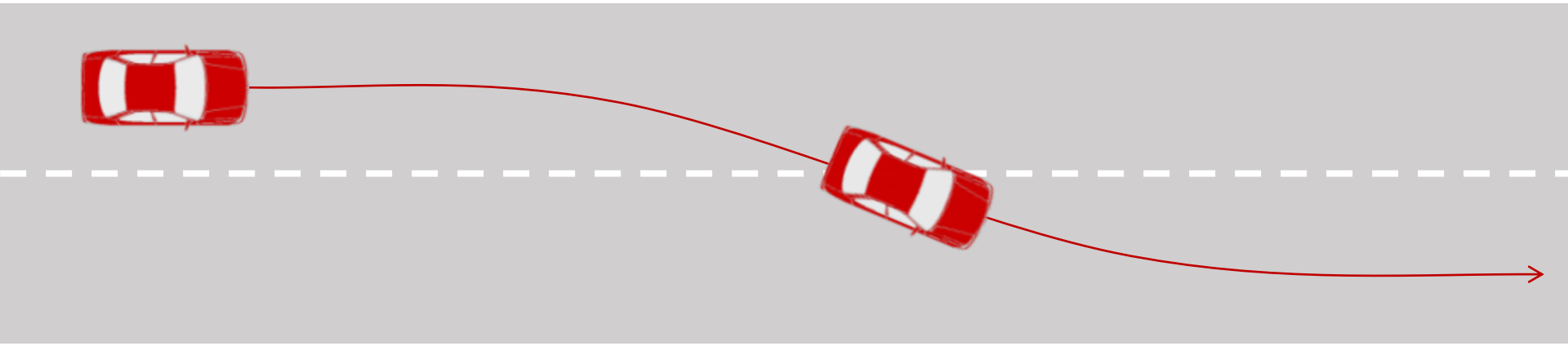
DATA2: 6362 cut-in data form The Highway Drone Dataset (High-D)

- Naturalistic Trajectories of 110 500 Vehicles Recorded at German Highways

https://www.highd-dataset.com/

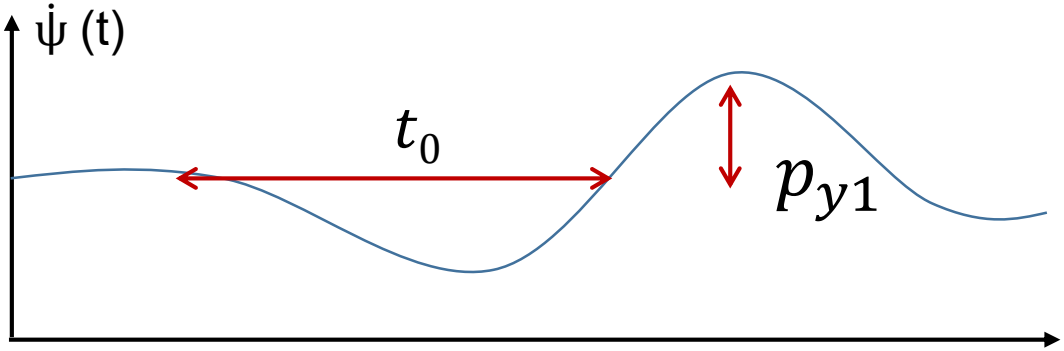
Krajewski, Robert,. Bock, Julian, Kloeker, Laurent,. Eckstein, Lutz , The highD Dataset: A Drone Dataset of Naturalistic Vehicle Trajectories on German Highways for Validation of Highly Automated Driving Systems, ITSC, 2018.

Kinematic model of cut-in maneuvers



Lateral (steering) parameters

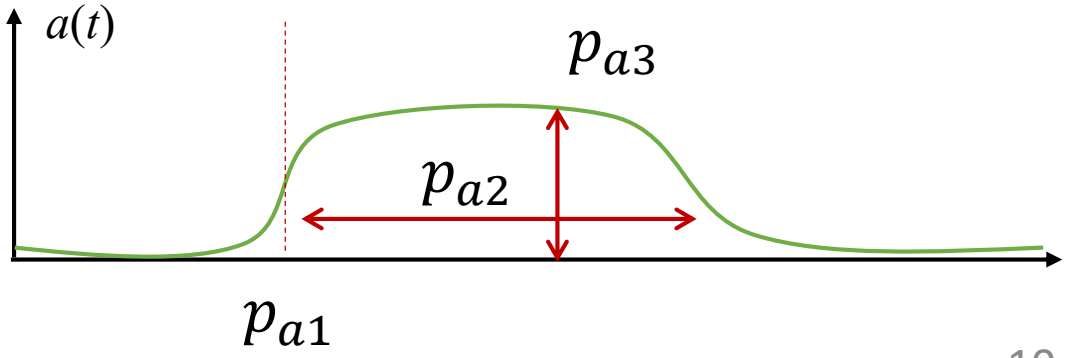
$$\dot{\psi}(t) = p_{y1} \sin(\pi t / t_0)$$



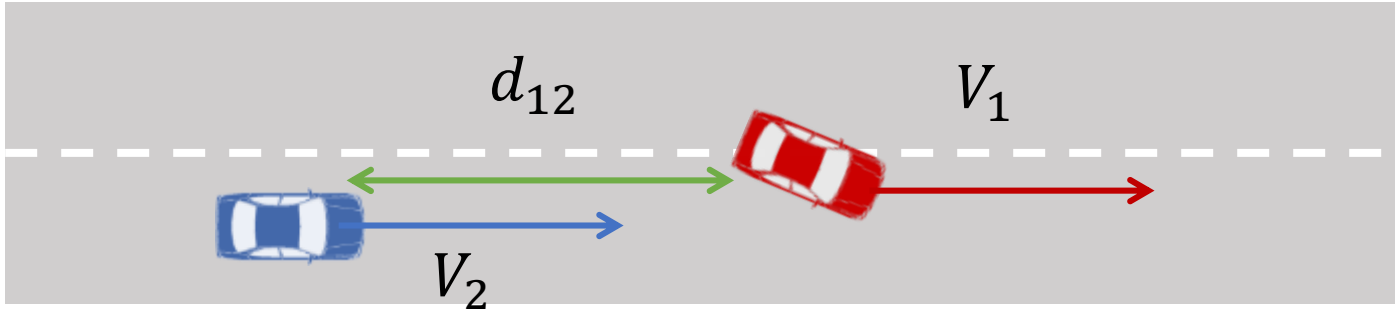
Longitudinal motion parameters

$$v(t) = v_0 + \int a(t)\mathrm{d}t$$

$$a(t) = \mathrm{rect}(t, p_{a1}, p_{a2}, p_{a3})$$



Risk index of cut-in maneuver



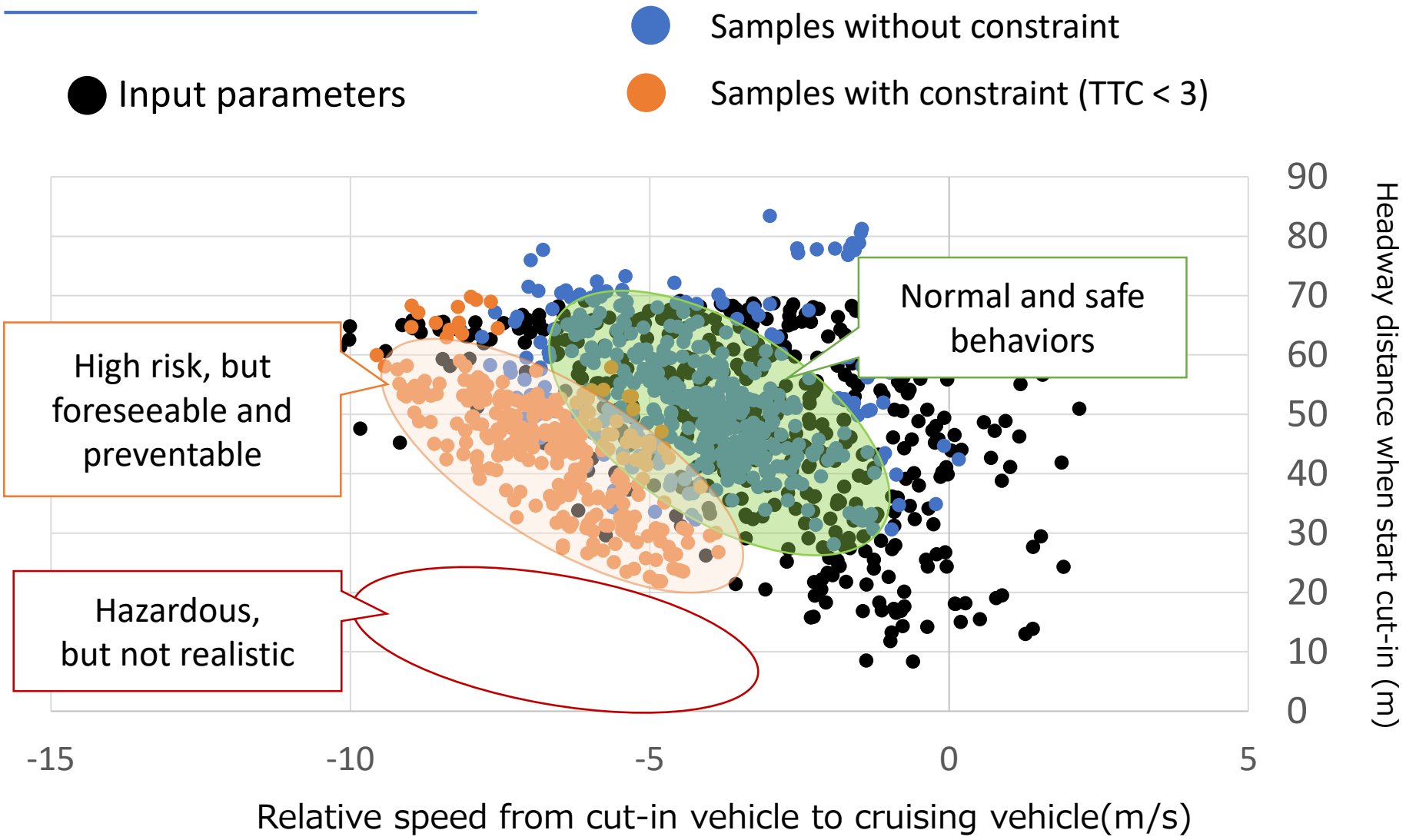
Risk-index : Time to collision (TTC)

$$TTC = d_{12}/(V_1 - V_2)$$

$$P = \{p_{y1}, p_t, p_{a1}, p_{a2}, p_{a3}, p_{vo}, TTC\}$$

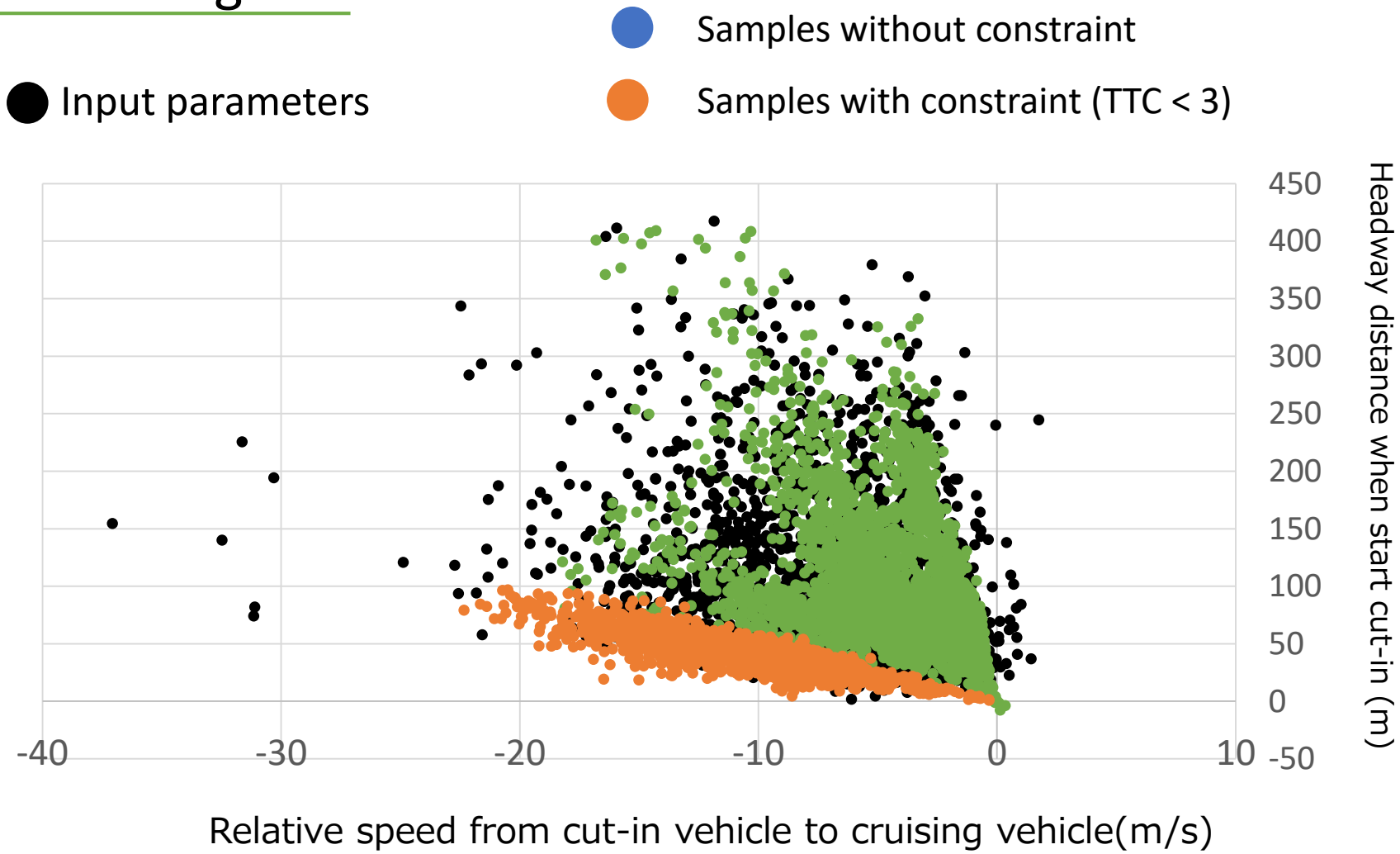
Experimental evaluation

DATA1: JARI dataset



Experimental evaluation

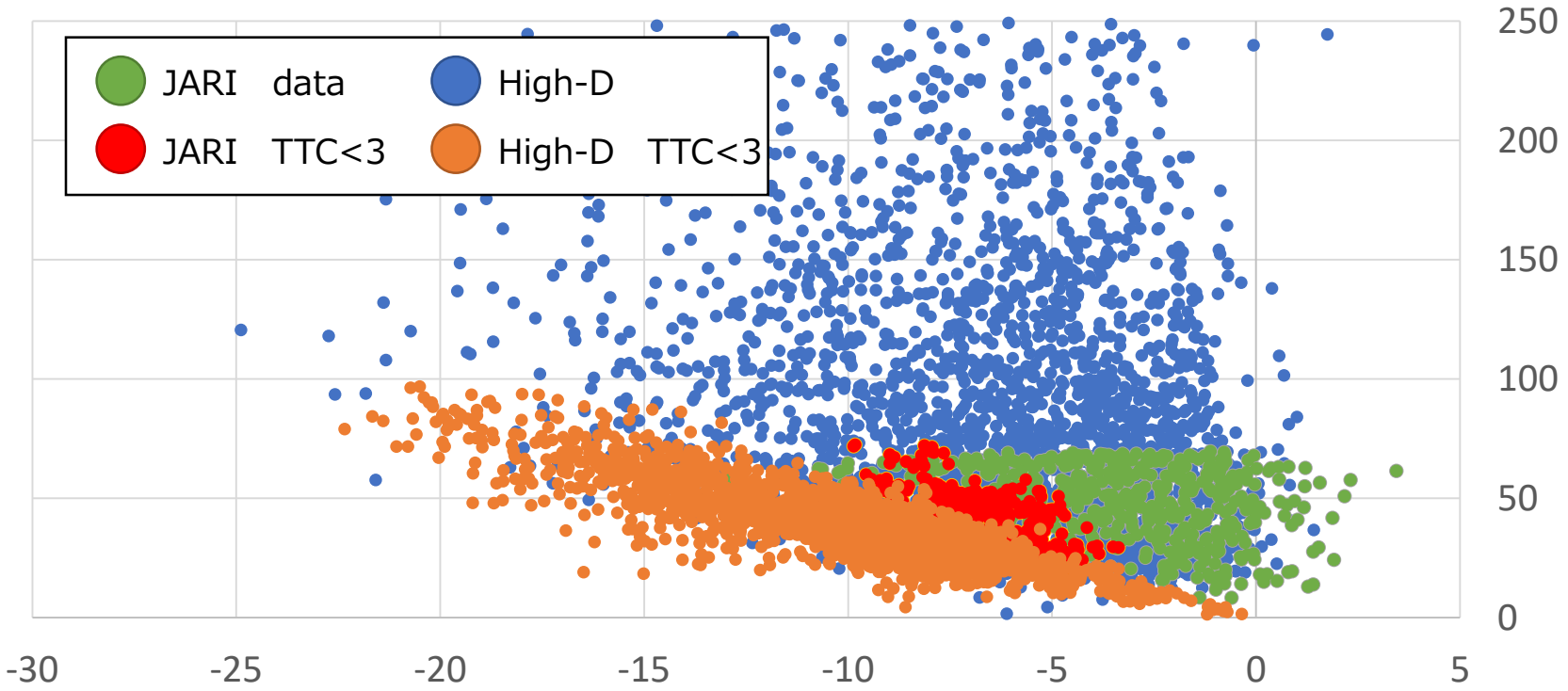
DATA2: High-D



Experimental evaluation

Conversion of JARI and High-D datasets

There is a difference in the scope (difficulty) of the sampled scenarios.
The importance of collecting data from multiple points (countries) and measurement methods is shown.



Conclusions

- We propose a framework to analyze data and generate test scenarios for safety evaluation of ADs.
- The method analyzes actual traffic data (NDD) using a probabilistic model that is independent from driving behavior modeling.
- The proposed method enables to sample test scenarios reflecting high risk behaviors from original data that mostly contain safe driving situations.