Expression might be enough: representing pressure and demand for reinforcement learning based traffic signal control

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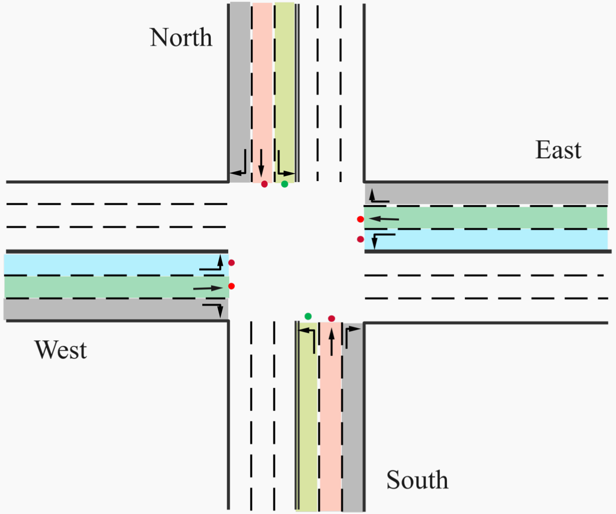
Traffic Signal Control

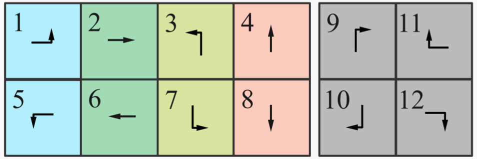
Traffic signal control aims to maximize the throughput and minimize the average travel time of all the vehicles.

Upper East Side, Manhattan, New York, USA

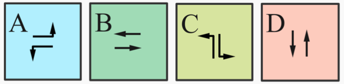
Cite [Wei et al., 2019a]



(a) Illustration of an intersection



(b) Twelve traffic movements



(c) Four phases

Related Works -- Typical Traditional Methods

SOTL [Cools et al., 2013]

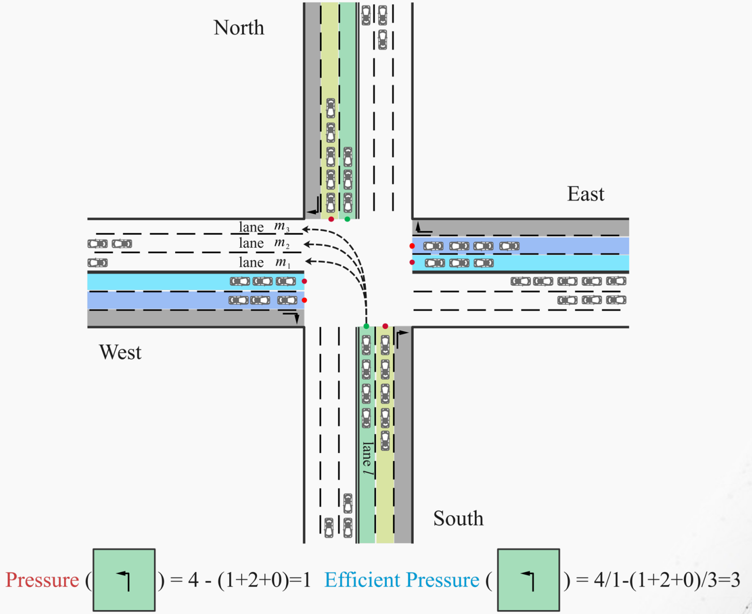
Self Organizing Traffic Lights

Input: minimal phase duration t_{min}; threshold θ and μ; distance ω

Parameters: vehicle counter c_i^r and c_i^g; records of time step t_{step}

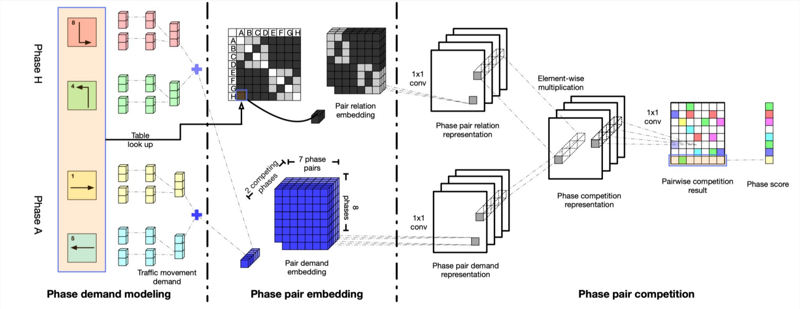
for (time step) **do**
  if ($t_{step}>t_{min}$) **then**
    c_i^r = vehicles approaching red phase
    c_i^g = vehicles approaching green phase within ω
    if not ($0<c_i^r<\mu$) **then**
      if ($c_i^r>\theta$) **then**
        switch light;
      end if
    end if
  end if
end for

Max Pressure [Varaiya 2013]
Efficient-MP [Wu et al., 2021]

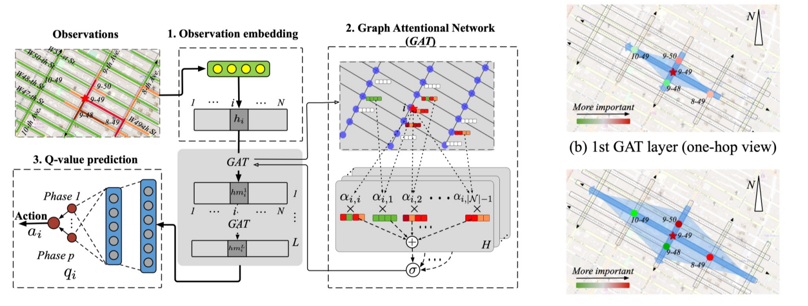


Related Works -- Recent RL Methods

FRAP [Zheng et al. 2019]



CoLight [Wei et al. 2019a]



(a) Model framework
(b) 1st GAT layer (one-hop view)
(c) 2nd GAT layer (two-hop view)

PressLight [Wei et al. 2019b]

PressLight introduces pressure into the state and reward design.

Efficient-XLight [Wu et al. 2021]

Efficient-XLight proposes efficient traffic movement pressure and adopts it as an effective state representation.

Advanced-XLight

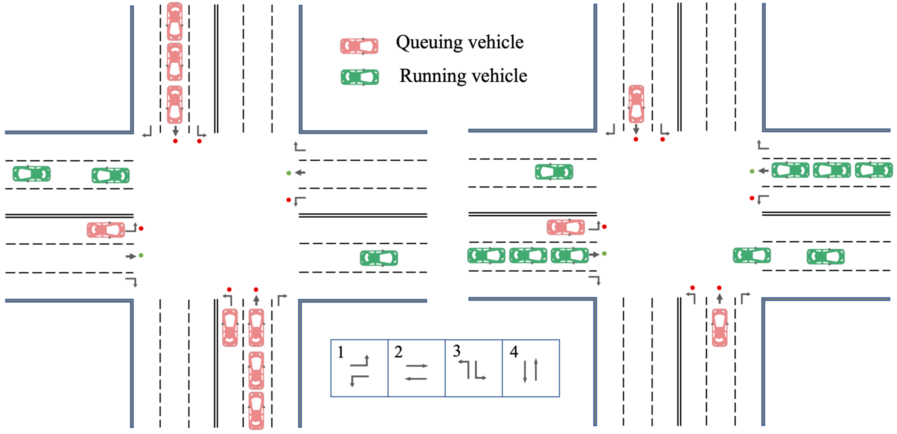
Main idea

Pay attention to both moving and waiting vehicles, find a trad-off to determine whether to maintain or change current signal phase.

Main Contribution

- Propose a novel traditional method Advanced Max-Pressure
- Propose a novel RL template Advanced-XLight

Advanced-XLight -- Definitions



(a) There are few running vehicles at current phase (b) There are many running vehicles at current phase

Effective range

The effective range is the maximum distance to the intersection that a vehicle can pass through within $t_{duration}$

Effective running vehicle number

The effective running vehicle number is the number of running vehicles of the incoming lanes within the effective range to the intersection

Traffic movement pressure

The average queue length between upstream and downstream

Phase demand

The demand of each phase is the sum of the effective running vehicle number from the phase

Advanced-XLight

Algorithm 1 Advanced Max-Pressure control

Parameter: time $t = 0$, action duration $t_{duration}$, weights W_1, current phase a_{cur}

For each intersection, get $p(s)$
$a_{cur} = \arg\max\ (p(s)|, s \in \mathcal{S}_i)$
for (time-step) **do**
  $t = t + 1$
  if $t = t_{duration}$ **then**
    For each intersection, get $p(s)$ and $d(s)$
    if $d(a_{cur}) \times W_1 > max\{p(s)\}$ **then**
      Maintain the current phase
    else
      $a_{cur} = \arg\max\ (p(s)|, s \in \mathcal{S}_i)$
    end if
    Set the phase as a_{cur}.
    $t = 0$
  end if
end for

Advanced Traffic State (ATS)

The traffic movement pressure and effective running vehicle number are proposed as ATS

Advanced-XLight

Parameter: current phase time *t*, action duration $t_{duration}$
for (time step) **do**
  $t = t+1$
  if ($t = t_{duration}$) **then**
    Get ATS for each intersection
    Set the phase by X RL model
    t=0
  end if
end for

Advanced-MPLight

Based on the framework of MPLight, using current phase and ATS as the state

Advanced-CoLight

Based on the framework of CoLight, using current phase and ATS as the state

Experiments

Method	JiNan			HangZhou		New York
	1	2	3	1	2	1
FixedTime	428.11	368.77	383.01	495.57	406.65	1507.12
MaxPressure	273.96	245.38	245.81	288.54	348.98	1179.55
Efficient-MP	269.87	239.75	240.03	284.44	327.62	1122.00
MPLight	297.46	270.05	276.15	314.60	357.61	1321.40
CoLight	272.06	252.44	249.56	297.02	347.27	1065.64
AttendLight	277.53	250.29	248.82	293.89	345.72	1586.09
PRGLight	291.27	257.52	261.74	301.06	369.98	1283.37
Efficient-MPLight	261.81	241.35	238.80	284.49	**321.08**	1301.83
Efficient-CoLight	**256.84**	**239.58**	**236.72**	**282.07**	324.27	**1032.11**
Advanced-MP	**253.61**	**238.62**	**235.21**	**279.47**	**318.67**	1060.41
Advanced-MPLight	**251.29**	**234.78**	**231.76**	**273.26**	**312.68**	1198.64
Advanced-CoLight	**245.73**	**232.63**	**229.01**	**270.45**	**310.74**	**970.05**

Table 1. Overall comparison. For average travel time, the smaller the better.

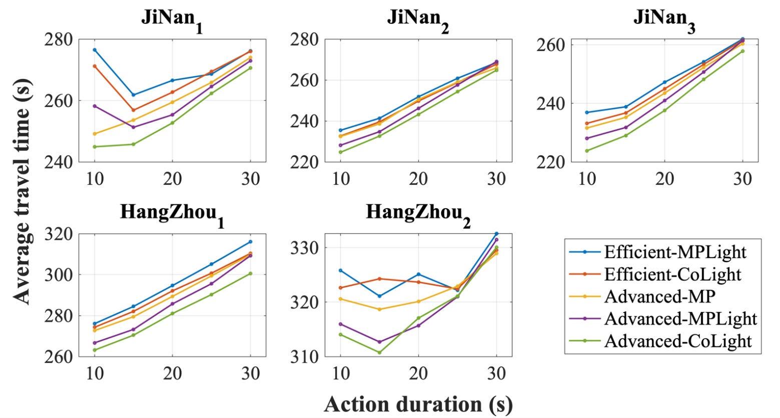


Figure 1. Model performance under different action duration.

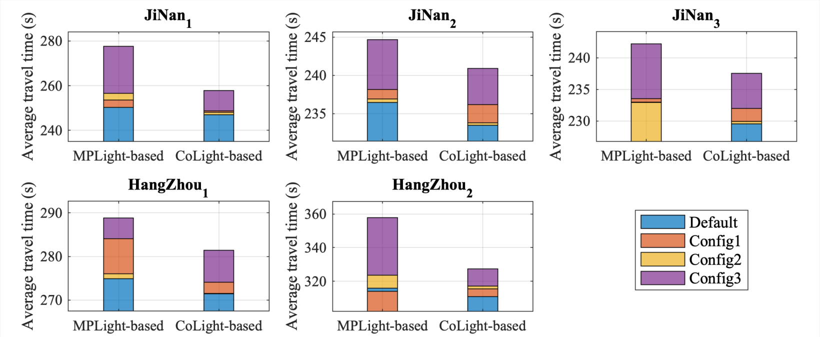


Figure 2. Model performance under different observation ranges.

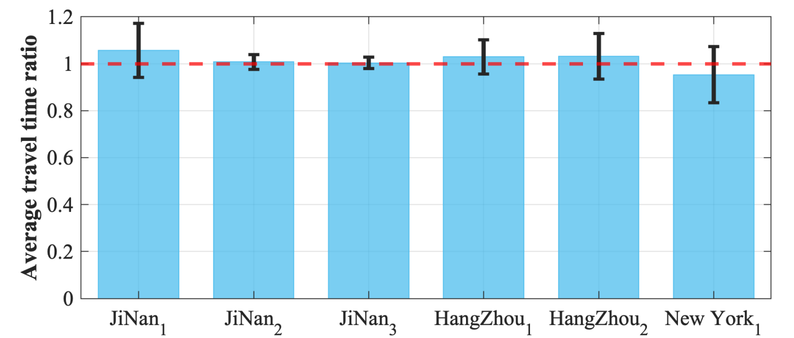
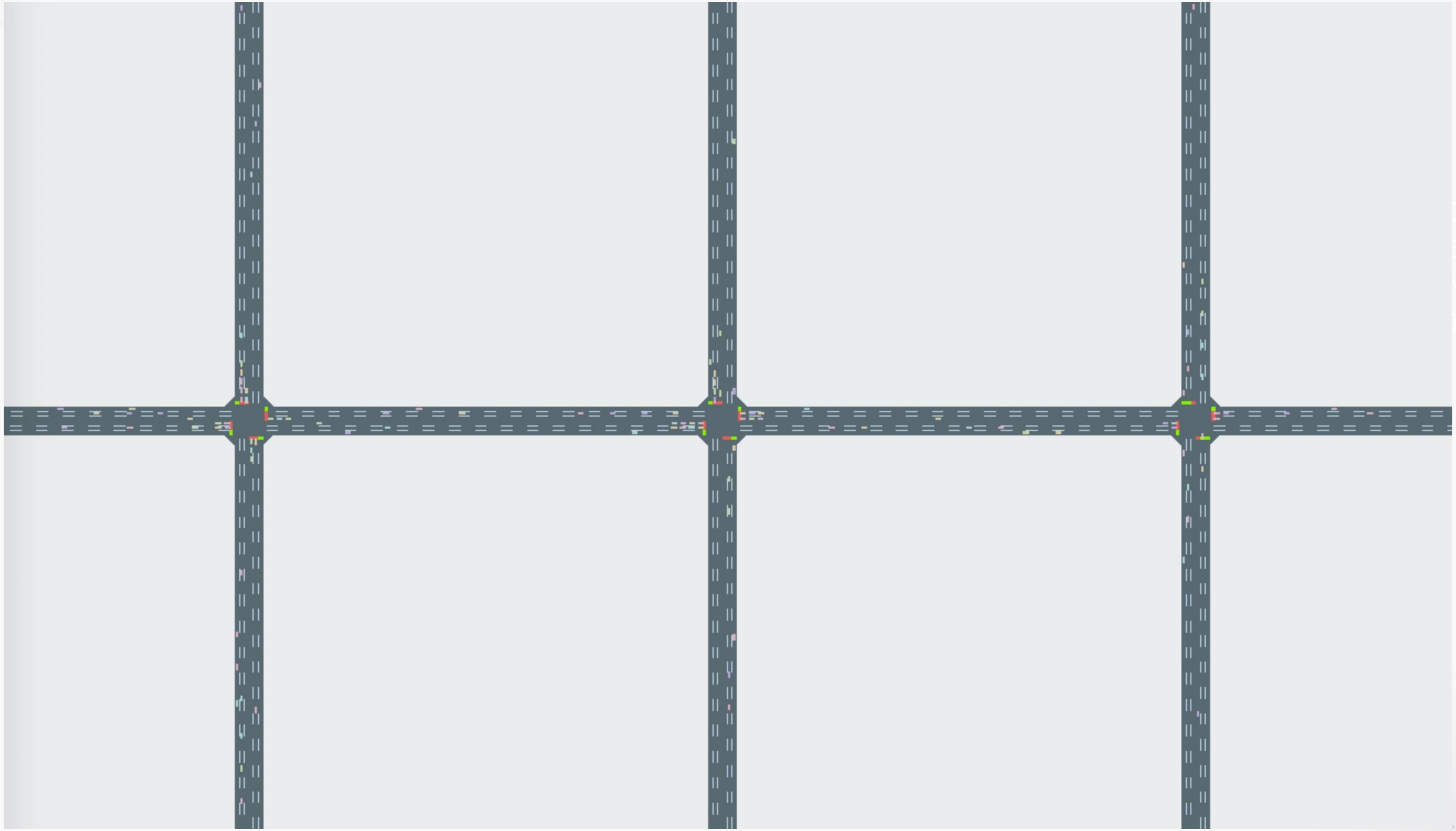


Figure 3. The transferability of Advanced-MPLight.

Instance Demonstration



Reference

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