KDD cup 2021: How many vehicles can you serve at most with a city-scale road network

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Overview

- Background
- The competition
- Benchmark solutions
- Get started
- Q&A

Background

KDD cup

- KDD cup is the most prestigious Data Science competition that's been run by SIGKDD (Special Interest Group on Knowledge Discovery and Data Mining) since 1997.
- In KDD Cup 2019, it had more than **2,800** registered teams from over **39** countries and **230** institutions. Among the **1,200** most actively participating teams, over **5,000** individuals participated, and more than **17,000** submissions were made.
- Recently, data driven intelligent transportation has attracted a surge of interest from machine learning and data mining researchers. There are transportation-related competitions in KDD Cup 2017 and 2020.
- This year, we are hosting "**The City Brain Challenge**", aiming for an efficient traffic coordination strategy to **serve more vehicles** in a city-scale road network.

KDD

https://www.kdd.org/kdd2021/

Urban traffic congestion

Background

	Tokyo	New York City
Number of registered vehicles	3.13 million **(+43%)**	2.19 million
Road network mileage (km)	24,650 **(+32%)**	18,684
Number of traffic signals	15,000 **(+15%)**	13,000

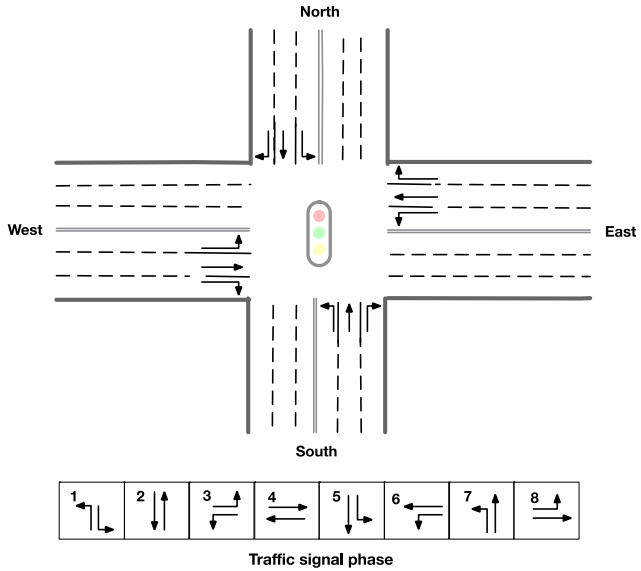
- **Question**: How many **vehicles can be served** with a city-scale road network (meanwhile, maintaining an acceptable delay)?
  - Road network size (usually remain unchanged)
  - Traffic demands
  - Traffic management strategy

The competition

Problem statement

- **Scenario:**
  - City-scale road network (more than **1000** intersections)
  - Traffic signal timing can be optimized
- **Objective:** maximizing **total number of vehicles served** via optimizing traffic signal setting:
  - For each intersection, select a **signal phase** to be actuated for each time step.
- **Given:**
  - Road network (including traffic signal installation);
  - Sample OD demand and fixed route (mitigate the impact of randomness)

City road network



Traffic signal

Evaluation/scoring metrics

- **Cumulative number of vehicles served**
  - The vehicles that are in the network
  - The vehicles that have left the network

The trip delay D_i of vehicle i is defined as $D_i = \frac{TT_i + TT_i^r}{TT_i^f}$, where,

- TT_i: travel time of vehicle i;
- TT_i^r: rest of trip travel time, estimated with free-flow speed;
- TT_i^f: full trip travel time at free-flow speed

- **Delay index (>1.0)**
  - For a trip, the delay is computed as actual travel time divided by free-flow travel time;
  - For an uncompleted trip, the rest of trip travel time is estimated using free-flow speed;
  - The overall delay index is computed as average over all vehicles served.

- **For scoring:**
  - We will keep monitoring the **delay index** computed over all vehicles;
  - Once the delay index reaches the predefined threshold (say 2.0), the test process will be terminated and the solution is scored as **cumulative number of vehicles served**
  - *Note: For the first/warmup round, we did not set the delay index threshold*.

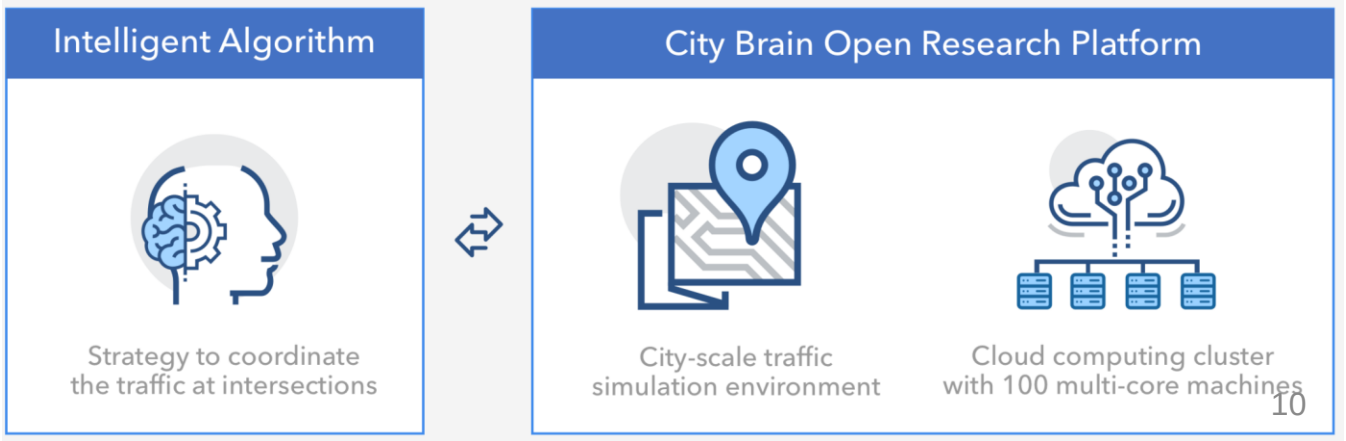
https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/city-brain-challenge.html#evaluation

Competition phases

- **Warmup** (4/1/2021-4/30/2021)
- Participants will practice with regional road network with light traffic to get familiar with the simulation environment**. All participants (team members) need to sign-up by 4/30/2021.**
- **Qualification** (5/1/2021-5/31/2021)
- Participants will deal with city-scale road network **(about 1000 intersections)** traffic. Teams that can serve more vehicles will enter the final round (**test traffic will be provided**).
  - The test traffic data are given, but you are encouraged to create your own dataset for training if use data-driven method
- **Final** (6/1/2021-6/30/2021)
- Large-scale **cloud computing platform** is provided. Teams will develop methods to handle diverse unknown traffic flows at the city-scale **(about 1000 intersections)**.
  - The sample traffic data are given, however, the traffic data for scoring **differs from the sample data**;
  - Hence, the solution need to adapt to changes in demands of OD pairs.

City Brain open research platform - CBEngine

- **High-efficiency engine**
  - Support experiments with more than 1000 intersections and 100,000 vehicles
  - Large-scale parallel computing
  - Cloud computing cluster with 100 multi-core machines
- **Microscopic traffic simulation environment**
  - Fixed route (mitigate the impact of randomness)
  - Safety distance car-following models
  - Lane change models
    - Mandatory (for turn movement) and discretionary (deprecated to minimize randomness) lane change
    - Safety distance gap acceptance



Benchmark solutions

Benchmark solutions

Rule based method (transportation engineering)

- Fixed time (pre-timed, e.g. Webster);
- Green wave (Maxband);
- Max-pressure (Decentralized);
- Perimeter metering control (MFD-based) …

Reinforcement learning based method

- IntelliLight
- PressLight …

For more information, please refer to:

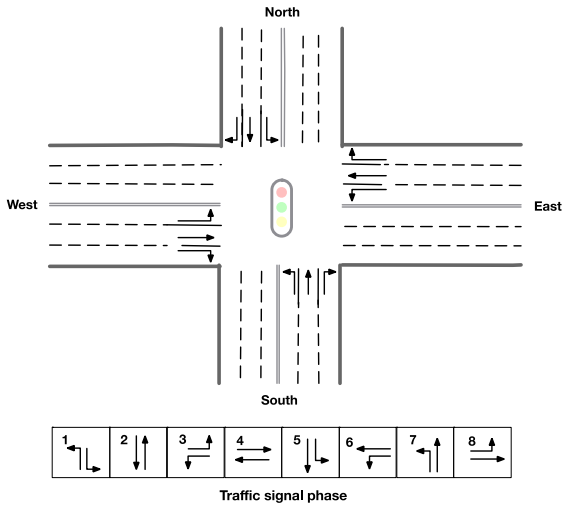
- Reinforcement learning for traffic signal control: https://traffic-signal-control.github.io/
- A Survey on Traffic Signal Control Methods: https://arxiv.org/pdf/1904.08117.pdf

Rule based method (transportation engineering)

Fixed time (pre-timed)

- Signal phase setting (phase set and phase sequence)
- Cycle length
- Phase split

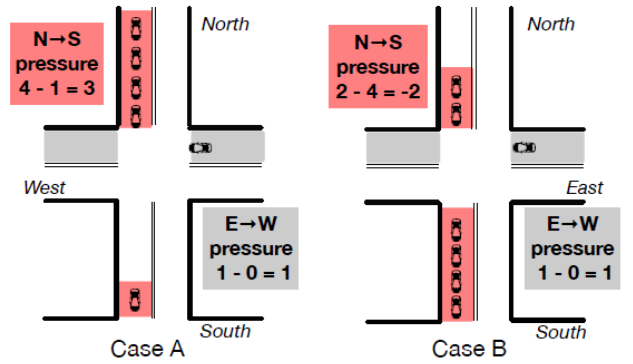
Example: Phase-1: 30s, Phase-2: 20s, Phase-3: 40s, Phase-4: 30s, cycle length = 120s.



Max pressure (decentralized controller)

- A simple MP controller: Each time step (10s), actuate the signal phase with maximum difference in upstream and downstream queue lengths

Example: In Case-A, Phase-2 (southbound and northbound through movement) is actuated.



Algorithm 1: Max-pressure Control

Input: Current phase time t, minimum phase duration length t_{min}

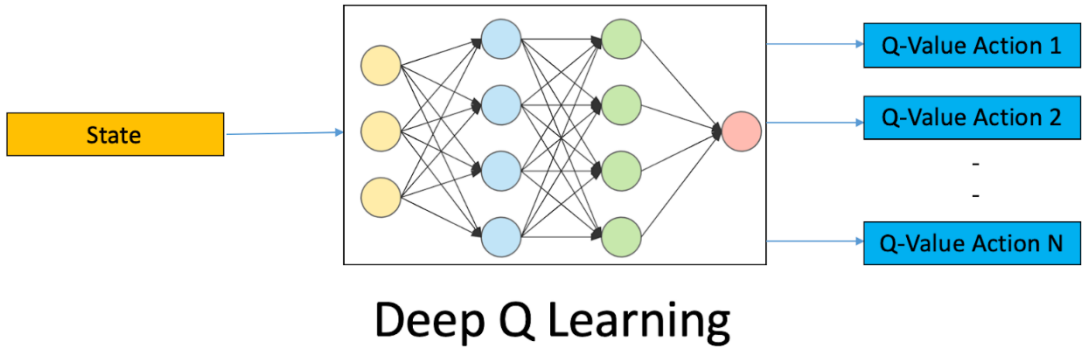
forall *timestamp* **do**
  $t = t + 1$
  if $t >= t_{min}$ **then**
    Calculate the pressure P_i for each phase i;
    Set the next phase as $\arg\max_i\{P_i\}$;
    $t = 0$;
  end
end

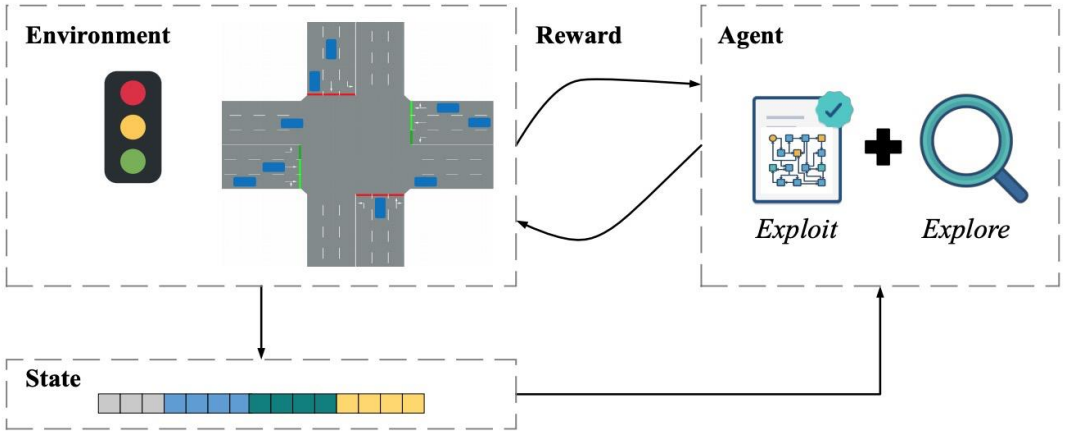
Reference:
Wei et al., 2019, PressLight: Learning Max Pressure Control to Coordinate Traffic Signals in Arterial Network

Reinforcement learning based method

A RL agent learns about the sequences of decision to inform future decisions.

- Environment
- Agent
- State
- Action
- Reward





State (observation)

- Queue length, volume, delay, speed
- Phase duration, position of vehicles, etc.

Reward

- Queue length, waiting time, change of delay, speed
- Number of stops, throughput, frequency of signal change, pressure, etc.

Action: signal phase actuation

Sources:

https://medium.com/@novacek_48158/connect-x-with-dqn-and-pbt-be11915dd860

Wei et al., 2018, IntelliLight: a Reinforcement Learning Approach for Intelligent Traffic Light Control

Get started

- Competition environment setup
- Code structure
- Visualization
- Demos

Get started: competition environment setup (CBEngine)

Step - 1 download docker image and the starter-kit

- docker pull citybrainchallenge/cbengine:0.1.1
- git clone https://github.com/CityBrainChallenge/KDDCup2021-CityBrainChallenge-starter-kit.git

Step - 2 run test file in the docker

- docker run -it -v /path/to/your/starter-kit:/starter-kit citybrainchallenge/cbengine:0.1.1 bash
- cd starter-kit
- python3 evaluate.py --input_dir agent --output_dir out --sim_cfg cfg/simulator.cfg # run evaluate.py

Tutorial: https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/

Get started: code structure explained

docker image citybrainchallenge/cbengine:0.1.1: Simulator and OpenAI Gym APIs

starter-kit: agent.py to be implemented，evaluate.py for solution evaluation.

To be implemented:

agent/agent.py

To submit your results, you need to update:

agent/gym_cfg.py

cfg/simulator.cfg

To evaluate and score your results

evaluate.py

To train your model, you need modify

evaluate.py

A simple demo:

demo.py

Other files:

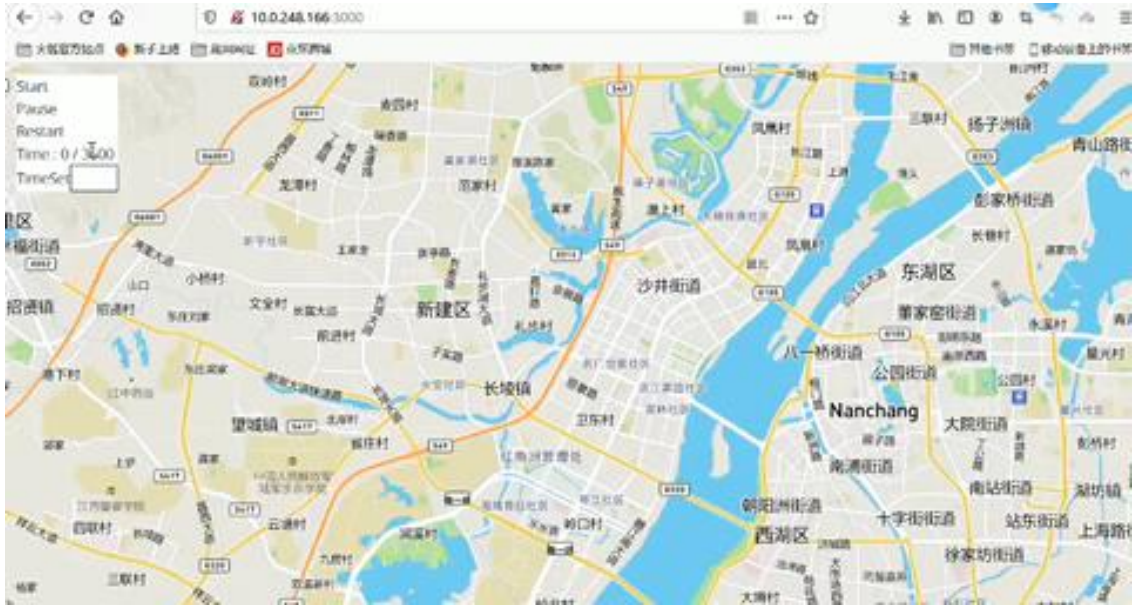
data/

log/

out/ # output

Tutorial: https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/

Get started: visualization



Prerequisites:

- You need install **yarn**
- You need apply a **mapbox** token via creating your own mapbox account

To visualize your results:

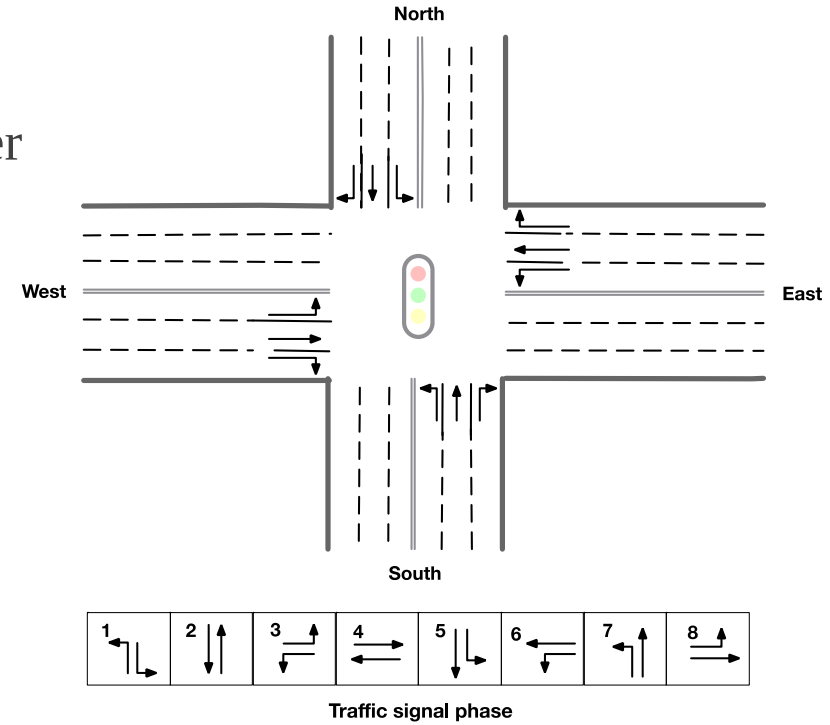
- **Move** log/lightinfo.json, log/roadinfo.json, log/time*.json files **into** ui/src/log
- **Modify** ui/src/index.js **and set** this.maxTime (in seconds) and mapboxgl.accessToken (Your mapbox token)
- cd (change disk) ui/, then: yarn start
- Open your browser at: localhost:3000

Tutorial: https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/

Get started: A demo of Fixed Time implementation

- All traffic signal phases are pre-timed;
- Traffic signal phases will be selected sequentially in a pre-defined order
- Select signal phase based on current time step.

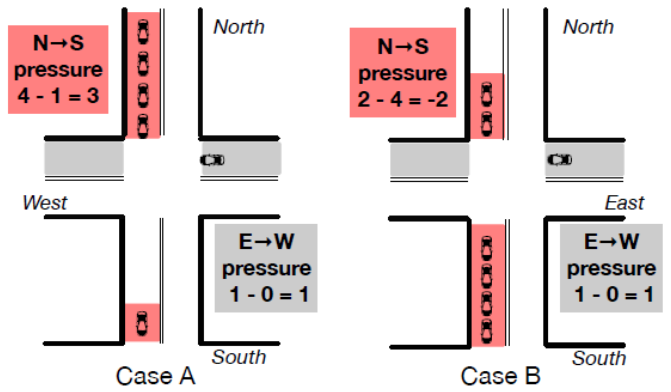
```
# get actions
for agent in self.agent_list:
    # select the now_step
    for k,v in observations_for_agent[agent].items():
        now_step = v[0]
        break
    step_diff = now_step - self.last_change_step[agent]
    if(step_diff >= self.green_sec):
        self.now_phase[agent] = self.now_phase[agent] % self.max_phase + 1
        self.last_change_step[agent] = now_step


    actions[agent] = self.now_phase[agent]
return actions
```



Tutorial: https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/

Get started: a demo of DQN implementation

- **State**: number of vehicles by lane
- **Action**: select signal phase each time step
- **Reward:** traffic pressure




```python
def get_action(self, ob):

    # The epsilon-greedy action selector.

    if np.random.rand() <= self.epsilon:
        return self.sample()
    ob = self._reshape_ob(ob)
    act_values = self.model.predict([ob])
    return np.argmax(act_values[0])
```

```python
# The main loop
for e in range(args.episodes):
    last_obs = env.reset()
    # Begins one simulation.
    i = 0
    while i < args.steps:
        if i % args.action_interval == 0:
            # Get the state.
            observations_for_agent = {}
            for key, val in observations.items():
            # Get the action, note that we use act_() for training.
            actions = agent.act_(observations_for_agent)
            # We keep the same action for a certain time
            for _ in range(args.action_interval):
                i += 1
                # Interacts with the environment and get the reward.
                observations, rewards, dones, infos = env.step(actions_)
            # Get next state.
            new_observations_for_agent = {}
            for key, val in observations.items():
            # Remember (state, action, reward, next_state) into memory buffer.
            for agent_id in agent_id_list:
                agent.remember(observations_for_agent[agent_id]['lane'], actions[agent_id], rewards[agent_id],
                               new_observations_for_agent[agent_id]['lane'])
                episodes_rewards[agent_id] += rewards[agent_id]
            total_decision_num += 1
            last_obs = observations
        # Update the network
        if total_decision_num > agent.learning_start and total_decision_num % agent.update_model_freq == 0:
            agent.replay()
        if total_decision_num > agent.learning_start and total_decision_num % agent.update_target_model_freq == 0:
            agent.update_target_network()
        if all(dones.values()):
            break
```

Reference: Wei et al., 2019, PressLight: Learning Max Pressure Control to Coordinate Traffic Signals in Arterial Network

Tutorial: https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/

Timeline

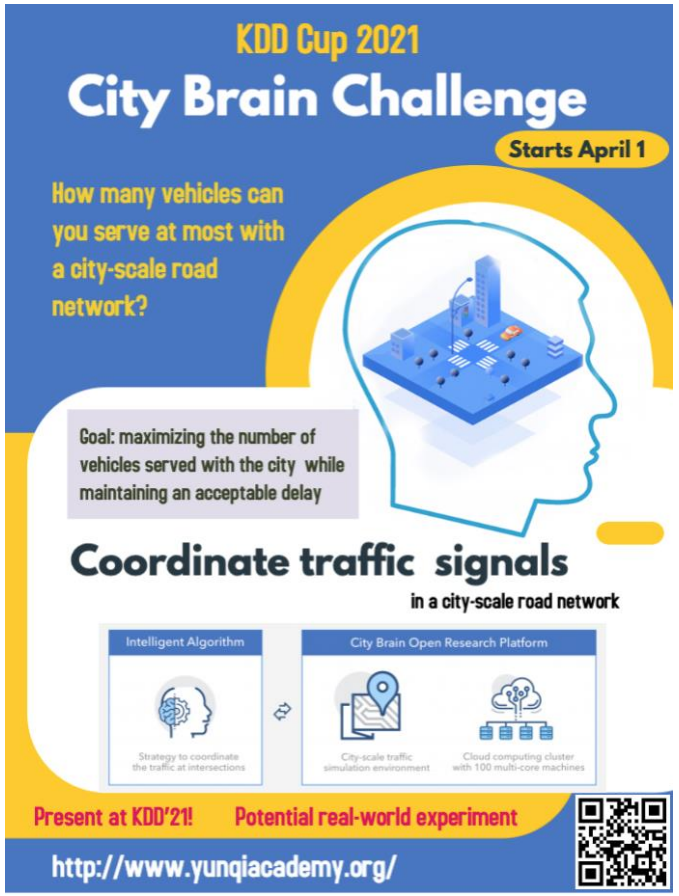
- **Important dates**
  - All participants need to sign-up by **4/30/2021 11:59 PM** (anywhere on earth).

- **Warmup** (4/1/2021-4/30/2021)
- **Qualification** (5/1/2021 - 5/31/2021)
- **Final** (6/1/2021 - 6/30/2021)

Note: all deadlines are on 23:59pm anywhere on earth

Q&A

Come and join the KDD Cup 2021 - City Brain Challenge!



Homepage: http://www.yunqiacademy.org/

Tutorial:
https://kddcup2021-citybrainchallenge.readthedocs.io/en/latest/

- Email: CityBrainChallenge@gmail.com
- Slack: citybrainchal-kwx6085.slack.com
- Google groups: https://groups.google.com/g/citybrainchallenge
- Github: https://github.com/CityBrainChallenge/KDDCup2021-CityBrainChallenge-starter-kit.git

https://www.kdd.org/kdd2021/