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SMART CONTROL FOR TRAFFIC SIGNALS

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Issue



3s: Button
Pressed

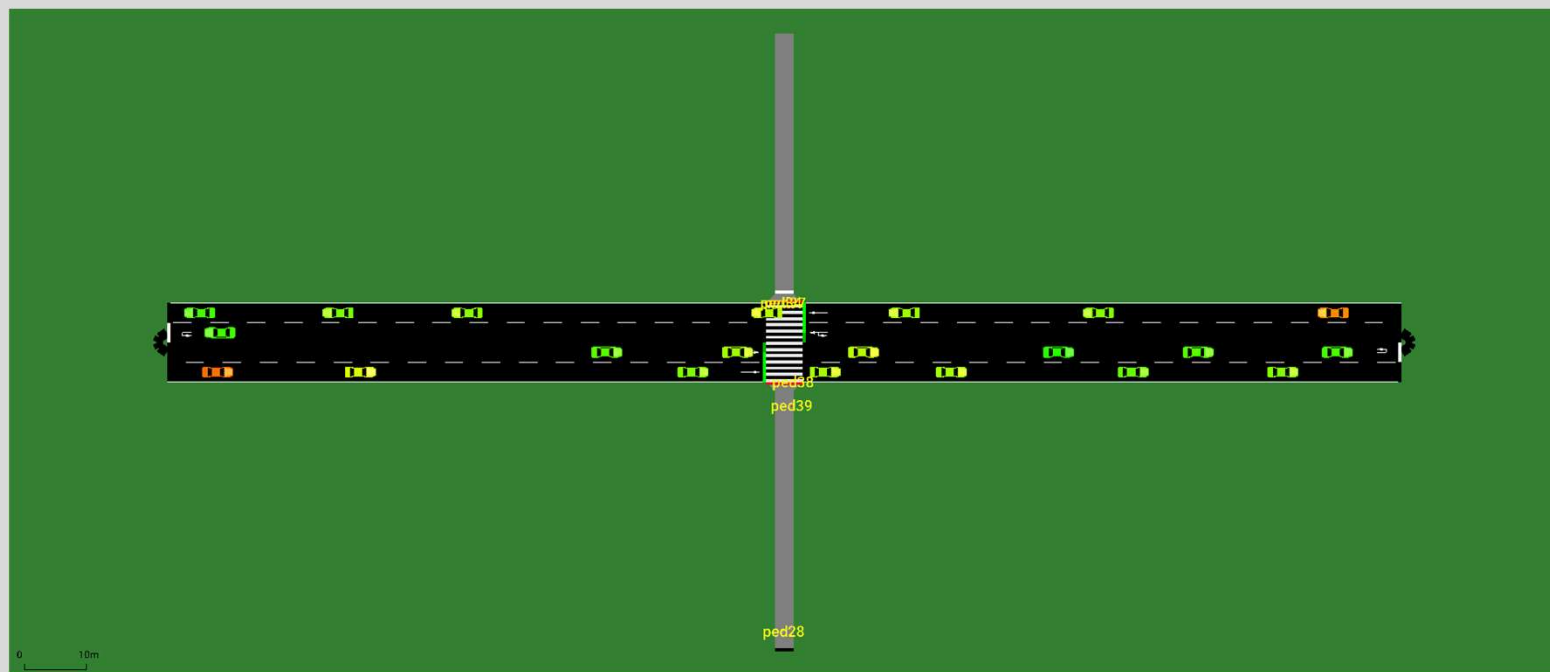
1m5s:
Pedestrian
Green
Triggered

Problem Statement

- Road users at crosswalks – pedestrians + vehicles
- Objective: reduce total *delay* for all road users



SUMO



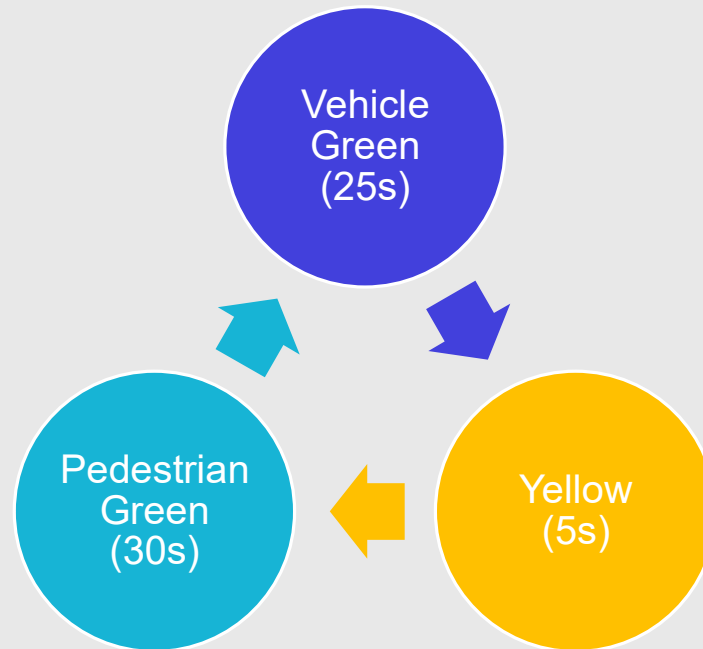
Total Cumulative Wait Time (Delay)

$$TCWT_t = \sum n_{ped,t} + n_{veh,t}$$

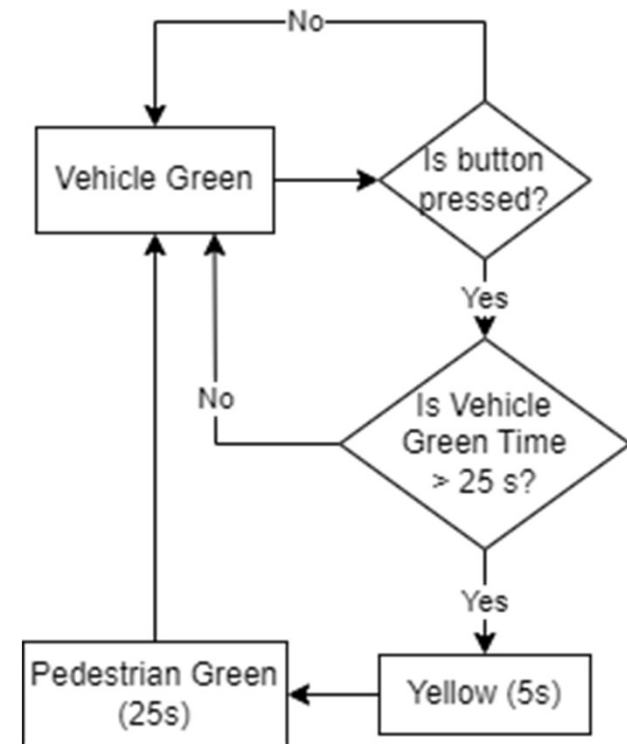
$n_{ped,t}$: Number of waiting pedestrians at time t

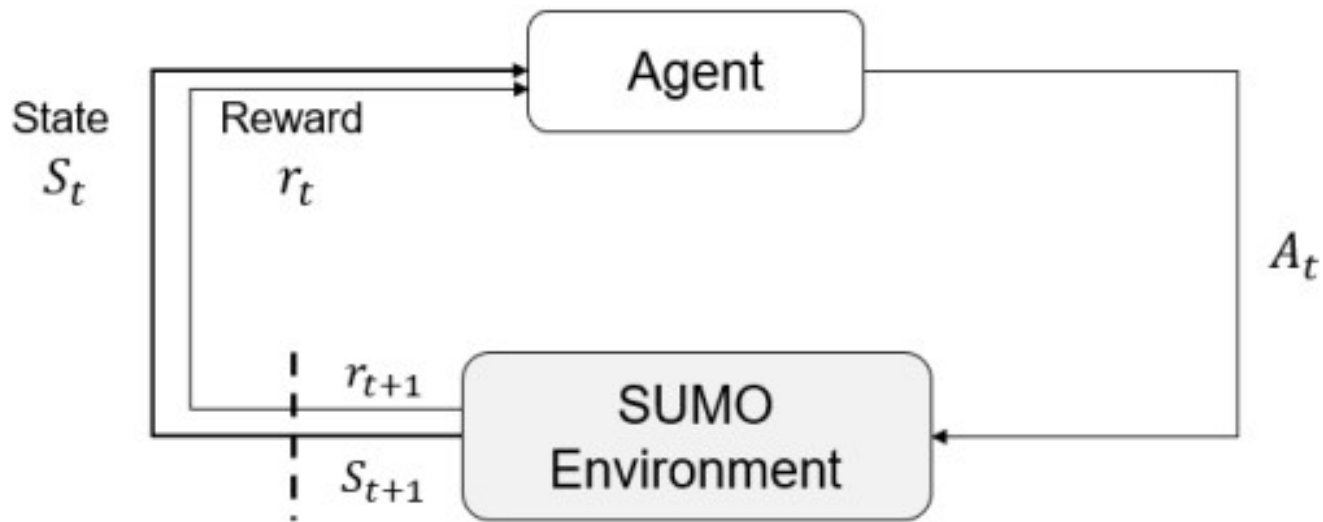
$n_{veh,t}$: Number of vehicles in queue at time t

Baseline Fixed Time Control



Adaptive Time Control



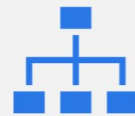


Reinforcement Learning Based Control

Why RL?



Automate learning based on reward system

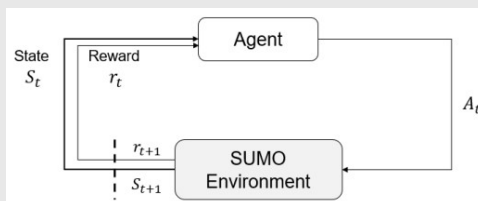


Improvement over fixed and adaptive time (rule-based) controls

Agent

Traffic Signal Controller

State, Action, Reward



State

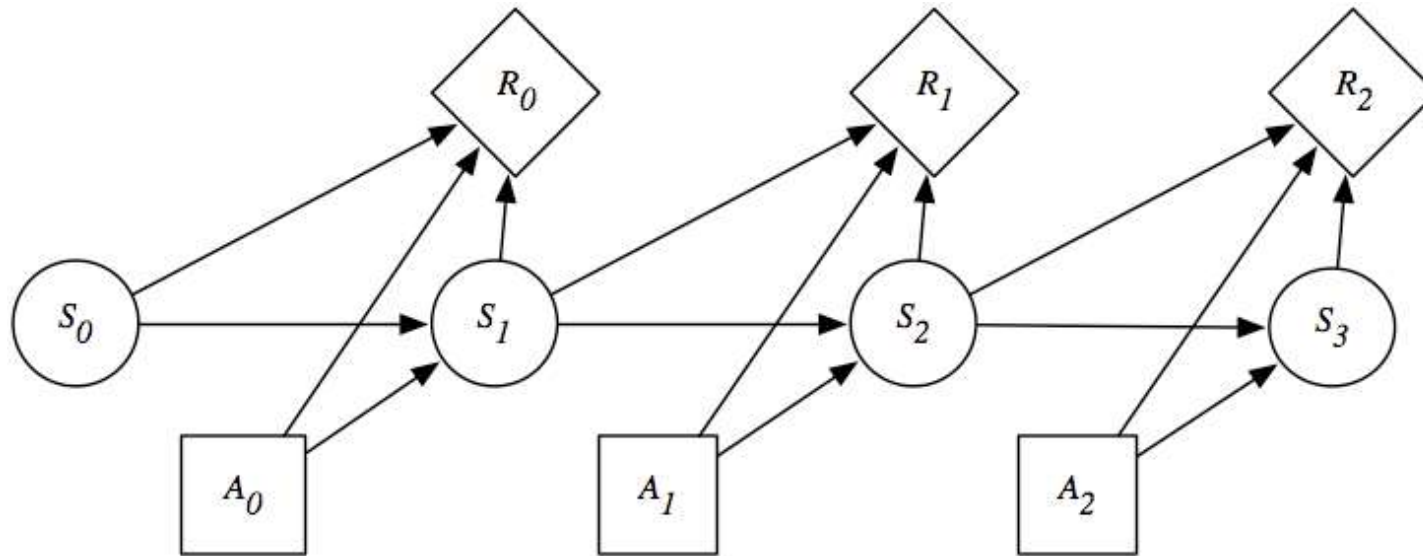
- $(n_{ped,t}, n_{veh,t})$

Action

- {Vehicle Green, Pedestrian Green}

Reward

- Less Delay = More Reward

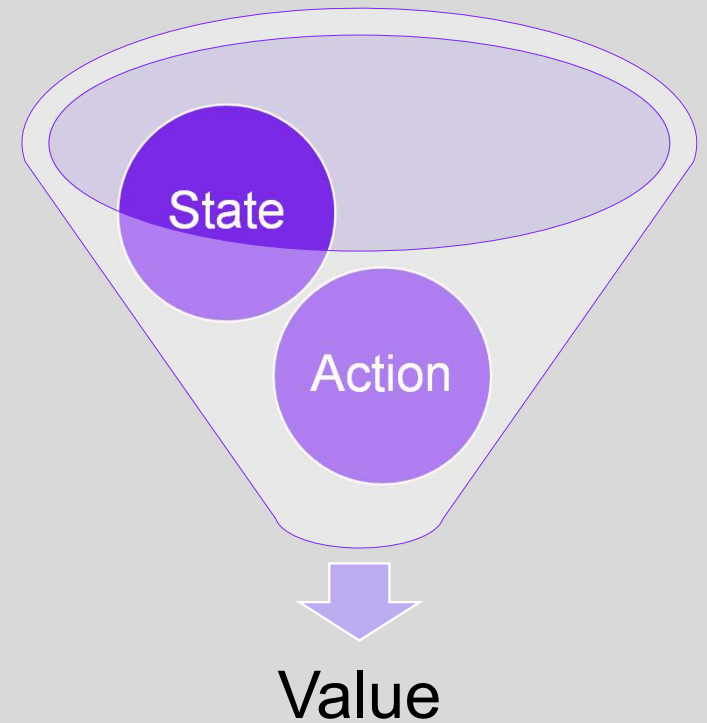


Markov Decision Process

Next state only depends on current state and action

Q-Value Function

- $Q: S \times A \rightarrow \mathbb{R}$
- “How good is taking this action at that state?”
 - Reward-to-go
- Represented by
 - Lookup Table (Q-Table), or
 - Neural Network – Deep Q-Network (DQN)



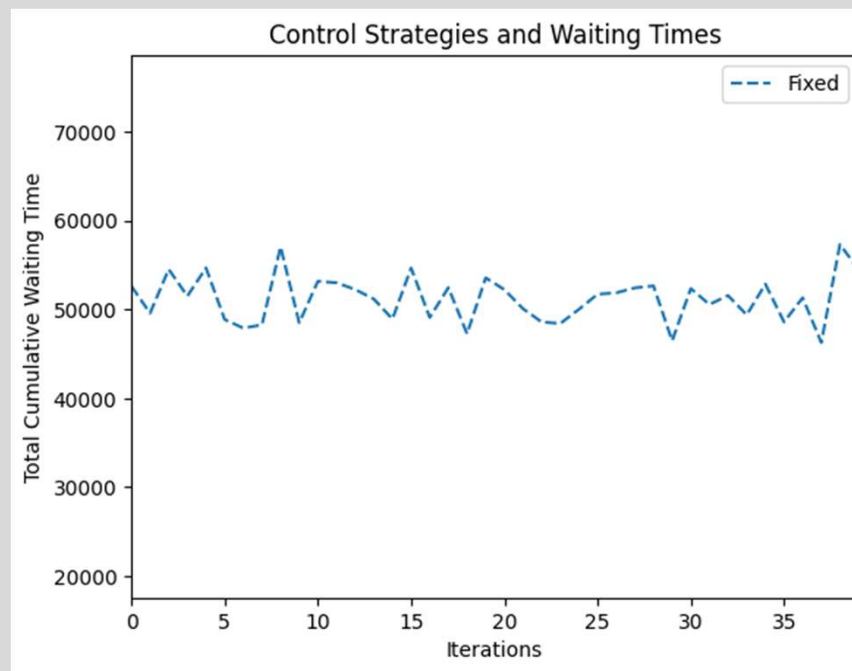


Policy

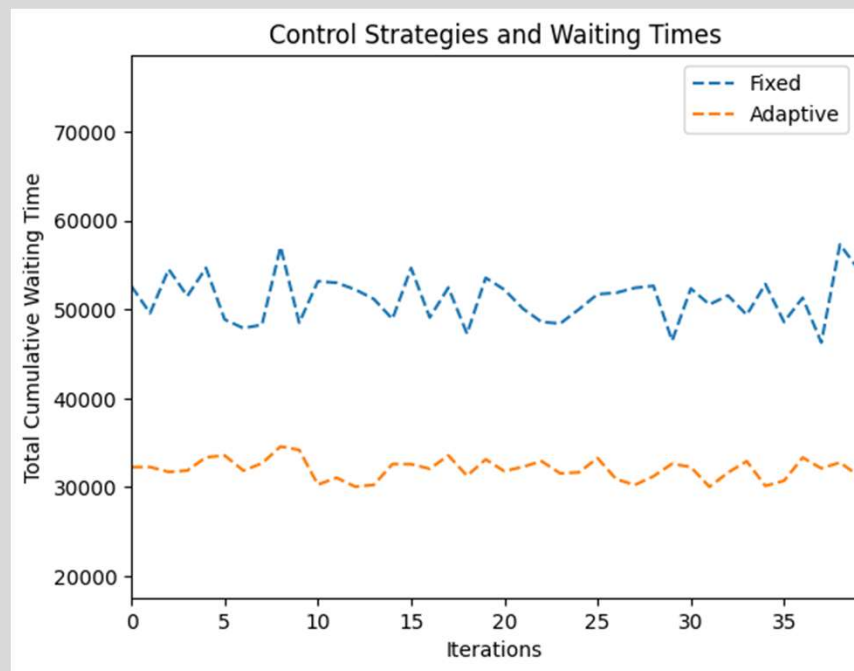
- $\pi: S \rightarrow A$
- “Which action should I take at each state?”
- Choose from reward-to-go

$$\pi(s) = \operatorname{argmax}_a Q(s, a)$$

TCWT (Baseline - Fixed)



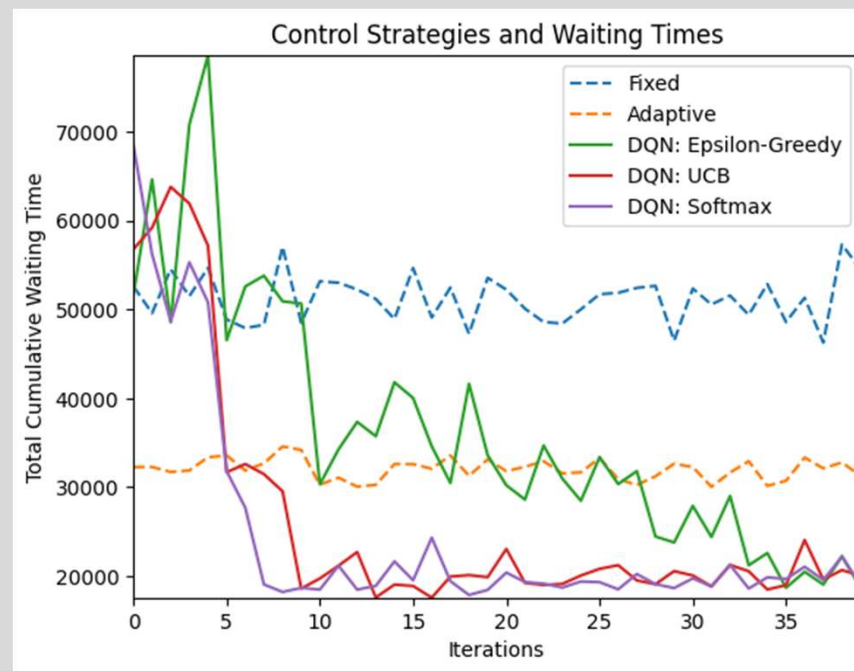
TCWT (Adaptive)



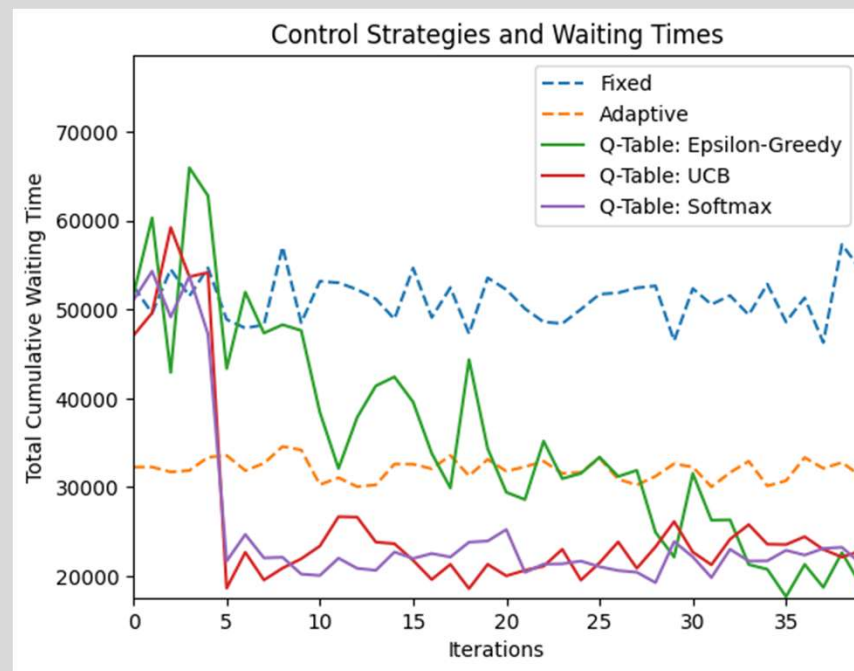
TCWT (DQN: ϵ -Greedy)



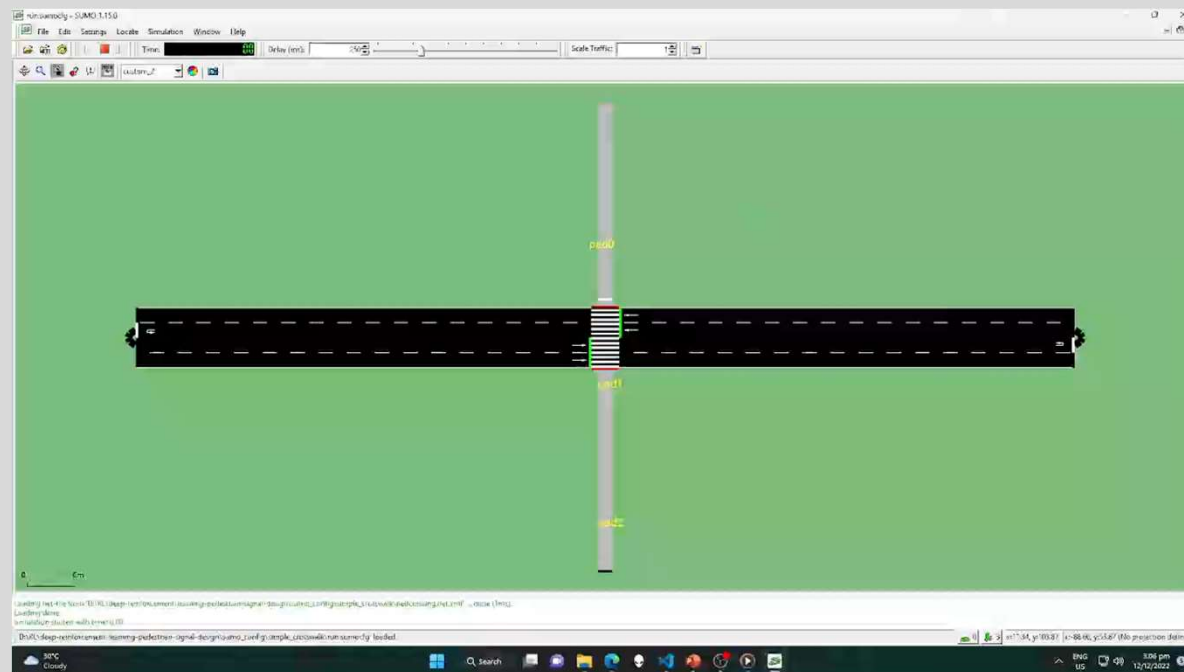
TCWT (DQN)



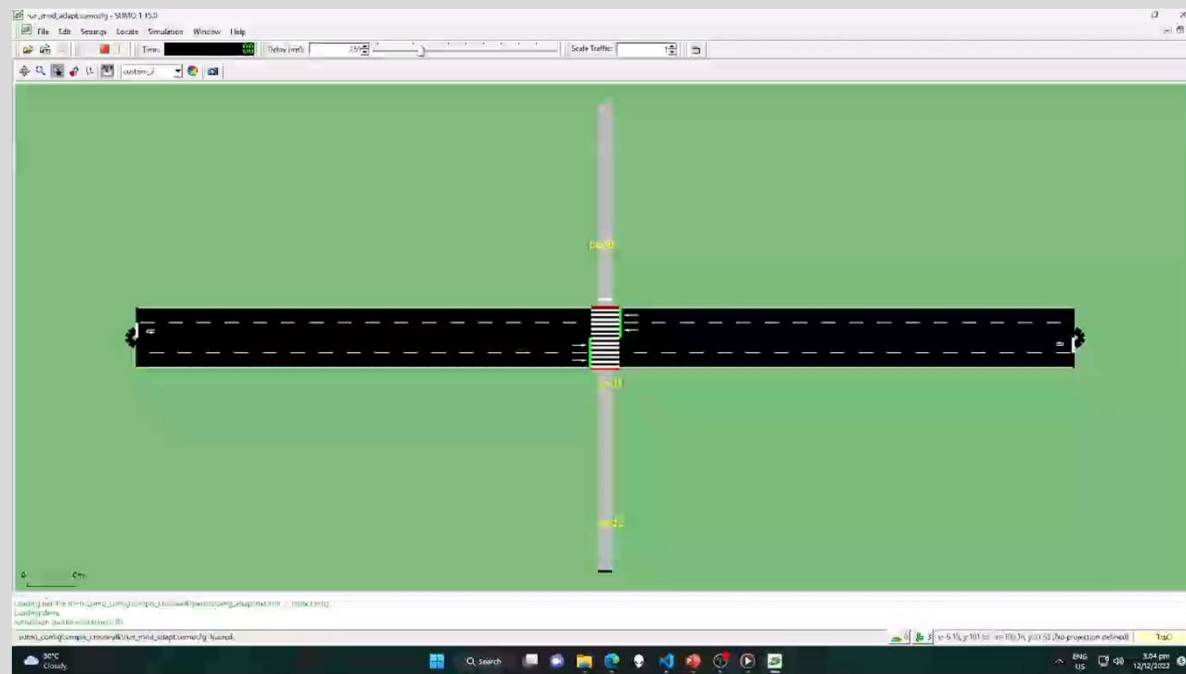
TCWT (Q-Table)



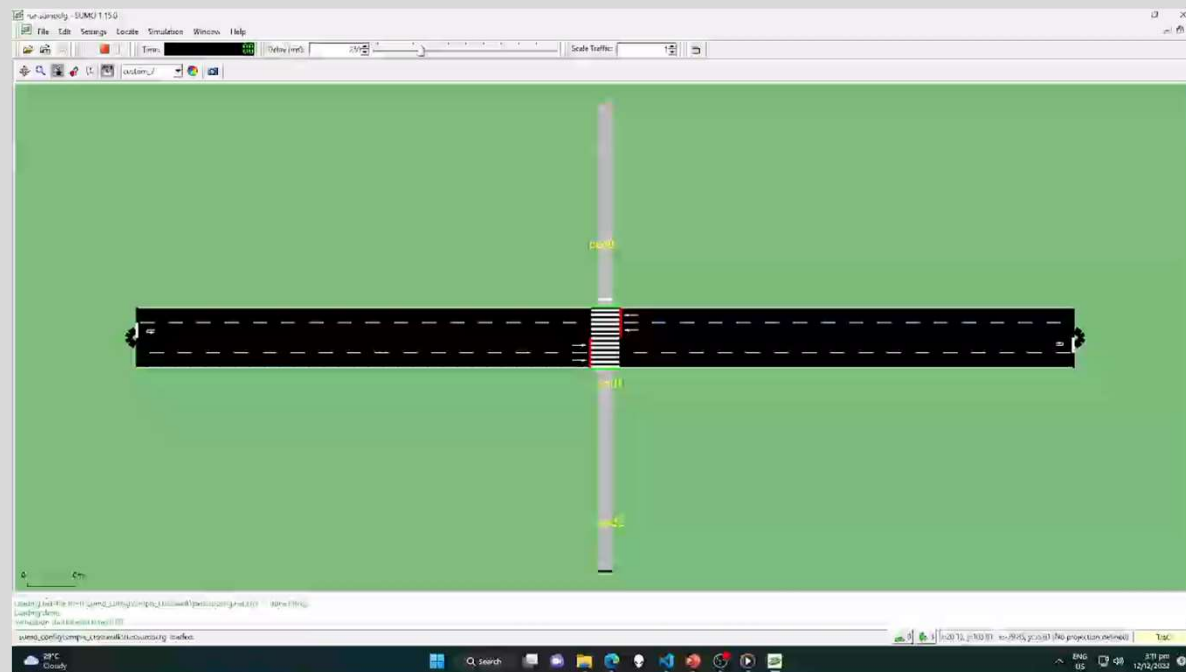
SUMO (Fixed)



SUMO (Adaptive)



SUMO (RL)



Discussion

RL improves over rule-based control

Tabular RL fast but not scalable

Deep RL can scale to larger state space

Future Directions



Complex Crosswalks



Increase State Space

Vehicle Directions
Vehicle Types



Increase Action Space

Timing



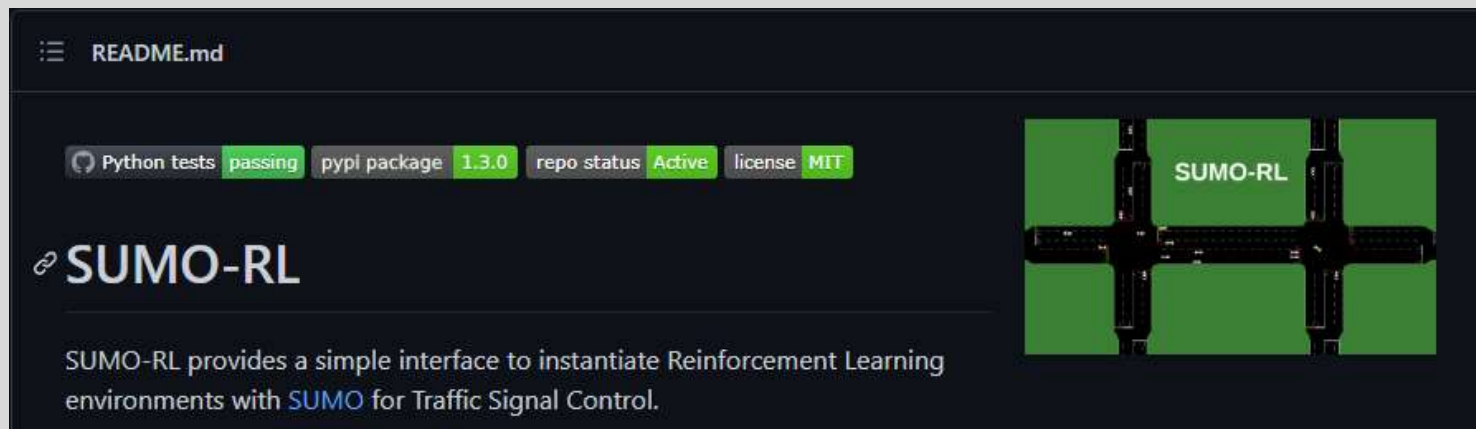
Reward

Safety Metric



Multi-Agent

SUMO-RL



[LucasAlegre/sumo-rl: Reinforcement Learning environments for Traffic Signal Control with SUMO. Compatible with Gym, PettingZoo, and popular RL libraries. \(github.com\)](https://github.com/LucasAlegre/sumo-rl)