Paper reproducibility confirmation

Background

Please refer to the original paper [1] and Group19's source code [2].
In this analysis, we are focusing on some parameters

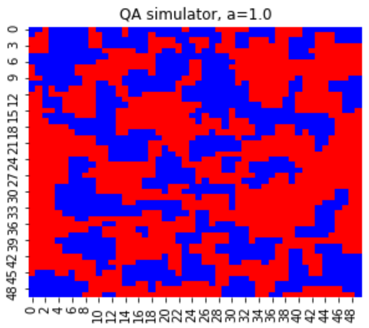
- a tells the ratio of cars whether go straight or turn left/right in an intersection. For example, $a = 0.9$ means 90% of cars are going straight. $a = 0.1$ means 90% of cars are turning either left or right. We wonder how does this ratio influence the traffic signals.
- θ is the parameter for local control method. Local control method is similar as in our real-world daily life. A traffic signal changes if an intersection's traffic flow in a direction (for example north-south direction) is larger than a predefined threshold.

Here are some fundamental information you might need to understand our results in following figures

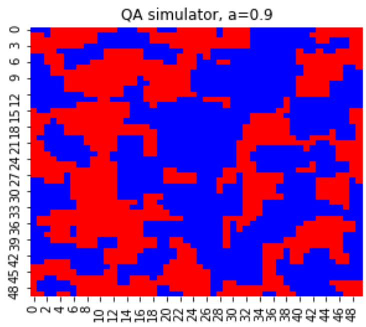
- The colors (red and blue) represent the traffic signals of an intersection. In our experiments, we assumed a map with 50x50 intersections. A red color means that intersection's traffic signal in north-south direction is green (you can imagine that cars are going vertical direction). A blue color means cars are going horizontal direction.
- In the energy plot, the lower energy, the less traffic jams. Both local control and QA methods are designed for reducing traffic jams, in other words, reducing this energy.

Result analysis

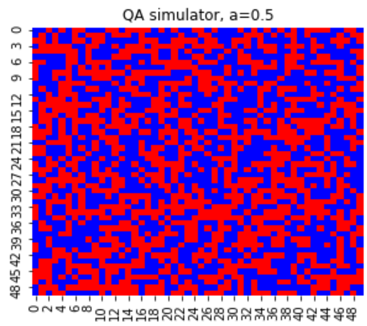
How does ratio of going straight, a, influence traffic signals



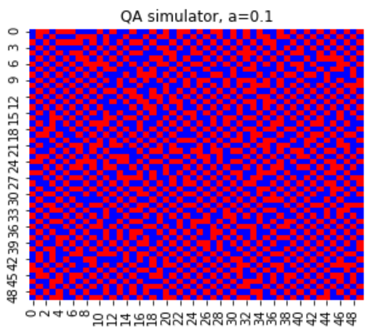
(a) $a = 1.0$



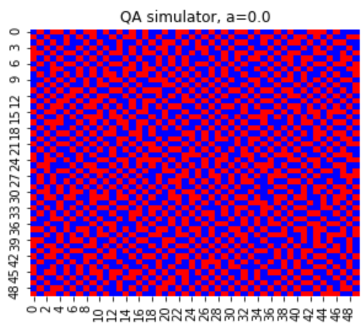
(b) $a = 0.9$



(c) $a = 0.5$

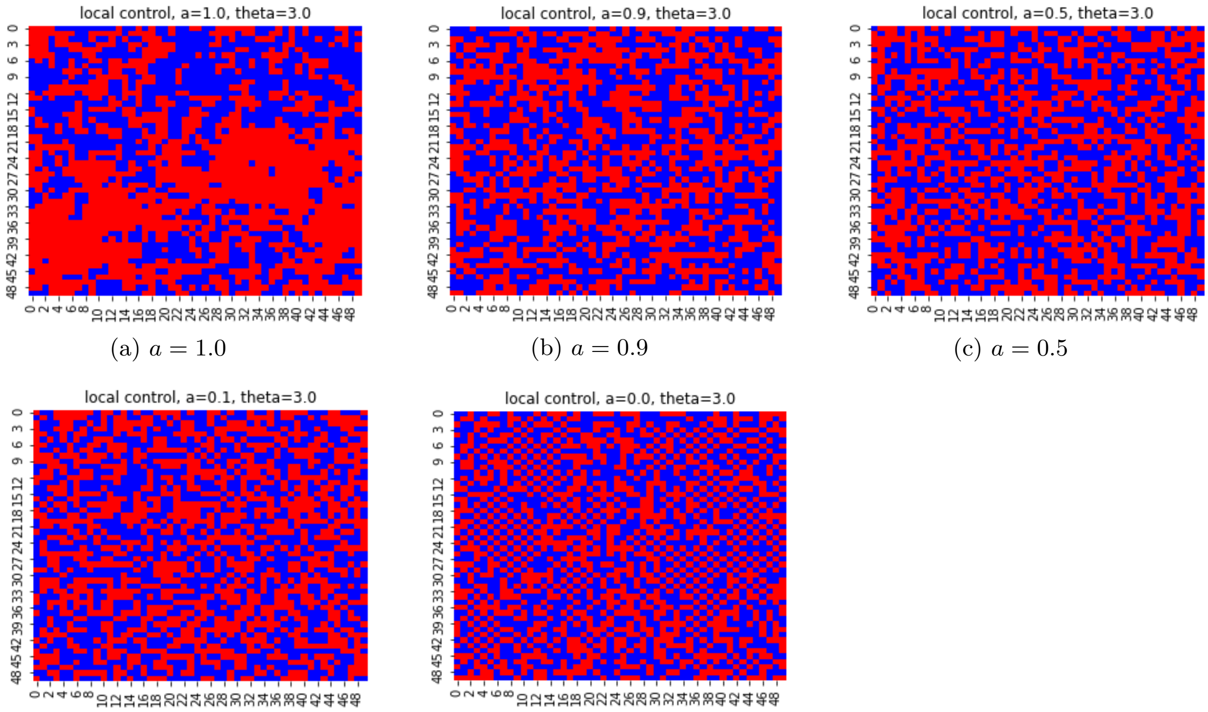


(d) $a = 0.1$



(e) $a = 0.0$

Figure 1: Traffic signals from QA simulator



(a) $a = 1.0$ (b) $a = 0.9$ (c) $a = 0.5$

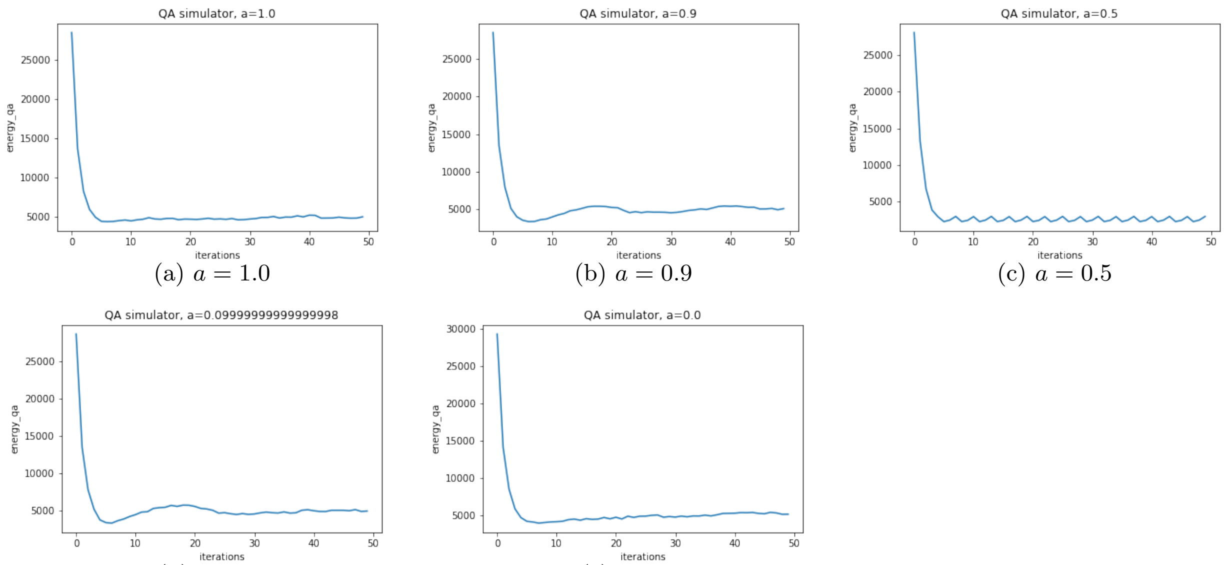
(d) $a = 0.1$ (e) $a = 0.0$

Figure 2: Traffic signals from local controller

The larger value of a, the more cars are going straight, thus the traffic signals prefer to have continuous straight regions like in figure 1(a) and figure 1(b). Otherwise, if the majority of cars are going to turn either left or right, the traffic signals tend to be cross like figure 1(d) and figure 1(e).

Results from QA simulator (openjij) seems much better than local controller. To know how good it is, we also evaluate them quantitively.

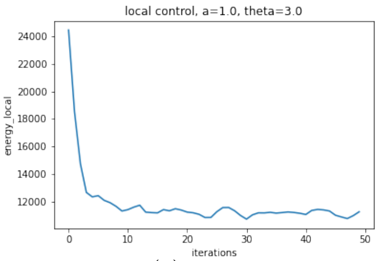
Energy (traffic jams reduction) analysis



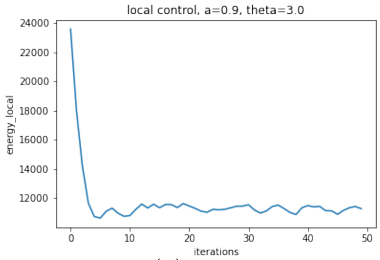
(a) $a = 1.0$ (b) $a = 0.9$ (c) $a = 0.5$

(d) $a = 0.1$ (e) $a = 0.0$

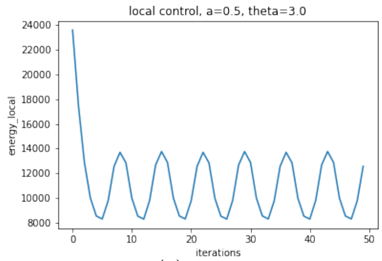
Figure 3: Energy (traffic jams reduction) from QA simulator



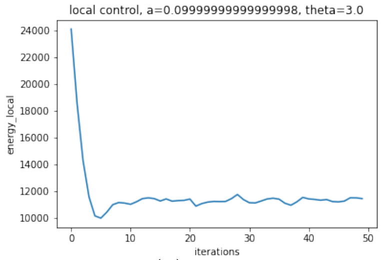
(a) $a = 1.0$



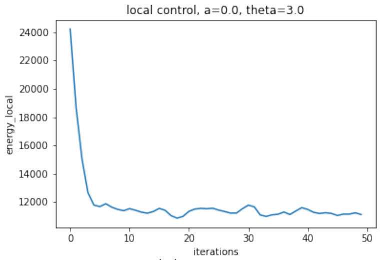
(b) $a = 0.9$



(c) $a = 0.5$



(d) $a = 0.1$



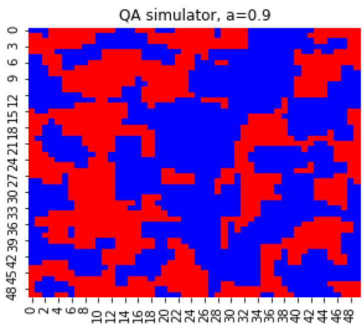
(e) $a = 0.0$

Figure 4: Energy (traffic jams reduction) from local controller

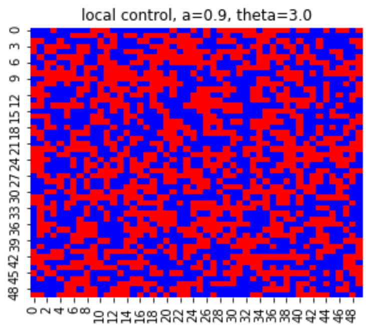
With the time iterations, energy reduces which means the traffic jams are reducing. The absolute values of minimum energies from QA simulator (around 4,500) are much lower than local controller (around 8,000). This tells QA method can really reduce traffic jams better than traditional local controller.

One interesting disconvery is when a hald of cars are going straight and a half are turning, the energies fluctuate a lot in figure 3(c) and figure 4(c).

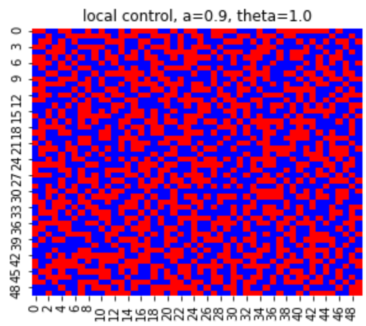
The effect of local control threshold, θ



(a) QA results

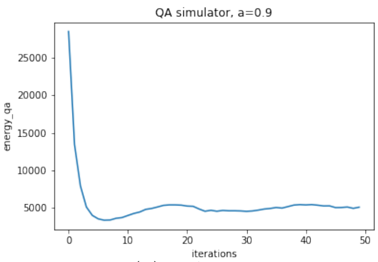


(b) local controller when $\theta = 3$

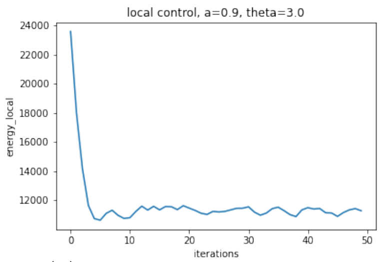


(c) local controller when $\theta = 1$

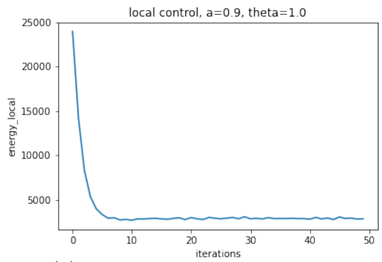
Figure 5: Traffic signals influenced by θ



(a) QA results



(b) local controller when $\theta = 3$



(c) local controller when $\theta = 1$

Figure 6: Energies influenced by θ

A smaller value of θ means the traffic signals will be changed as soon as the accumulated numbers of cars in an intersection is "large". But in real-world situations, too small value of θ will result in the traffic signals being changed too frequently.

If we compare the energy results from figure 6(c) and figure 6(a), we can find that the local controller with small θ can reduce traffic jams even better than QA. But it has the risk on frequent changes on traffic signals.

Conclusions

Our group19 conducted reproductive experiments of the original paper this week. Since the d-wave execution time for a free account is limited, we only conduct experiments in QA simulato (openjij). Luckily, Prof. Ohzeki provided us a d-wave token for this workshop. We are going to run the programs in real QA machine later.

Next week, we are going to modify the assumptions and conditions in the previous papar [1] to make it more closer to real-world scenarios.

References

[1] Daisuke Inoue, Akihisa Okada, Tadayoshi Matsumori, Kazuyuki Aihara, and Hiroaki Yoshida. Traffic signal optimization on a square lattice with quantum annealing. *Scientific Reports*, 11(1):3303, Feb 2021.

[2] github repository. `https://github.com/zminglu/QA4U-workshop`.