Augmenting Physical Safety by Modifying Vehicular Networking Communication Methods

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Background

- Future vehicles will communicate to augment safety
- Vehicles will broadcast at least position, speed, heading, and acceleration on regular intervals
- Current US protocol uses static interval of 100ms
- Current EU protocol has a dynamic frequency

Task

=> Evaluate frequency of safety messages to identify what adjustments could augment vehicle safety and reduce network congestion

Methodology

1. **Quantified physical safety.** Prior work estimates the chance of collision and multiplies it by a relative velocity factor. $$Q = \sum_{\text{cars expected to collide in near future}} (\text{relative velocity})^2$$
2. **Analyzed the SafetyPilot Dataset.** We explored an existing Ann Arbor dataset for vehicular networking.
3. **Created a vehicular networking simulator.** Vehicles spawn, communicate, and navigate to dest.
4. **Trained a neural network with reinforcement learning in the simulator.** Environment penalizes off-roading, collisions, and hard braking.
5. **Built BSM Communication.** Vehicles alerted of other vehicles using a simulator safety message.
6. **Compared successful or crashed trips.**

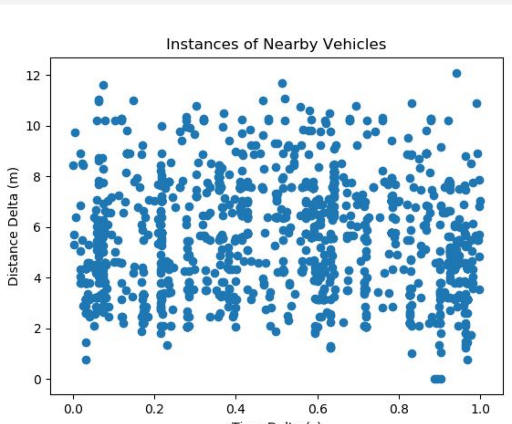


Figure 1: Plot showing closest distance and time pairs in SafetyPilot dataset

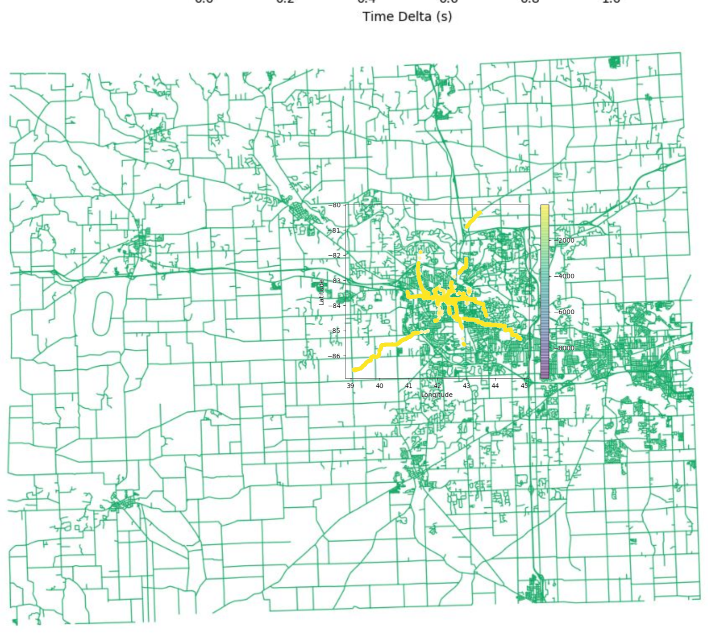


Figure 2: Superimposed trace of SafetyPilot vehicle locations and Washtenaw county roads

Figure 3: Vehicular simulator overview with 1000 vehicles and destinations, dots are vehicles and squares are destinations

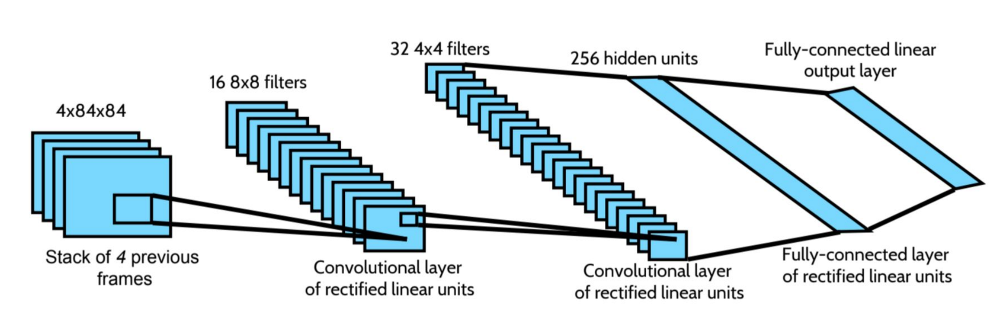
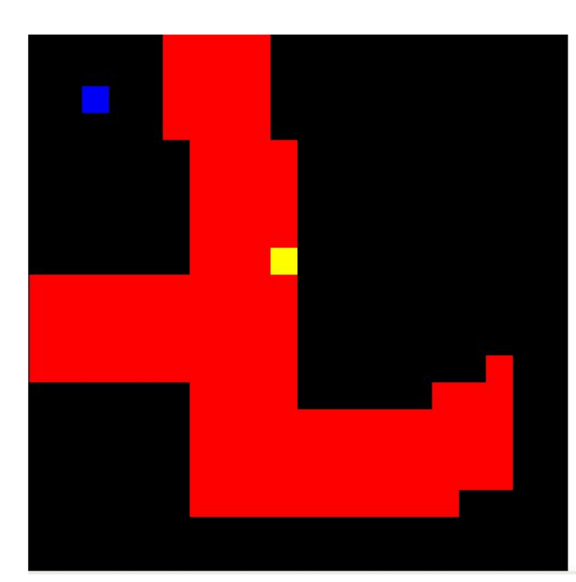


Figure 5: Original DQN Neural Network Architecture for learning from input grids, ours is a derivation



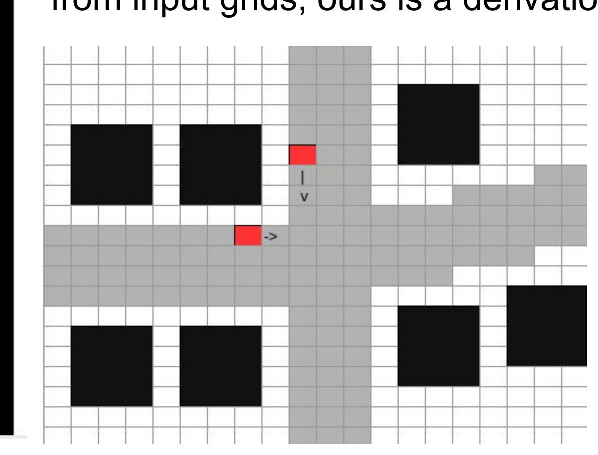


Figure 4: (a) Simulator visibility grid for a vehicle. Red is the road, yellow is the vehicle, and the blue marks a goal. (b) A mockup of a potential collision in the simulator.

Results

- Experiments conducted with varying neural network controllers, frequency of BSM updates, types of controller (velocity/heading change vs. velocity/heading selection).
- Simulator vehicles drive an average of 36.4mph, compared to a national city average of around 30mph.
- The simple network completes vs. crashes at a 1:3 ratio. The convolutional network completes vs. crashes at a similar ratio. Experiments performed at varying vehicle densities.
- Since crashes are frequent, we reported crash rate in our results.
- Evaluated locations where collisions occur.

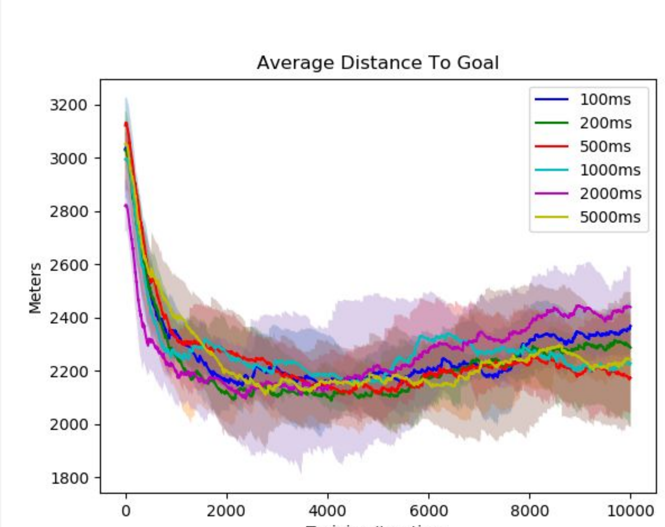


Figure 6 (left): Our agents learn to find their goals. This graph shows the average distance between a car and its goal.

Figure 7 (right): Cars communicating at 100ms crash less frequently

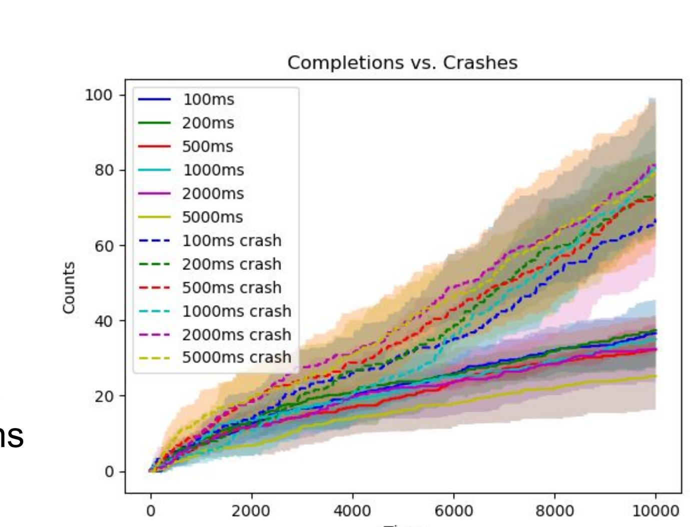


Figure 8: Heat map of collisions in a trial of 5000ms communication frequency. Radius of red dots indicates number of collisions at that point