Shockwave Detection and Visualisati
for Rear-End Collision Avoidance

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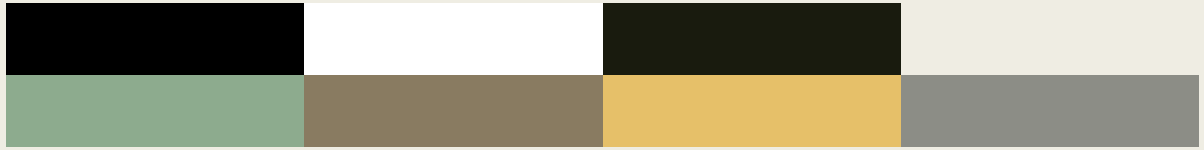

Background

- Growing demands for environmental measures in the automotive sector
- Traffic congestion and accidents remain critical issues despite of the spread o

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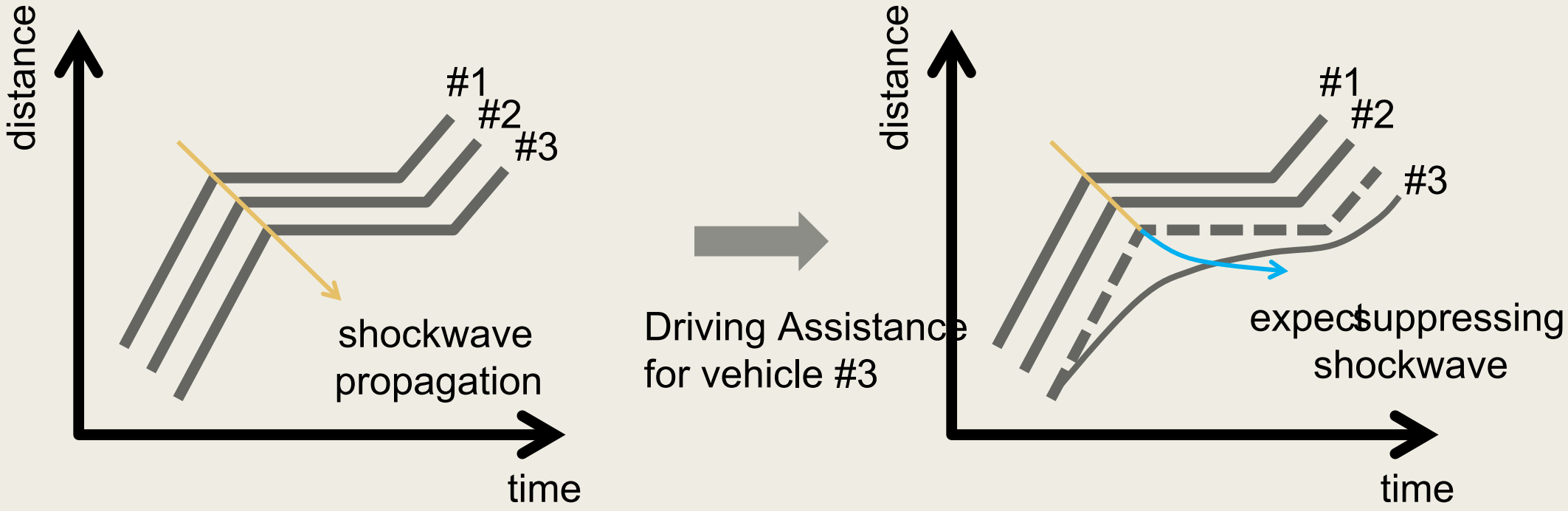
- One element causing traffic congestion is the propagation of shockwave

- However, drivers cannot directly see these shockwaves. Brake lights are curr only the device for signalling the deceleration of a preceding vehicle.

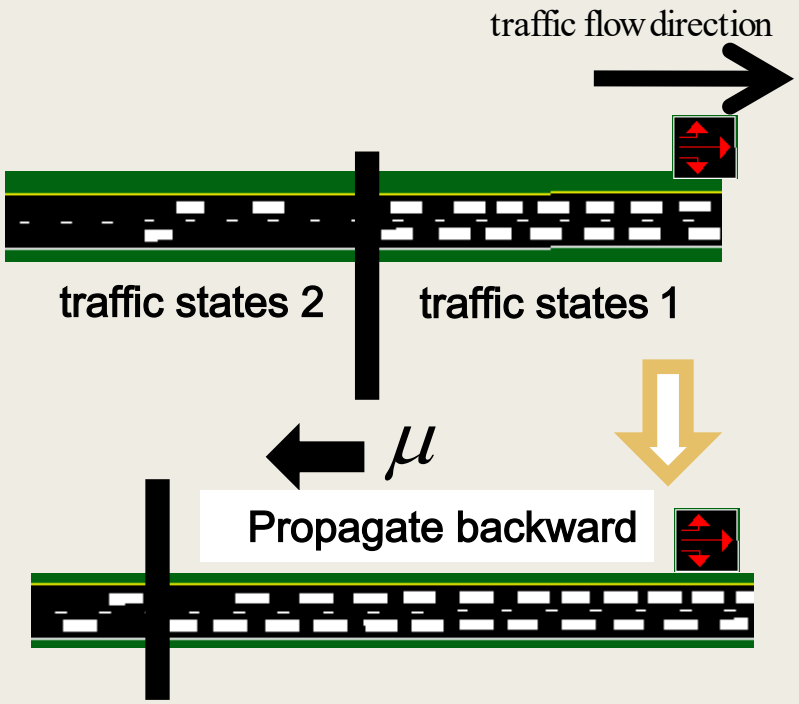
- It is believed that:
  - Suppressing shockwaves contributes to safer and more stable traffic
  - Dampening shockwaves enhance rear-end collision avoidance strategy

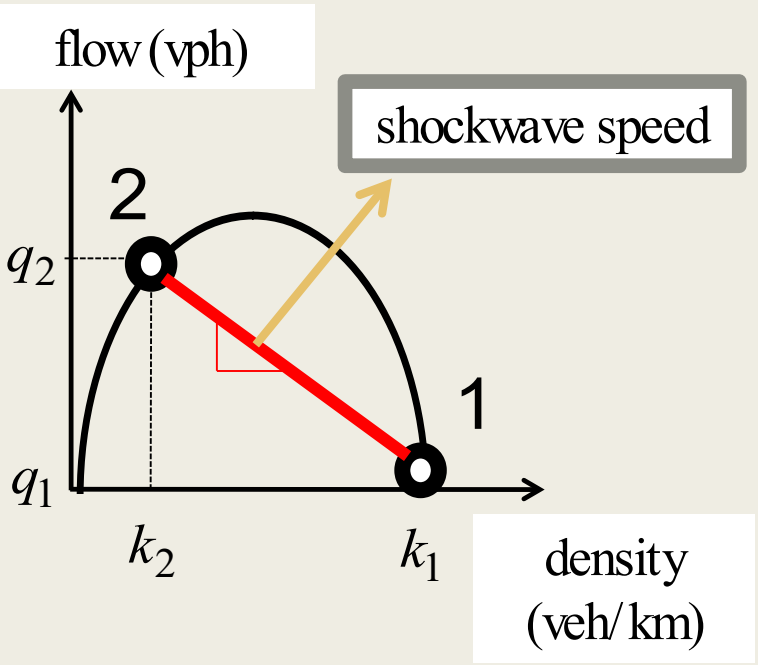
Objective

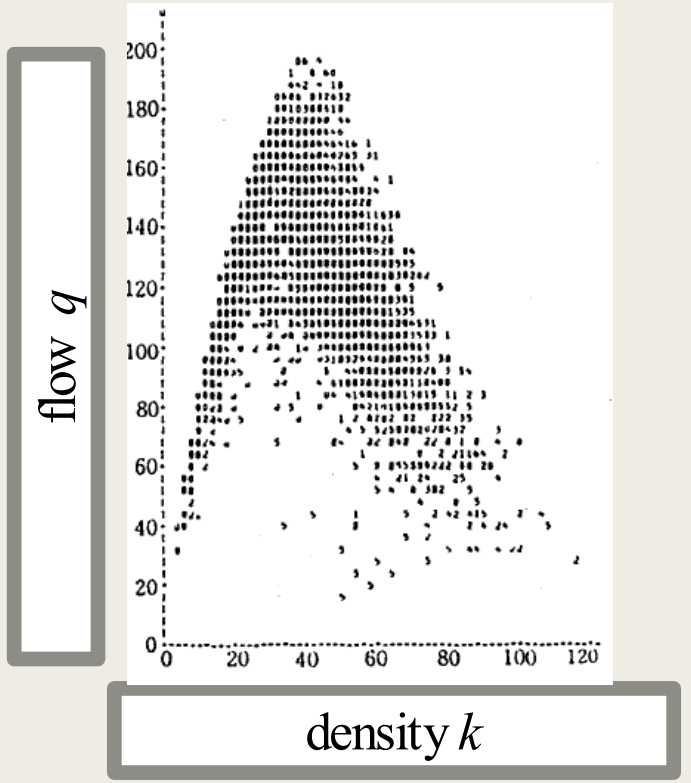
- To propose a shockwave visualization technique using only sensors equippe the vehicle itself
- Without requiring vehicle detectors or a large number of probe cars



Shockwave in Macroscopic Traffic Flow





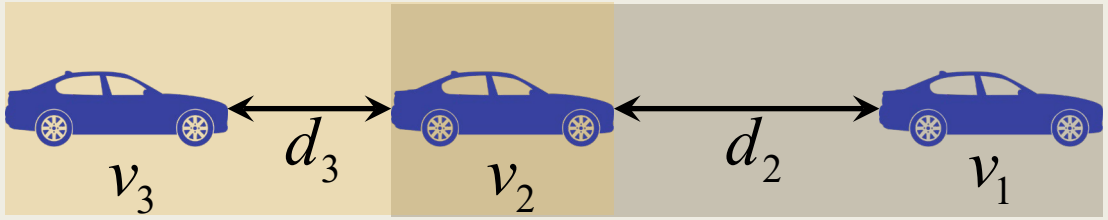


μ: Shockwave speed

$$\mu = \frac{q_1 - q_2}{k_1 - k_2}$$

from the conventional theory of traffic flow

Shockwave Formulation between Three Vehicles



- density can be the inverse of the time headway $k = \frac{1}{d}$
- flow = density X velocity $q = kv^* = \frac{v^*}{d}$ v^* : average speed of two consecutive vehicles
- shockwave propagation speed between three vehicles

$$\mu = \frac{q_2 - q_3}{k_2 - k_3} = \left(\frac{v_1 + v_2}{2d_2} - \frac{v_2 + v_3}{2d_3} \right) \Bigg/ \left(\frac{1}{d_2} - \frac{1}{d_3} \right)$$

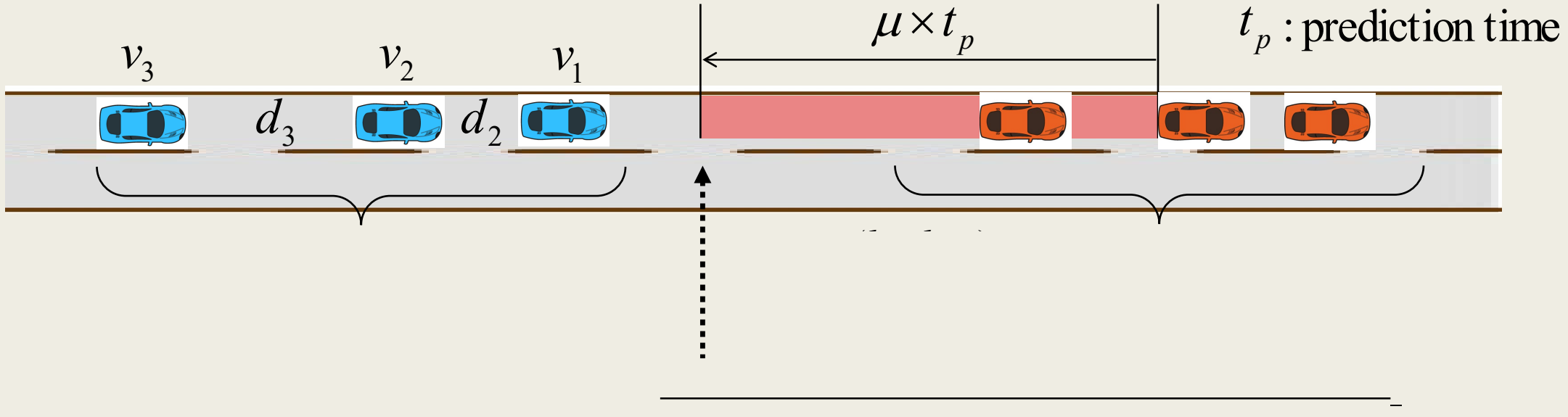
μ : speed relative to the ground

- Converted to the apparent velocity relative to the first vehicle

$$\mu = \left(\frac{v_1 + v_2}{2d_2} - \frac{v_2 + v_3}{2d_3} \right) \Bigg/ \left(\frac{1}{d_2} - \frac{1}{d_3} \right) - v_3 = \left(\frac{v_1 + v_2 - 2v_3}{2d_2} - \frac{v_2 - v_3}{2d_3} \right) \Bigg/ \left(\frac{1}{d_2} - \frac{1}{d_3} \right)$$

- assumption:
  - The velocity and headway distance of the 1st and the 2nd vehicles can be obtained by the sensors equipped with the 3rd vehicle.
- characteristic:
  - The detection and suppression of the shockwave propagation can be carried out by a single vehicle.

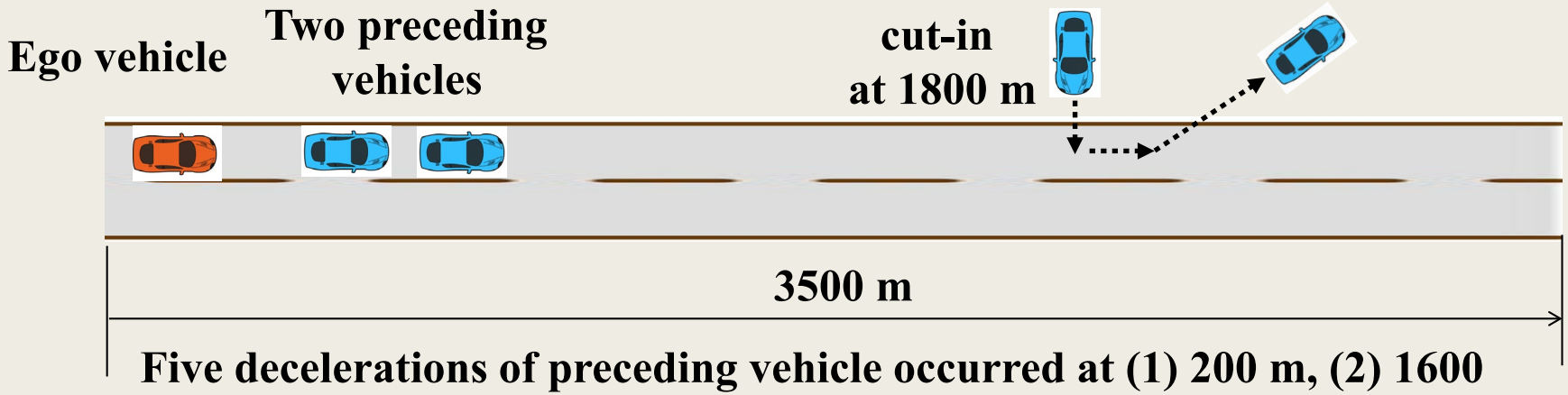
Shockwave Visualization Procedure



- Step 1: From the current speed and distance between vehicles, calculate the speed μ of the shockwave.
- Step 2: Predict the position of the three vehicles after t_p.
- Step 3: The value μ Xt_p is visualized and extended backward from the rear end of the predicted position of the 2nd vehicle.

Driving Simulator Experiment

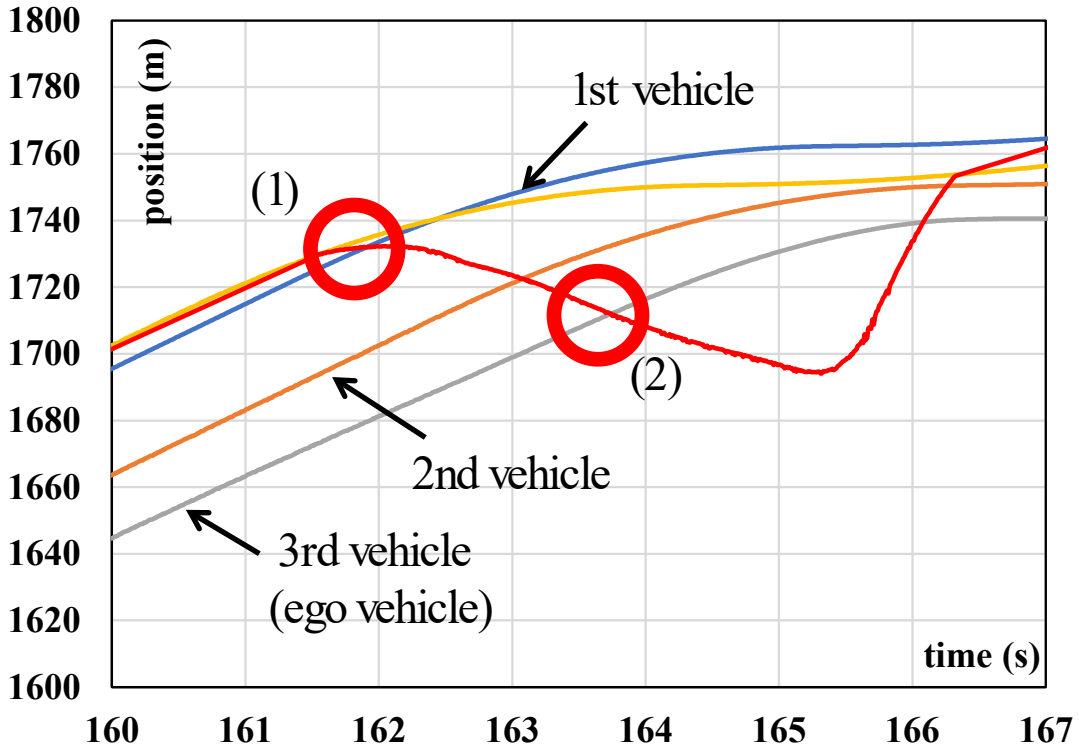
- A fixed motion driving simulator
- The ego vehicle follows the two preceding vehicles that decelerate five times travelling a 3.5 km straight corridor.
- Major task: to follow vehicles not to make collisions, Secondary task: to type text in a sm phone app
- Eight young driver (mean age: 22 years, mean driving experiment two years)



Five decelerations of preceding vehicle occurred at (1) 200 m, (2) 1600 m, (3) 1800 m, (4) 2200 m, (5) 3200 m from upstream node.

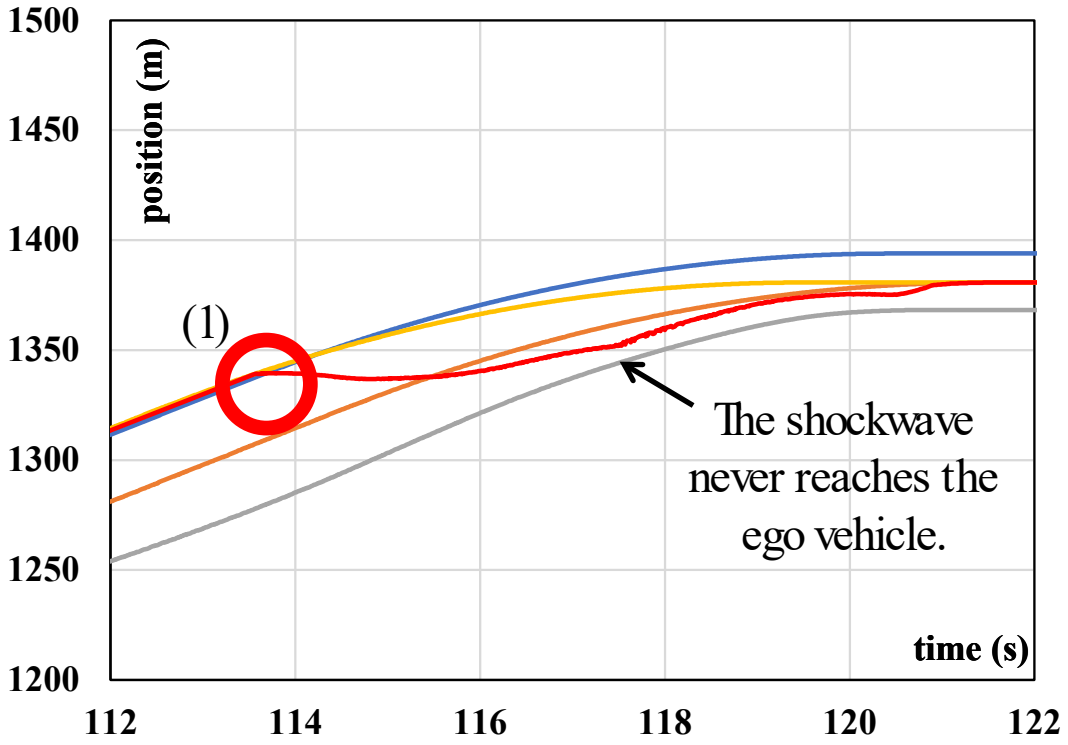
Approved by the Ethics Committee of the Nippon Institute of Technology

Validity of the Shockwave Visualization



(1)Ashockwave is generated

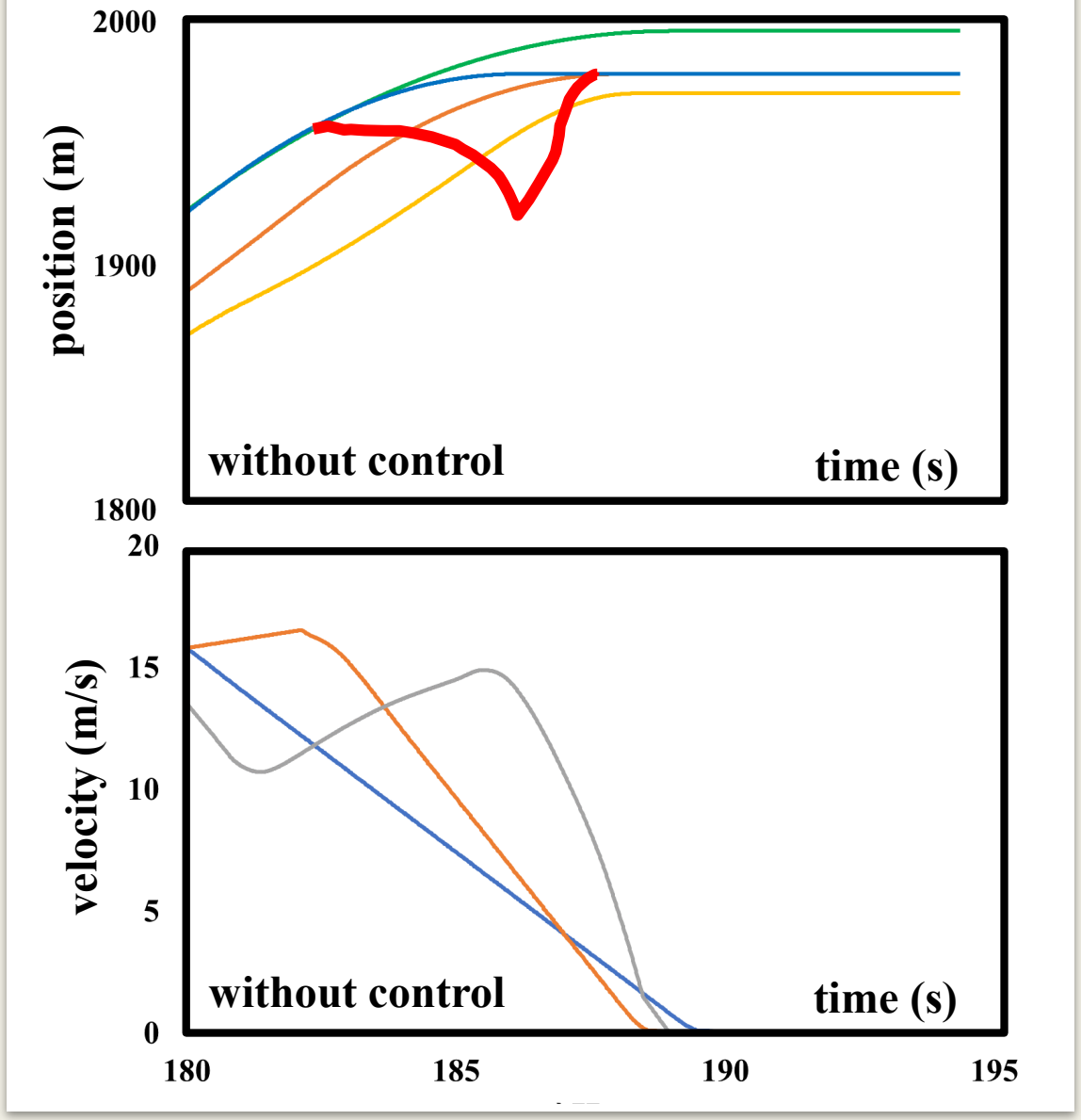
(2) The shockwave reaches the ego vehicle

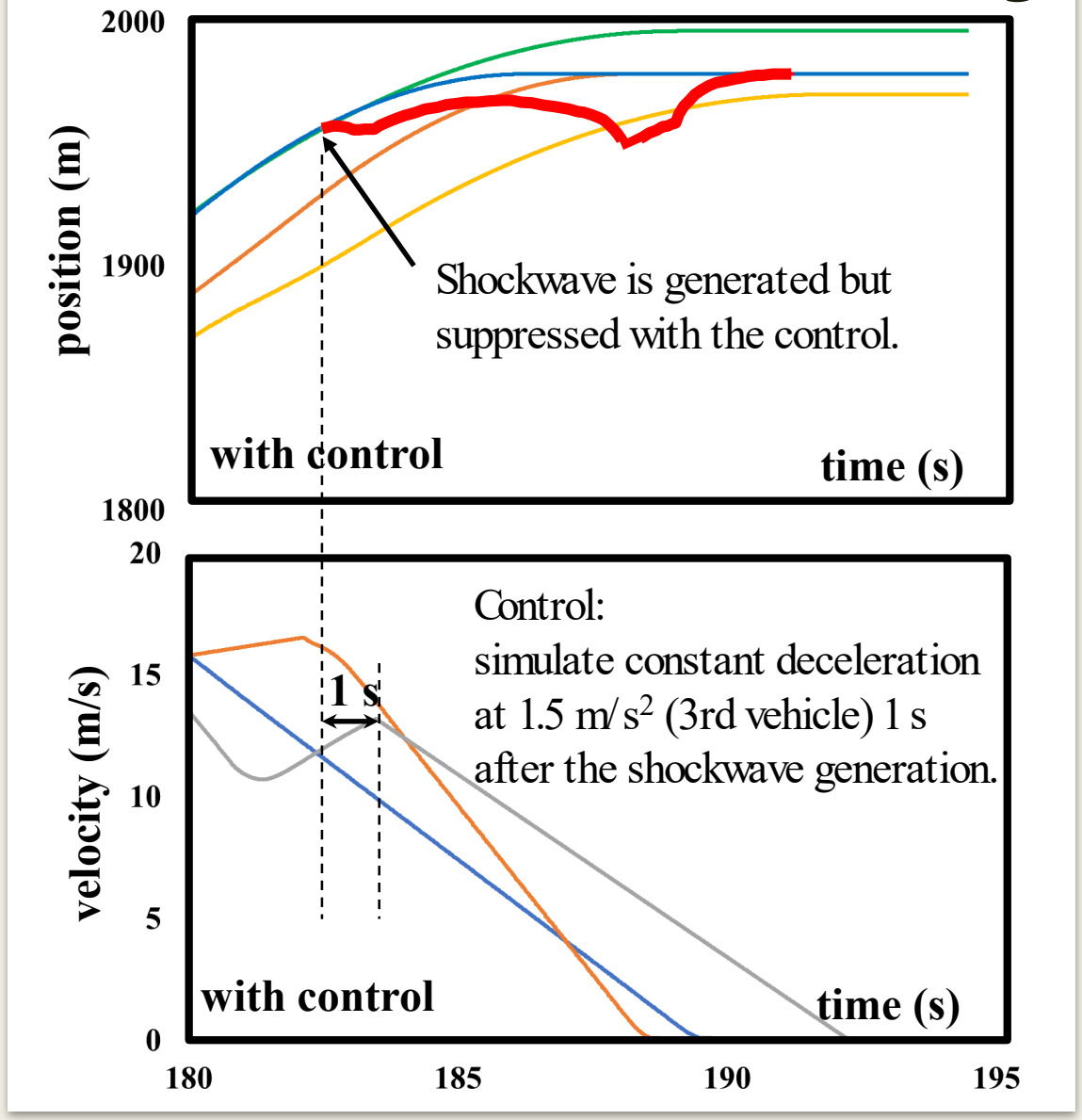


(1) Ashockwave is generated. But it never reaches the ego vehicle.

Invisible shockwave can be clearly visualized by the proposed method.

Simulation to Suppress Shockwave Propagation





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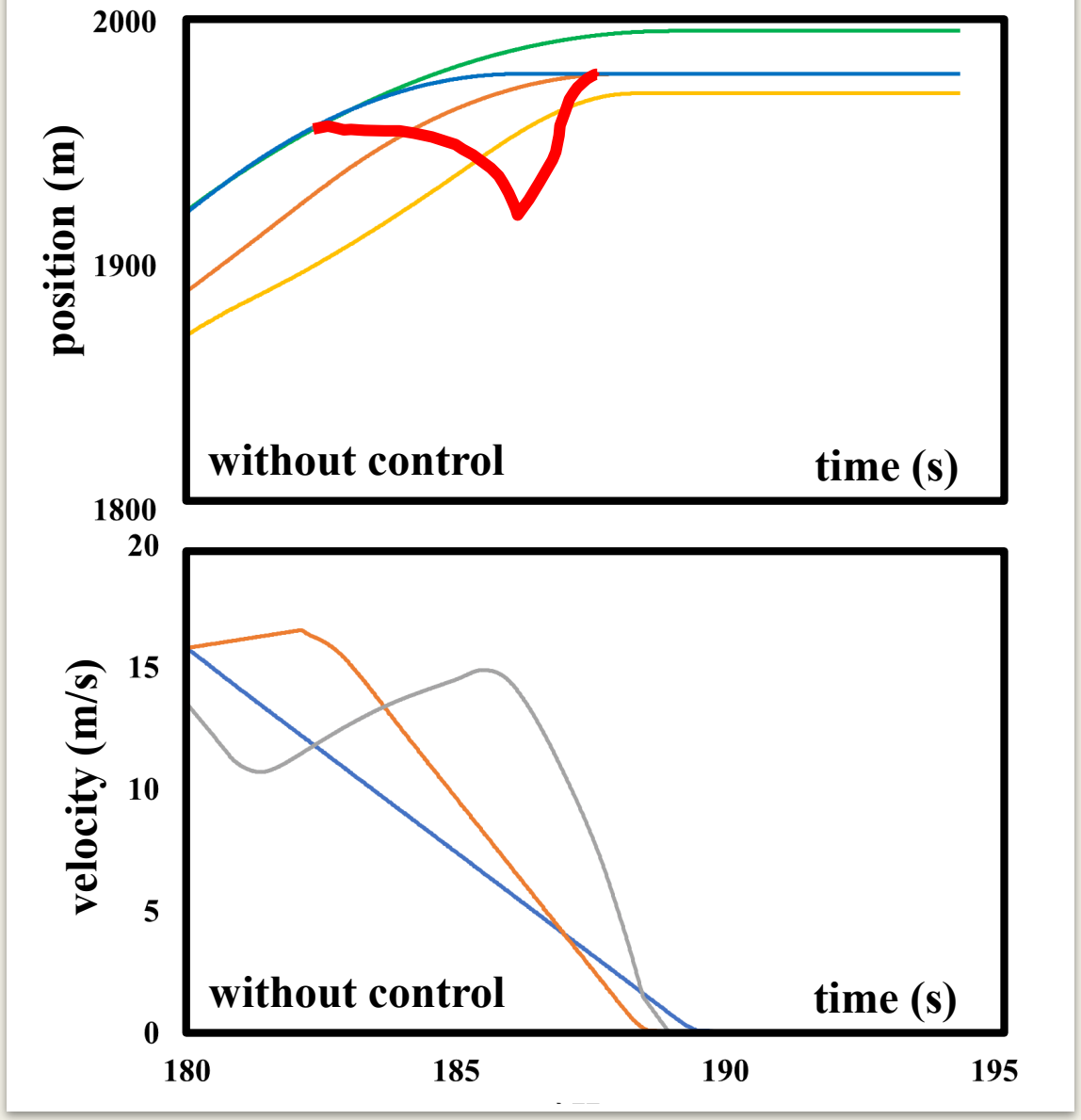

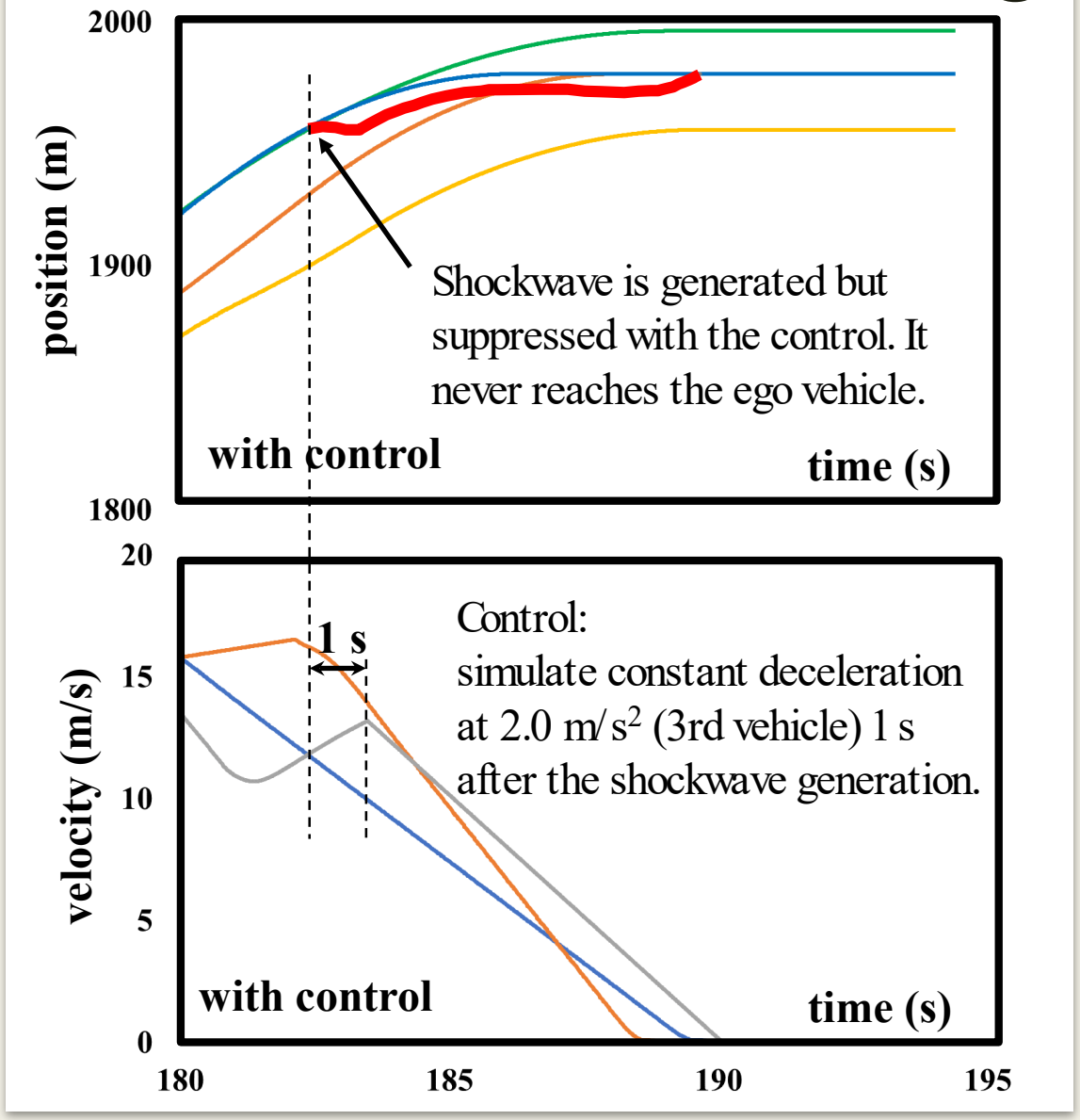

Conclusion

- We attempt to visualize shockwaves generated by three vehicles.
- Proposing a shockwave visualization technique using sensors equipped with a vehicle without requiring infrastructure devices.

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- We confirmed that:
  - invisible shockwave can be clearly visualized by the proposed method,
  - needs more data to confirm the validity,
  - earlier deceleration of the ego vehicle contributes to suppress the shockw propagation.
- Further studies are:
  - to fully validate the proposed model using many validation data,
  - to design an appropriate driver behaviour to suppress the shockwave prop