Graph neural networks and reinforcement learning in traffic optimization in cities

Kamil A. Kaczmarek

Outline

1. Introductions
2. Our approach
3. From simulation to meta-models to graph NN
4. Reinforcement learning

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Introductions

neptune.ai <-> TensorCell, the virtuous collaboration

- Neptune.ai
  - Experiment management
  - Collaboration

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- Neptune.ai
  - Experiment management
  - Collaboration
- TensorCell
  - Started 2016, over 20 researchers now
  - 100% remote work
  - Published on NeurIPS workshops, MT-ITS, TFML
  - Group is “informal” :)

Introductions

Traffic optimization - the significance of the problem

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Traffic optimization - the significance of the problem

~78.5 bln USD - estimated annual cost of congestion in the USA (cost of wasted time and fuel).

Source: https://www.ibtta.org/sites/default/files/documents/MAF/Costs-of-Congestion-INRIX-Cebr-Report%20(3).pdf

Introductior

Traffic optimizatio

~78.
of cc
fuel)
Source
https:/
on-INR

BIGGEST KILLER

Air Pollution Cuts Two Years Off The Average World Life Expectancy

That's more than five times as much as HIV/AIDS or Malaria.

VICTOR TANGERMANN | NOVEMBER 21ST 2018

Introductior

Traffic

World Health Organization

Health Topics | Countries | Newsroom | Emergencies | About Us

Home / Newsroom / Fact sheets / Detail / Road traffic injuries

Road traffic injuries

العربية | 中文 | Français | Русский | Español

- approx. 1.35 million people die each year as a result of road traffic crashes
- road traffic crashes cost most countries 3% of their gross domestic product

Source: http://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries (Dec 2018)

ıge World

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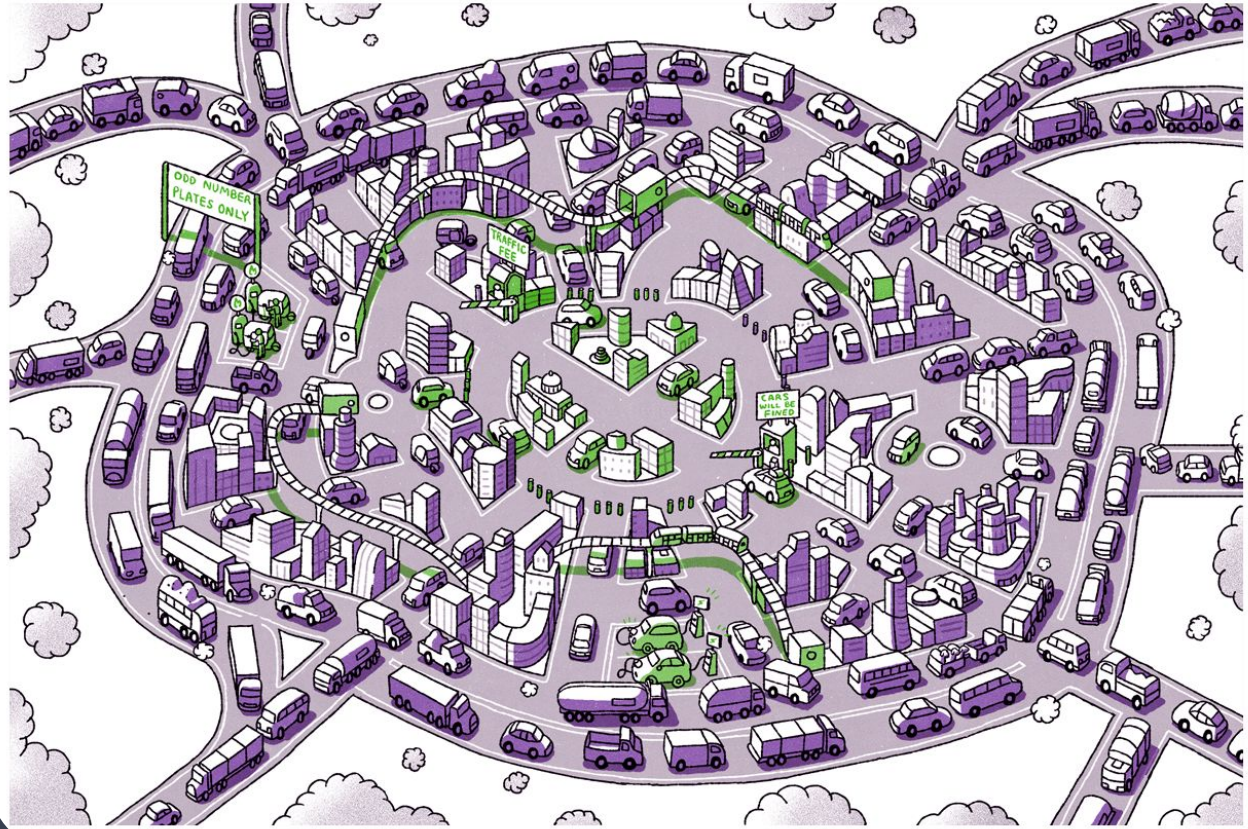
Introdu

Traffic

The New York Times

Cities Worldwide Are Reimagining Their Relationship With Cars

By Somini Sengupta and Nadja Popovich | Illustrations by Tim Peacock Nov. 14, 2019



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Our approach

Traffic Signal Setting

Our approach

Traffic Signal Setting

- Focus
  - Traffic prediction
  - Rare road events
  - “What-if” type of scenarios

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  - District in Warsaw named: “Ochota”

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Traffic Signal Setting

- Focus
  - Traffic prediction
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  - “What-if” type of scenarios
- Scope
  - District in Warsaw named: “Ochota”
- Goal
  - Minimize waiting time on red lights

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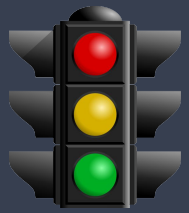
From simulation to meta-models to graph NN

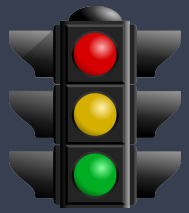
Traffic Simulation Framework

21 x 

(fixed) cycles

From simulation to meta-models to graph NN

Traffic Simulation Framework

21 x  +

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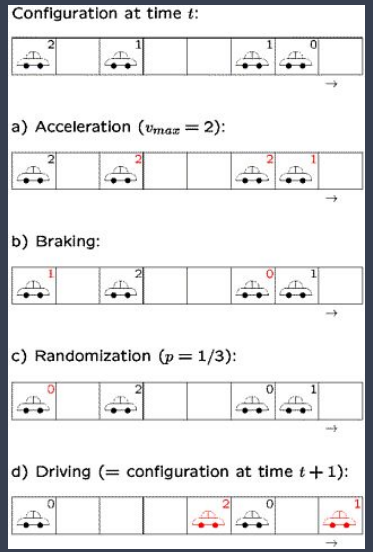

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A cellular automaton model for freeway traffic.
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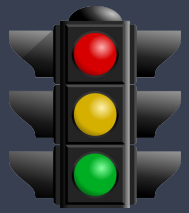
From simulation to meta-models to graph NN

Traffic Simulation Framework

21 x  +

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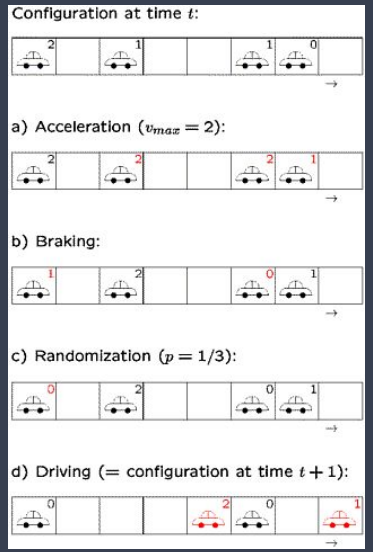

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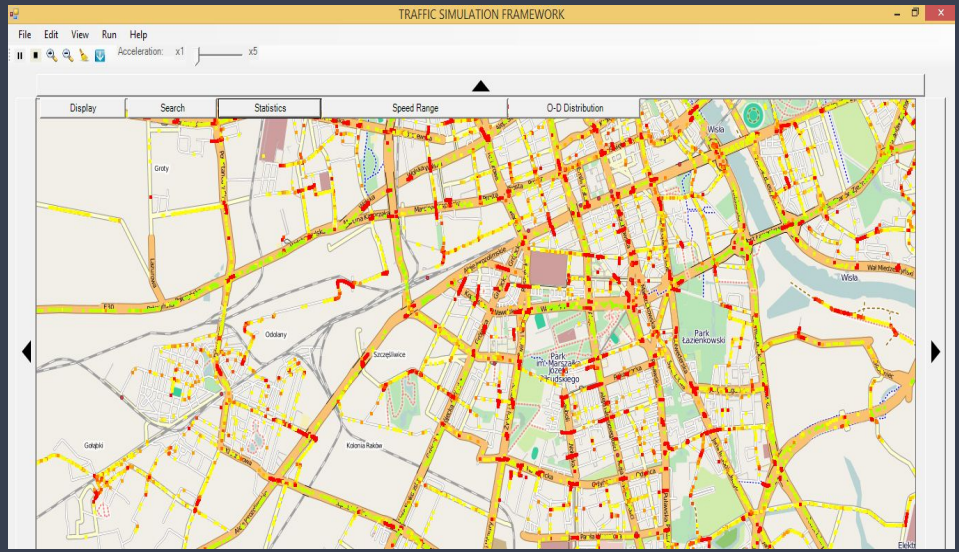

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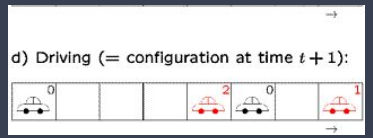
From simulation to meta-models to graph NN

Traffic Simulation Framework

Time & compute consuming



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From simulation to meta-models to graph NN

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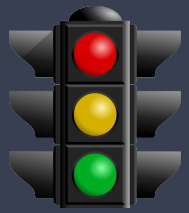

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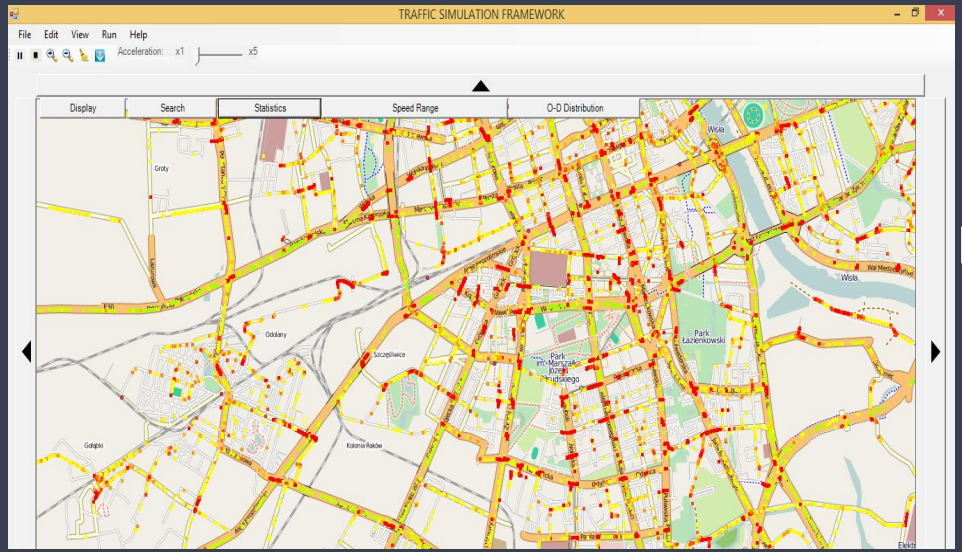
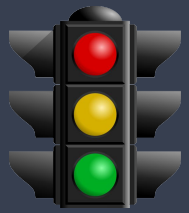


score

From simulation to meta-models to graph NN

21 x



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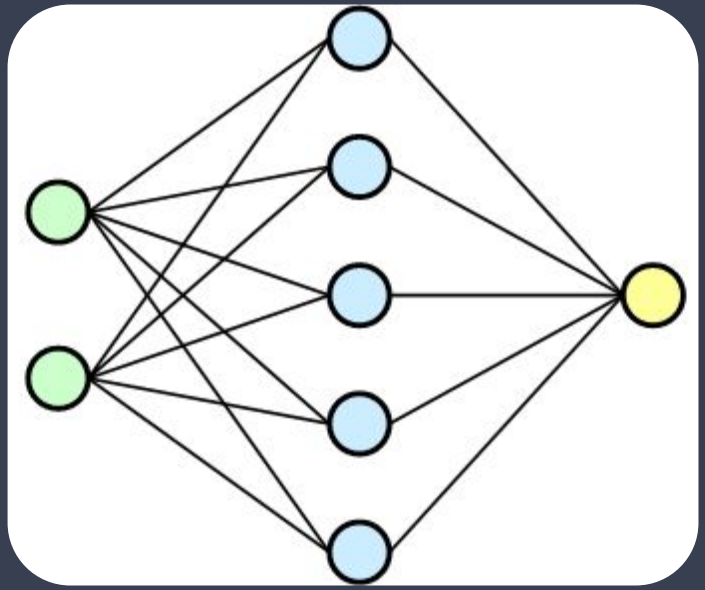


score

From simulation to meta-models to graph NN

meta-models: results

meta-model	inference time [ms]	approximation error
NN	0.8	1.62%
LightGBM	0.4	1.72%
Simulator	30’000	-

training set = 85336 elements
test set = 20000 elements
"element" is 10 minutes of traffic simulation with 42000 cars.

From simulation to meta-models to graph NN

meta-models: application

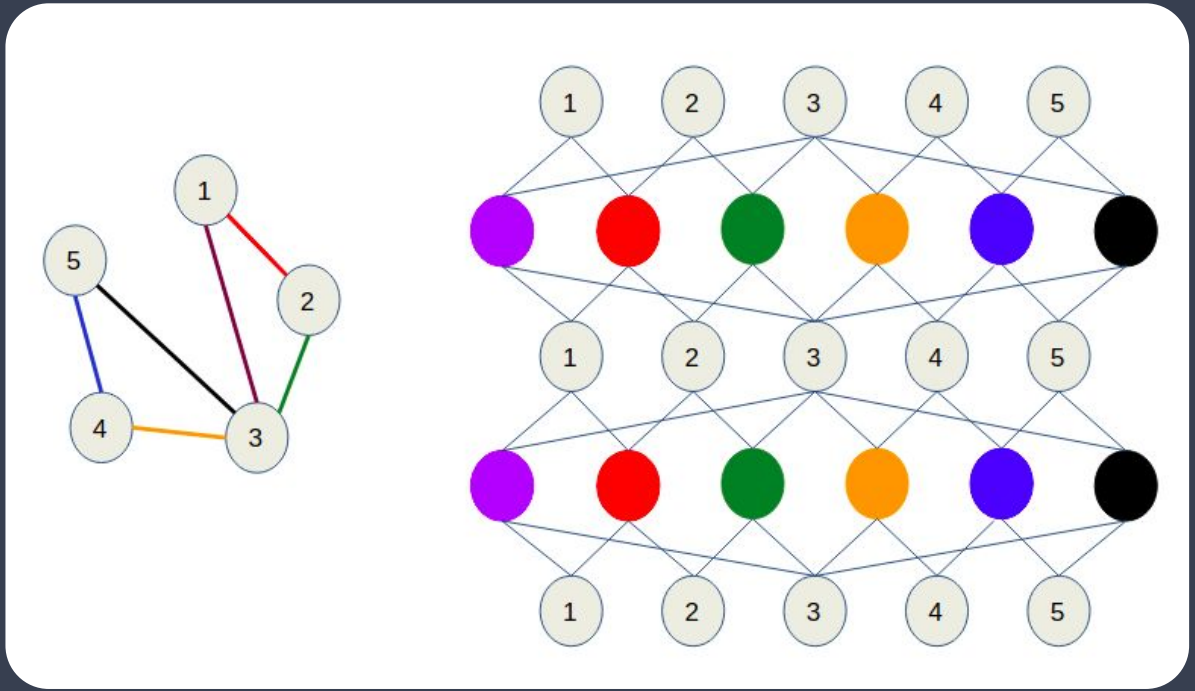
Goal: minimize waiting time on red lights.

optimization algorithm	[LightGBM] best result	[LightGBM] best result in simulation	[NN] best result	[NN] best result in simulation	[Simulation] best result
Genetic algorithm	25318	37693	31890	37179	31735
Simulated annealing	31910	33860	32681	35885	33217

Total waiting time for all cars in simulation [sec]

From simulation to meta-models to graph NN

Graph NN, architecture



Skowronek, Ł., Mozejko, M., Gora, P., & Klemenko, A. (2019).
Graph-based sparse neural networks for traffic signal optimization. (NeurIPS), 1–24.

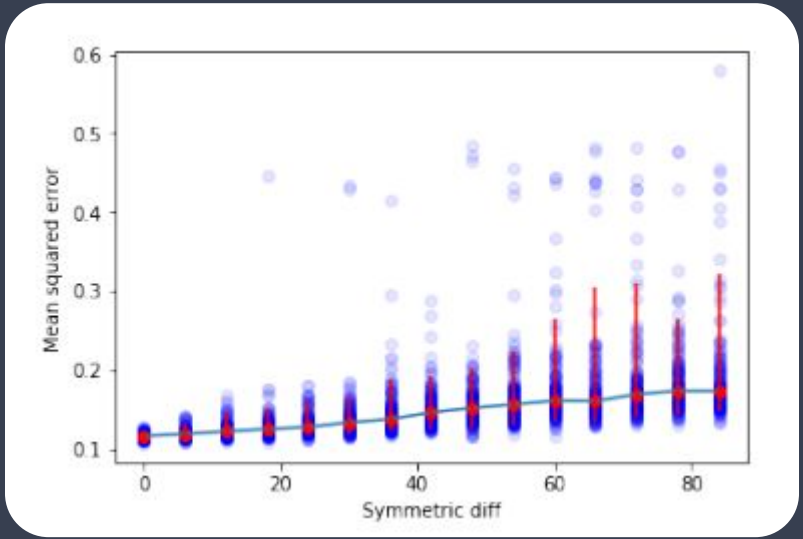
From simulation to meta-models to graph NN

meta-models: results

Statistic	Previous approach	Graph NN
Approximation error	1.62%	1.32%
Best result in simulation	31735 [s]	31827 [s]
Inference time	0.9 [ms]	2.8 [ms]

From simulation to meta-models to graph NN

Graph NN, sanity-check



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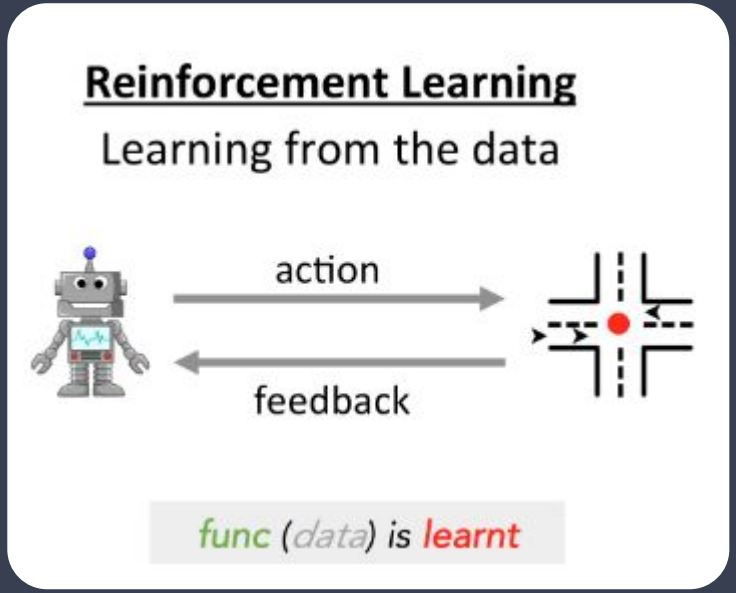
Reinforcement learning

Conceptual overview



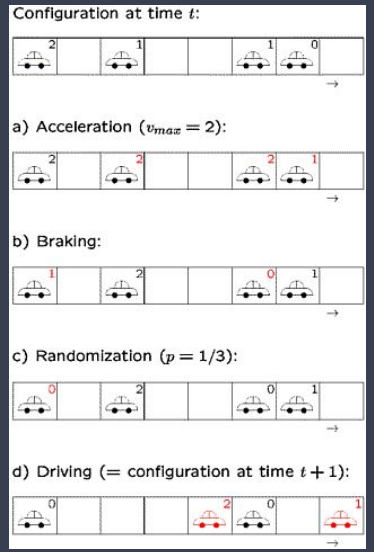
Wei, H., Zheng, G., Gayah, V., & Li, Z. (2019). A Survey on Traffic Signal Control Methods. 1(1). *http://arxiv.org/abs/1904.08117*

Reinforcement learning

Adaptive signal control

Reinforcement learning

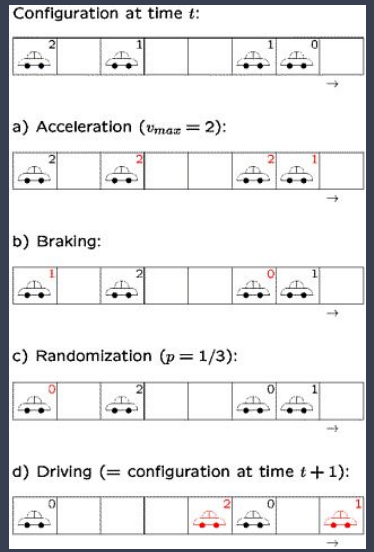
Adaptive signal control



Reinforcement learning

Adaptive signal control

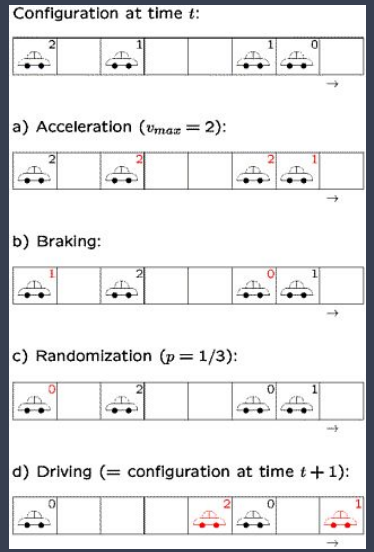
- Environment
  - Lightweight simulator



Reinforcement learning

Adaptive signal control

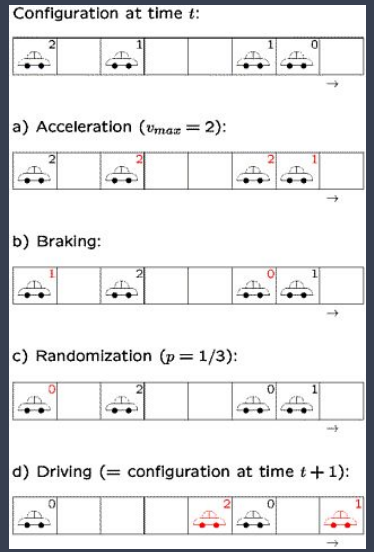
- Environment
  - Lightweight simulator
- State
  - state of the traffic



Reinforcement learning

Adaptive signal control

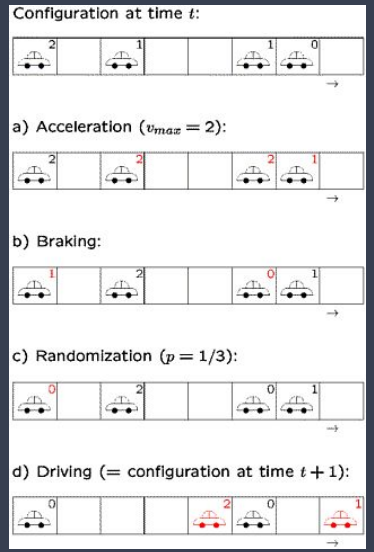
- Environment
  - Lightweight simulator
- State
  - state of the traffic
- Action
  - modification of traffic signal settings



Reinforcement learning

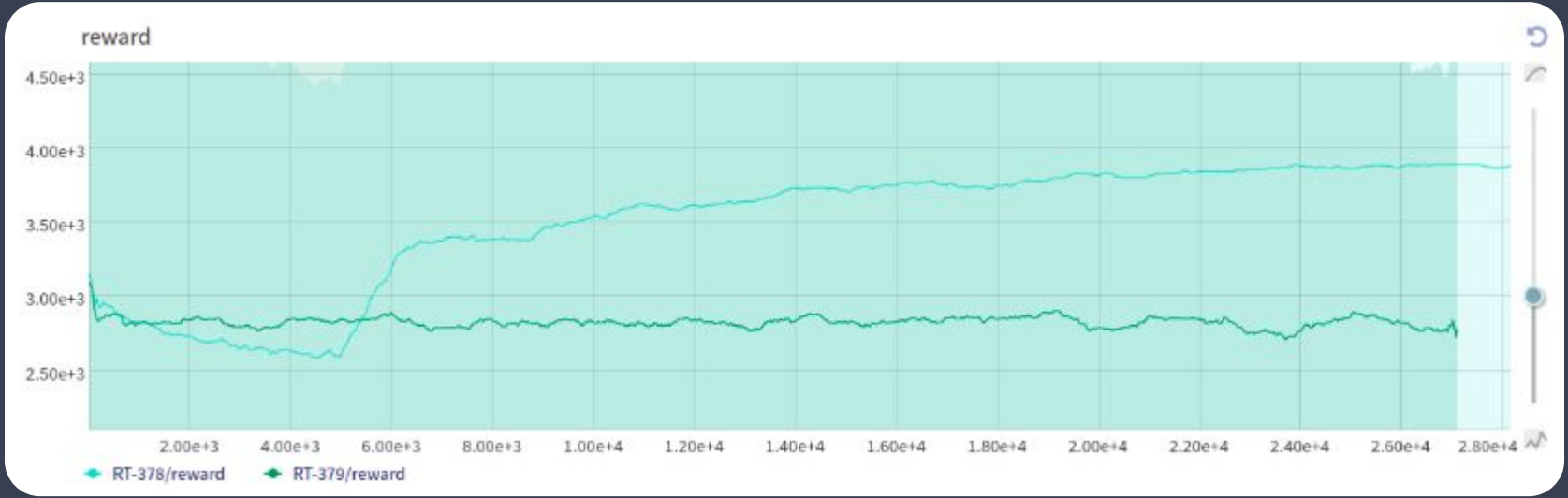
Adaptive signal control

- Environment
  - Lightweight simulator
- State
  - state of the traffic
- Action
  - modification of traffic signal settings
- Reward
  - quality of traffic in a given time period



Reinforcement learning

DQN, preliminary results



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https://neptune.ai (check for experiments management)
TensorCell is on Facebook (check for research updates)