Fuel Consumption Reduction of Multi-Lane Road Networks using Decentralized Mixed-Autonomy Control

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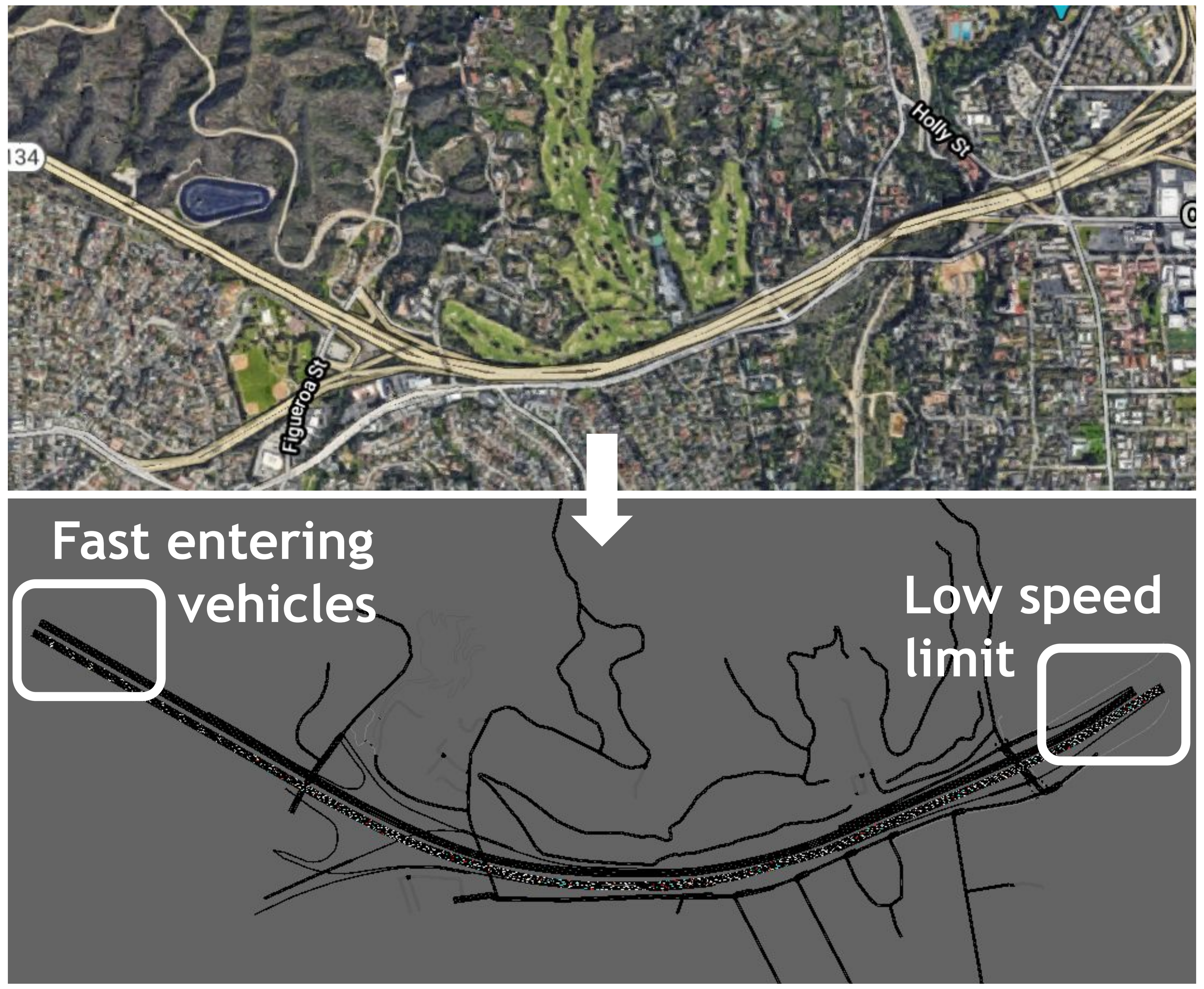


Problem Formulation

We consider a **complex traffic scenario** of the Interstate-210 highway near Los Angeles, pulled from OpenStreetMaps into simulation, allowing us to observe **realistic long-range interactions**.

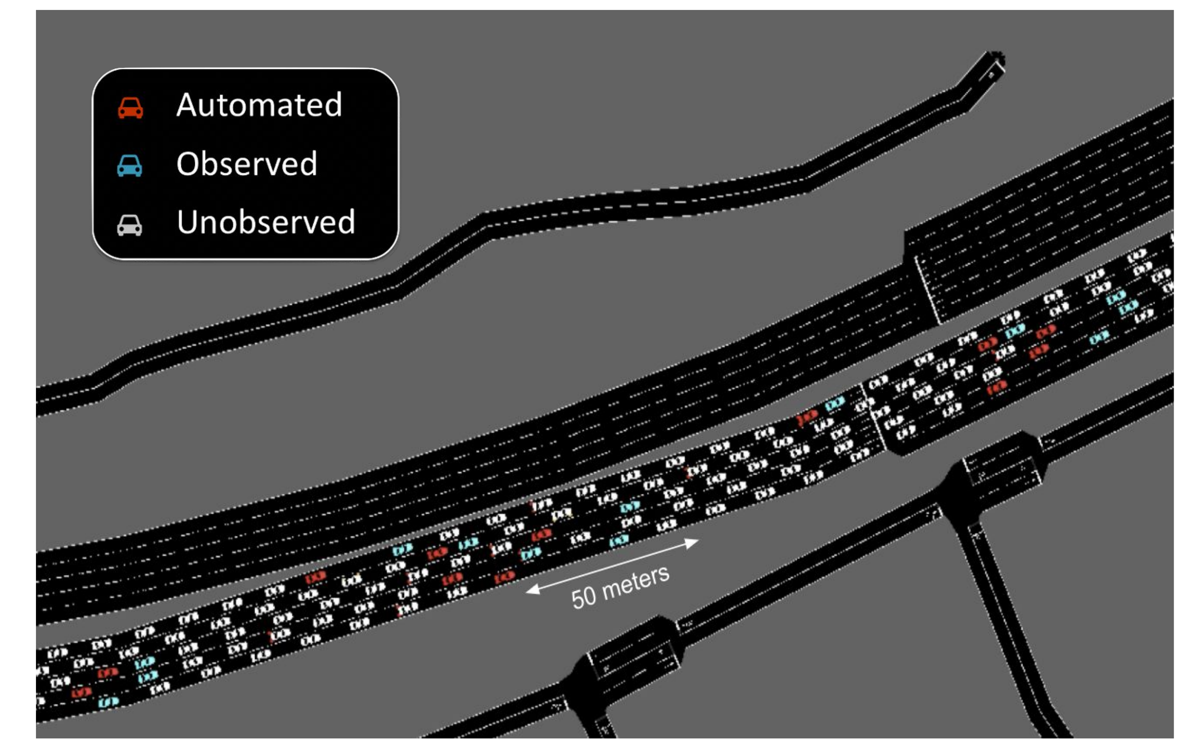
We introduce a downstream speed limit thus leading to the formation of stop-and-go waves. Introducing a **low proportion of autonomous vehicles (AV)** into the system, we aim to smooth out these waves thus **increasing the energy efficiency** of the highway.

Method

Using **multi-agent reinforcement learning**, we design an effective controller for the AVs. The controller is a neural network, computed independently for each AV, and trained with gradient descent to optimize the objective function.

- ➔ **States** (input): AV speed, leader speed, gap between the two
- ➔ **Action** (output): instantaneous acceleration for the AV
- ➔ **Reward function**: minimize the instantaneous energy consumption of the AV at each time-step, while penalizing large accelerations, crashes and low or large gaps.

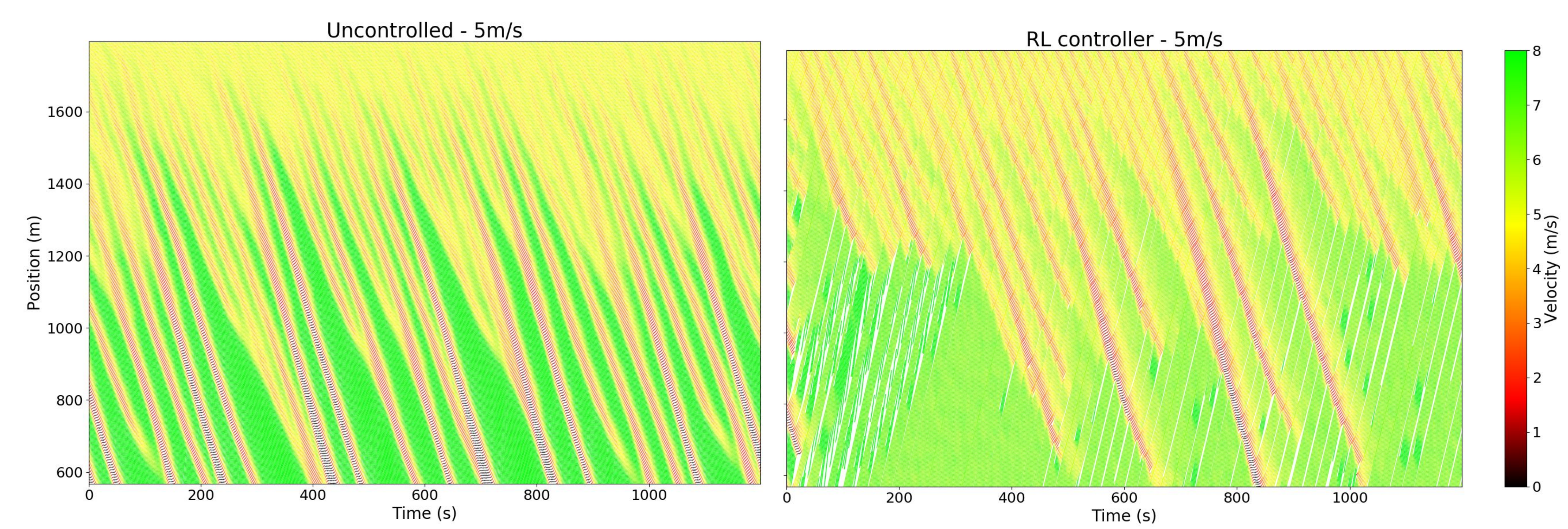
$$r_t = 1 - \mathbf{E}_t^{\text{av}} - c_0 \cdot a_t^2 - c_1 \cdot P_t^{\text{gap}} - c_2 \cdot P_t^{\text{crash}}$$



The small, local input state helps with generalization and with easy deployment of the controller.

Results

- ❖ **25% energy improvement** at a 10% AV penetration rate, without any throughput trade-off.
- ❖ Shows **generalization** outside of the training distribution and **robustness** to variations in penetration rate, downstream speed limit and driving dynamics.
- ❖ Performs comparably to a standard state-of-the-art control algorithm, but without requiring knowledge of the equilibrium speed of the system.



Our controller partially dampening the waves at a 10% penetration.

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