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8th EAI International Conference on Intelligent Transport Systems
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A Preliminary Approach To Verify Platoon Behaviour Using Execution Traces and Model Checking

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FORESEEN Project
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NOWADAYS

rapid growth of
autonomous vehicle technology

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PLATOON

group of vehicles that travel together,
based on wireless communication.

TWO PRIMARY ARCHITECTURES:

- centralized, leader or a server makes operational decisions,
- distributed, each vehicle autonomously deciding.

These systems require precise coordination and robust verification to ensure reliability under all conditions.

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Cooperative Adaptive Cruise Control

It uses vehicle-to-vehicle (V2X) communication and onboard sensors to dynamically adjust a vehicle's speed and maintain safe distances.

It can reduce some of the most common causes of accidents:

- inadvertent braking,
- rear-end collisions
- driver error.

Model Checking Techniques

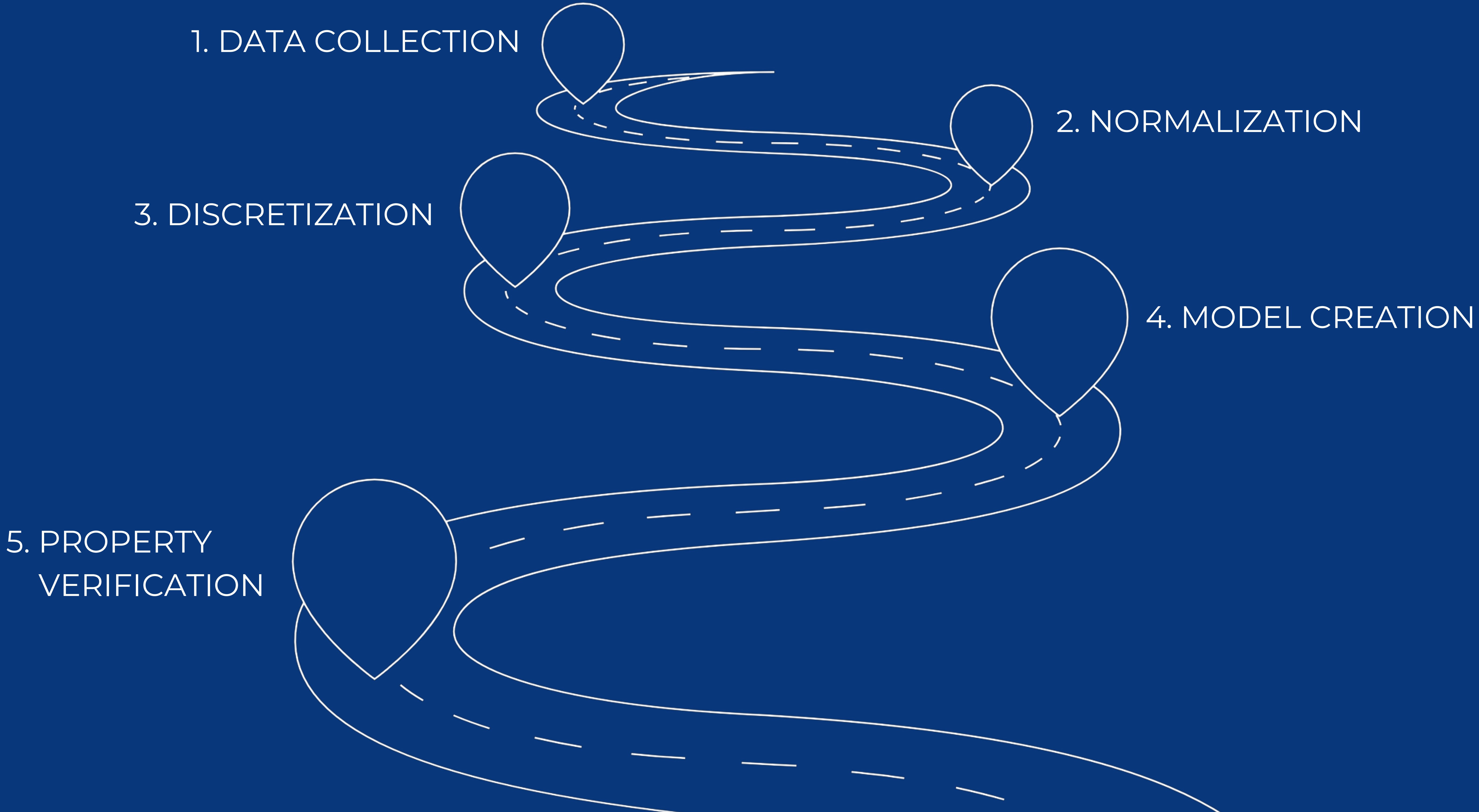
work by:

01
Creating a formal model of the system.

02
Defining logic formulas that represent desired system properties.

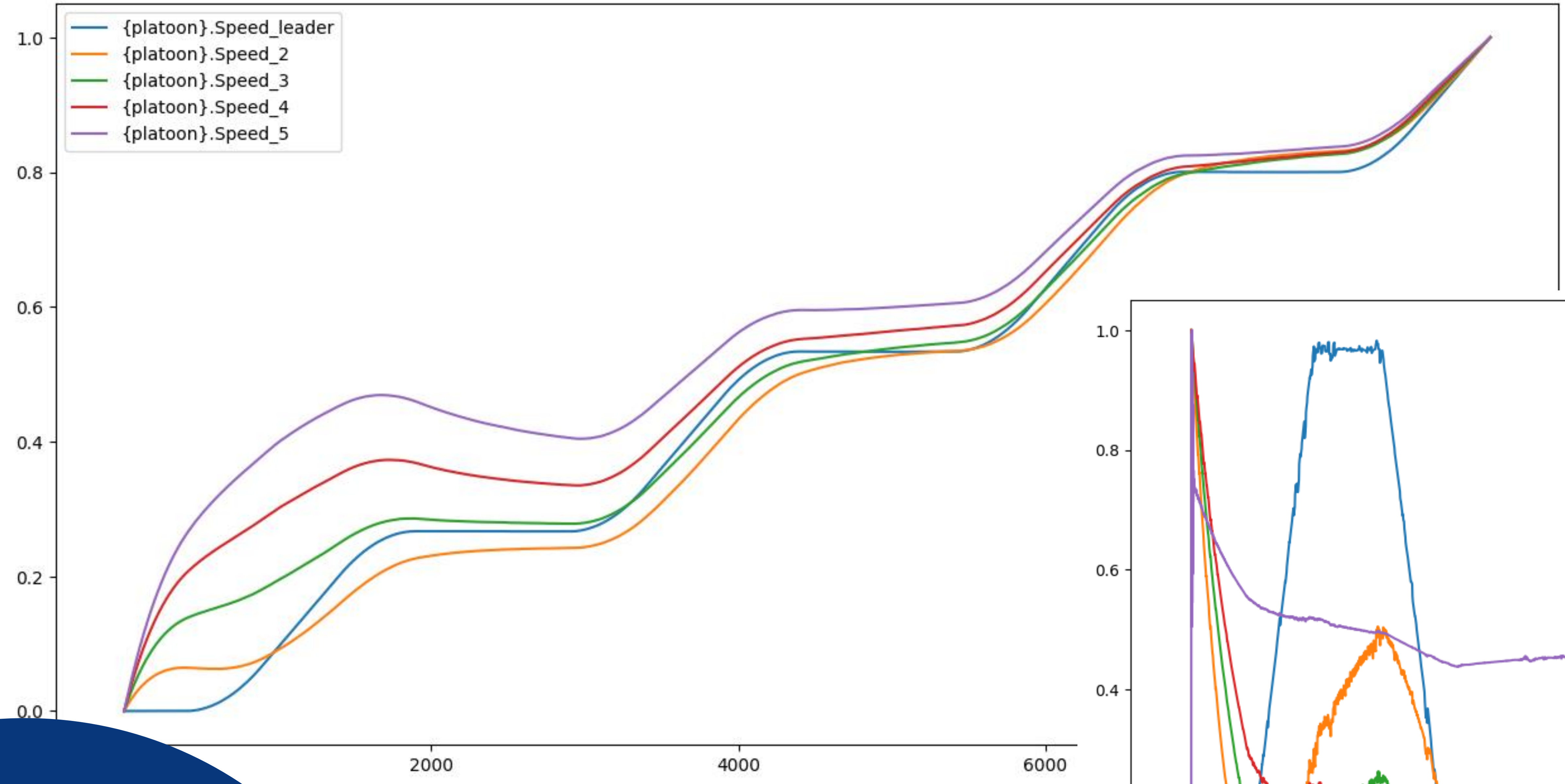
03
Running these inputs through a model checker, which determines if the properties hold or provides counterexamples if they don't.

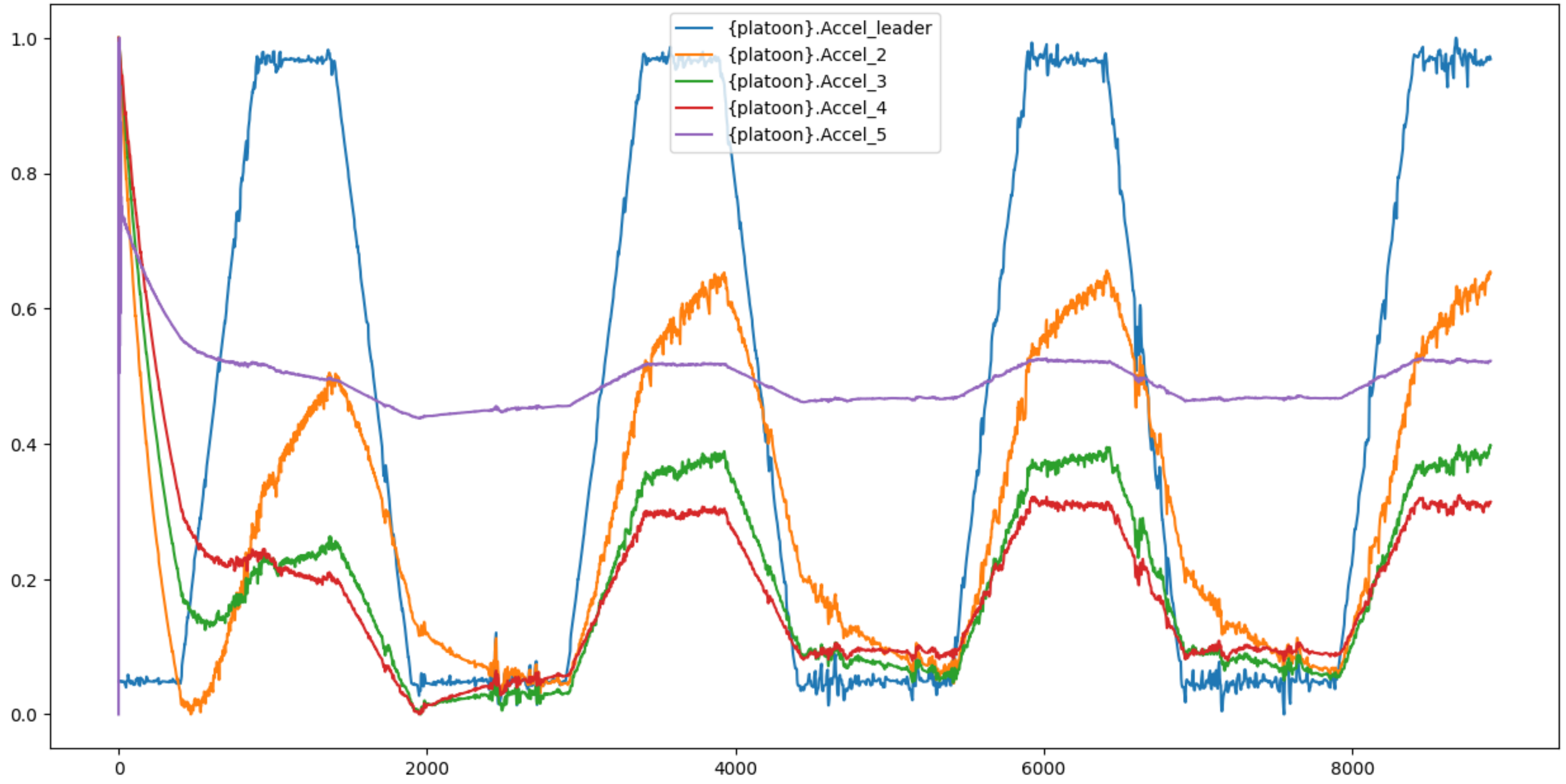
Proposed Workflow



Case Study

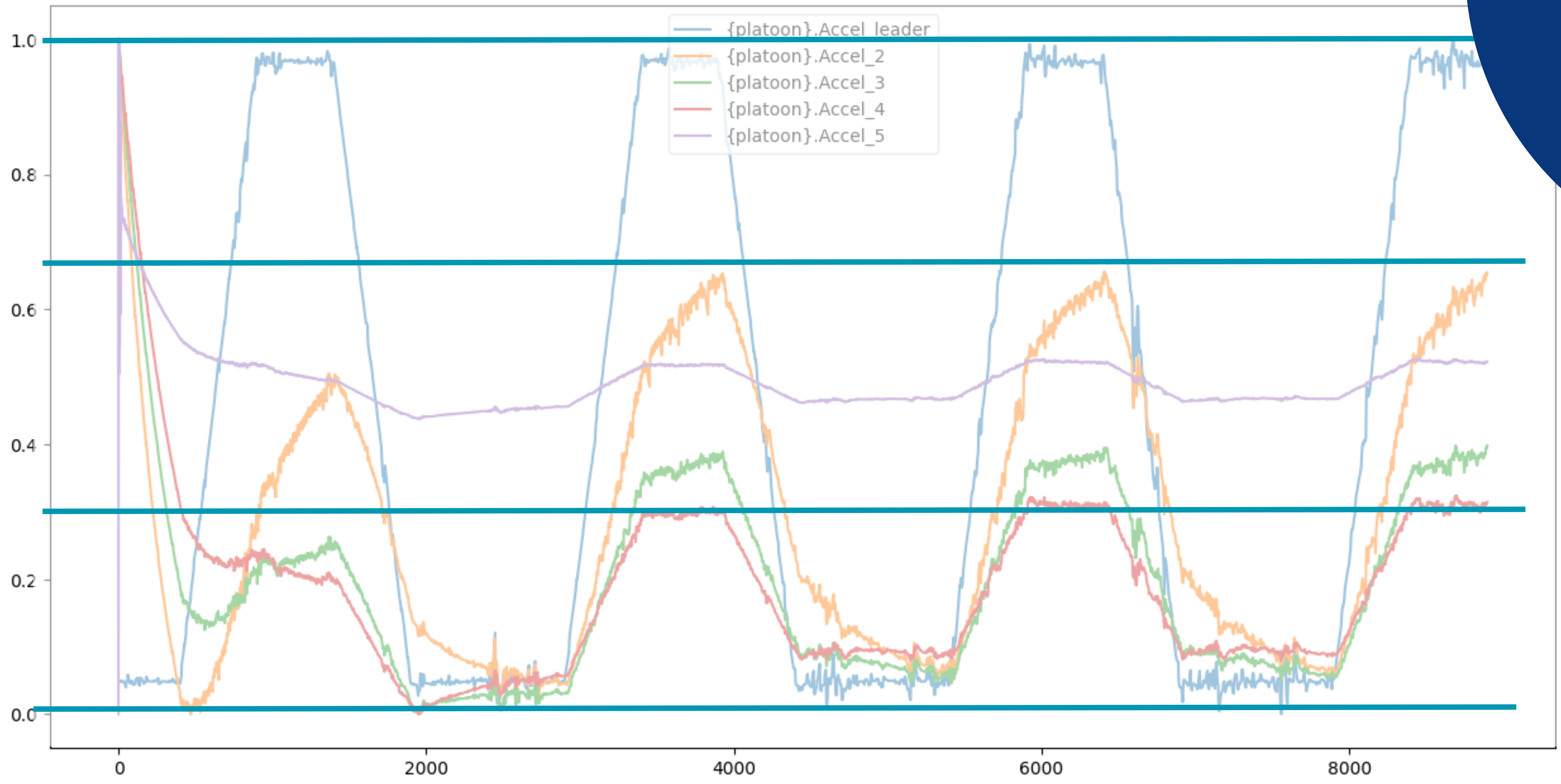
8,899 samples of acceleration and velocity of four vehicles





Case Study

DISCRETIZATION predefined intervals



Case Study

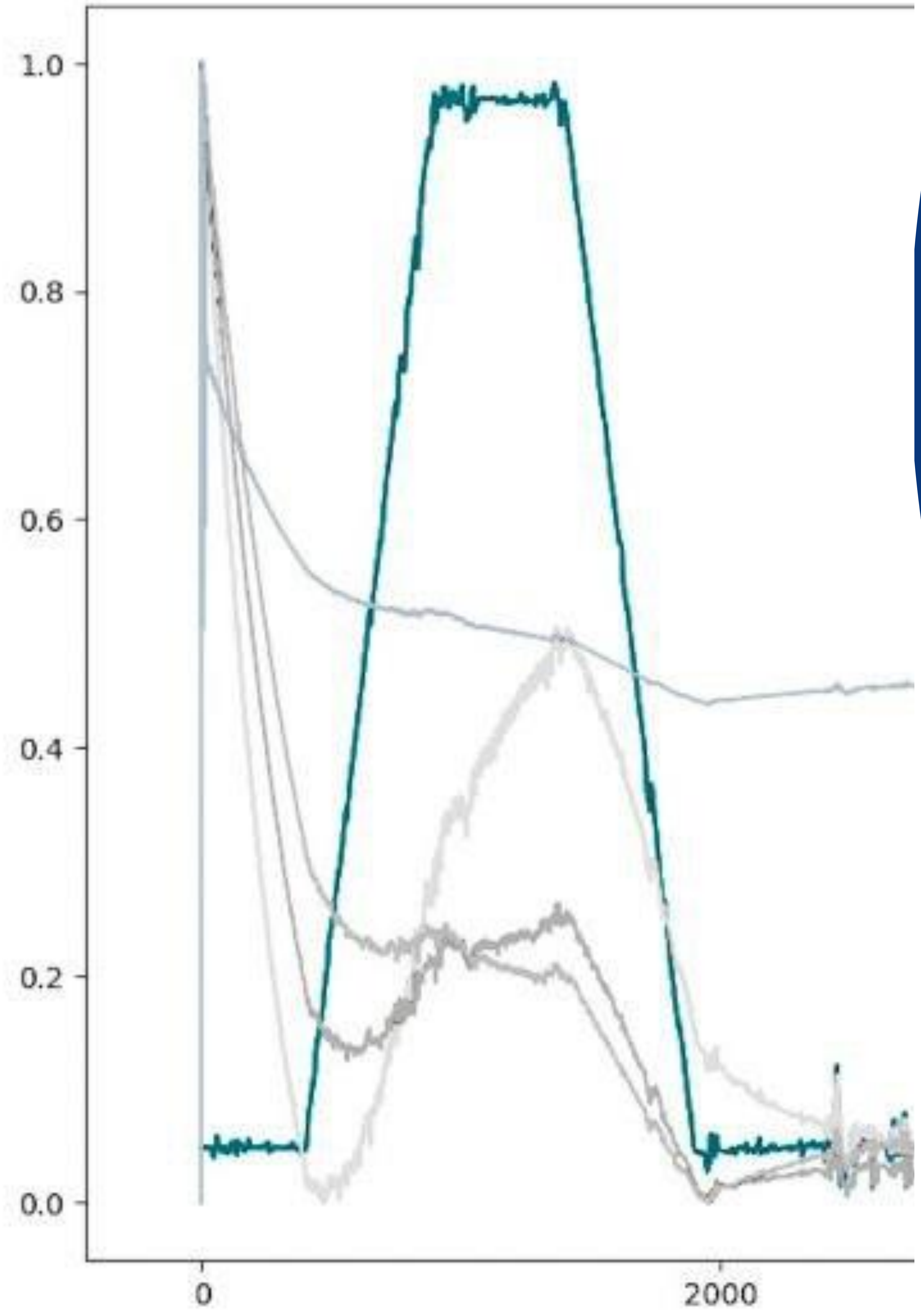
DISCRETIZATION

slope analysis

TWO PHASES:

1. Augmented Dickey-Fuller test to evaluate if the sample in a window were constant
2. Assessement of the slope to define if there were an increasing or decreasing.

several widths (50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550)



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Formal Models Creation

two transformation functions:

- f1, to model the sequential behavior of individual vehicles.

$$p_{i_j} \stackrel{\text{def}}{=} (Acceleration \parallel Velocity)\;; p_{i_{j+1}}$$

- f2, to synchronize multiple vehicles, mimicking their interactions during coordinated maneuvers.

$$p_{0_0} \stackrel{\text{def}}{=} (increasingAcc0.DONE \| increasingVel0.DONE); (\overline{synk_0}.go_0.p_{0_1})$$

Property Verification

01

Acceleration propagation

$$\begin{aligned}
\varphi_1 &= \mu X.\, \langle increasingAcc0 \rangle\, \varphi_{1_1} \vee \langle - increasingAcc0 \rangle\, X \\
\varphi_{1_1} &= \mu X.\, \langle increasingAcc2 \rangle\, \varphi_{1_2} \vee \langle - increasingAcc2 \rangle\, X \\
\varphi_{1_2} &= \mu X.\, \langle increasingAcc3 \rangle\, \varphi_{1_3} \vee \langle - increasingAcc3 \rangle\, X \\
\varphi_{1_3} &= \mu X.\, \langle increasingAcc4 \rangle\, \mathtt{tt} \vee \langle - increasingAcc4 \rangle\, X
\end{aligned}$$

02

Deceleration propagation

$$\begin{aligned}
\varphi_2 &= \mu X.\, \langle decreasingAcce0 \rangle\, \varphi_{2_1} \vee \langle - decreasingAcce0 \rangle\, X \\
\varphi_{2_1} &= \mu X.\, \langle decreasingAcce2 \rangle\, \varphi_{2_2} \vee \langle - decreasingAcce2 \rangle\, X \\
\varphi_{2_2} &= \mu X.\, \langle decreasingAcce3 \rangle\, \varphi_{2_3} \vee \langle - decreasingAcce3 \rangle\, X \\
\varphi_{2_3} &= \mu X.\, \langle decreasingAcce4 \rangle\, \mathtt{tt} \vee \langle - decreasingAcce4 \rangle\, X
\end{aligned}$$

Preliminary Results

for all several widths

50 ✓ 100 ✓ 150 ✓ 200 ✓ 250 ✓ 300 ✓ 350 ✓ 400 ✓ 450 ✓ 500 ✓ 550 ✓

Challenges and Limitations

- **State explosion**: as the number of vehicles or parameters increases, the complexity of verification grows exponentially.
- **Loss of detail**: discretization simplifies data but might overlook subtle anomalies.
- **Simulated data**: real-world factors like road conditions or driver interactions are not fully captured.

Future Work

- Integrating real-world datasets into our models to improve accuracy.
- Extending the framework to include more complex platoon behaviors and scenarios.
- Testing the system against adversarial conditions to verify robustness against attacks.

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Thank you

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