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Research Article

Dynamic Traffic Signal Split Control Method at Pedestrian Crossings

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Abstract

In order to facilitate and guarantee the safety of vehicular traffic on roadways, traffic control is crucial. Currently, there is a lot of study on how to effectively alter the control parameters of traffic lights for the aim of facilitating road traffic, but the observation targets of such research are restricted to vehicles. Traffic congestion in urban areas is a severe issue. However, the interference between automobiles and pedestrians creates the actual traffic, making pedestrians a vital aspect to take into account. In this article, we suggest a strategy for parameter-based traffic signal split control that will increase pedestrian traffic by taking both vehicle and pedestrian traffic into account.

Keywords: Traffic signal control, pedestrian, SUMO, split control method.

Yaya Geçitlerinde Dinamik Trafik Sinyali Bölünmüş Kontrol Yöntemi

Öz

Karayollarında araç trafiğinin güvenliğini sağlamak ve kolaylaştırmak için trafik kontrolü çok önemlidir. Karayolu trafiğini kolaylaştırmak amacıyla trafik ışıklarının kontrol parametrelerinin etkin bir şekilde nasıl değiştirilebileceğine dair birçok çalışma mevcuttur, ancak bu tür araştırmaların gözlem hedeflerinin temelini araçlaroluşturmaktadır. Kentsel alanlarda trafik sıkışıklığı ciddi bir sorun olmakla birlikte, otomobiller ve yayalar arasındaki müdahale gerçek trafiği oluşturarak yayaların da dikkate alınmasını gerektiren hayati bir unsur haline gelir. Bu çalışmada, hem araç hem de yaya trafiğini hesaba katarak yaya trafiğini artıracak parametre tabanlı trafik sinyali ayrım kontrolü için bir strateji önerilmiştir.

Anahtar Kelimeler: Trafik sinyal kontrolü, yaya, SUMO, bölünmüş kontrol yöntemi.

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1. Introduction

There is a method called fixed period control, which operates by selecting parameters set in advance. It has characteristics. A centralized type of control is the traffic control center consolidates sensor information and calculates area parameters based on that information. However, since this method aims to control the entire area, there remains the issue of responsiveness to dynamic and sudden changes in traffic flow at individual intersections (Alegre et al., 2021; Tomar et al., 2022).

On the other hand, a method has been proposed in which signal control is autonomously decentralized so that it is possible to quickly respond to changes in the conditions of individual intersections (Malena et al., 2022; Tomar et al., 2022). This is a system that changes traffic signal control parameters, and includes optimization of traffic signal control using vibration synchronization (Wang et al., 2021) and traffic signal control using multi-agent reinforcement learning.

A traffic signal control method with higher responsiveness is proposed by using autonomous decentralized traffic signal control in which each traffic signal autonomously determines its control parameters without going through the control center (Qu et al., 2022) In this control method, a control agent is assigned to each intersection, and each agent autonomously controls traffic signals. In addition, after solving the problem that it is difficult to respond quickly to the traffic conditions at individual intersections, the system is developed in a complex road environment assuming real space. It is proposed to apply the method at low cost.

On the other hand, in the method of controlling the traffic signal parameters to alleviate traffic congestion, it is important to consider pedestrians as well as vehicles (Han et al., 2022; Akyol et al., 2019).

An intersection is formed by a roadway and a sidewalk, and there is pedestrian traffic and vehicle traffic, and depending on the situation, the traffic flow changes due to interference (Sun et al., 2022).

In order to realize the application of control in a real environment, the control aimed only at smoothing vehicle traffic flow will increase the waiting time of pedestrians, and there will be situations that are not optimal for pedestrians. Pedestrian information is a factor that cannot be ignored (Artal-Villa and Bazzan, 2021).

In this study, based on the split control method proposed by Qu et al. (Qu et al., 2022), which achieved high responsiveness through autonomous decentralization, we proposed a traffic signal control method that considers pedestrian information in addition to vehicle information. We aim to smooth pedestrian traffic flow by improving the method.

The control parameters of traffic signals are appropriately manipulated according to traffic conditions to facilitate smooth traffic flow in this study. On the other hand, some studies have attempted to improve this by controlling the parameters of traffic signals, and have achieved certain results. Therefore, it is an important issue in traffic signal control to appropriately change the control parameters in response to such changes.

2. Traffic Signal Control

Traffic signal control aims to control the parameters that switch the “presentation"” and to smooth the traffic flow around the intersection or in the traffic network which represents right of way (Trächtler, 2022).

The main parameters (Han et al., 2022) that control the appearance are the cycle length (the time it takes for the appearance to cycle through blue, yellow, and red, and then turn to blue again), the split (the ratio of green time for each appearance within the intersection), and the offset (cycle start time lag between intersections) are used.

Based on a given cycle length, split control sets the percentage of green time to be allocated in consideration of excessive traffic volume for each phase, improving the traffic flow at intersections in the cycle.

In offset control, the distance between adjacent intersections and traffic conditions are taken into consideration, and the cycle start time is staggered in order to smooth traffic flow between intersections.

In this study, among the three parameter controls mentioned above, we focused on and examined the method of controlling the split value.

3. Proposal method

The traffic signal control method proposed in this research optimizes the entire network by determining the control parameters of each traffic signal by means of autonomous agents placed at individual intersections.

Each agent is independent for the whole network and uses only the traffic information about the intersections that it manages to autonomously control the traffic lights. In this research, we focus on the split as a traffic light control parameter.

Each agent performs split control at the intersection they are in charge of. The update formula for split control is based on the spring model (Qu et al., 2022).

An agent placed at each intersection incorporates the traffic volume of vehicles and pedestrians at the intersection it manages into the spring balance equation, and calculates and controls the split for the next cycle just before the end of one cycle. reflected as a parameter.

By repeating this process every cycle, control is performed over the entire simulation time.

In addition, each agent has information necessary for its own control, such as various information held by its own intersection (cycle length, split, current and corresponding direction, lane information) and traffic information observed by sensors number of vehicles, number of pedestrians) can be acquired.

3.1. Traffic

In this method, the split calculation is performed by measuring the traffic volume Q at the intersection. Here, both the vehicle traffic volume and the pedestrian traffic volume are considered in the traffic volume, so each is defined separately.

For the traffic volume of vehicles, in addition to the amount of vehicles flowing into the intersection, the number of remaining vehicles to be sorted is taken into consideration. In other words, the traffic volume $Q_{(n,v)}$ of vehicles on the roadside is expressed as follows and it represents the lane average of the number of vehicles entering the roadway.

$$Q_{(n,v)} = Q_{(n,in)} + a^{Q(n,res)} \quad (1)$$

The $Q_{(n,in)}$ term on the right side of Equation 1 is an exponential function with α coefficient n as the base, and by setting the condition of 1 to satisfy the condition of 1, it takes a larger value as the number of remaining vehicles at the intersection increases.

The first term on the right side of Equation 1, $Q_{(n,in)}$, represents the lane average of the number of inflowing vehicles on road n, and is the value obtained by dividing the total number of inflowing vehicles on road $n_{(v,in)}$ by n and the number of lanes on road n by n_{lane}.

The second term on the right side of Equation 1 is an exponential function with the coefficient α as the base. By setting the condition $\alpha > 1$, the larger the number of remaining vehicles at the intersection, the larger the value.

For the exponential jump, $Q_{(in,res)}$, the value obtained by dividing the total number of remaining vehicles $n_{(v,res)}$ on road n by the number of lanes is used.

For pedestrian traffic volume, we consider the number of pedestrians crossing the crosswalk at the intersection. Specifically, we adopt the number of pedestrians on the crosswalk $Q_{(m,cross)}$ observed at a specific timing in the scenario where the crosswalk nail is passable. Here, we assume that there are no pedestrians who cannot cross the crosswalk even in congested pedestrian traffic conditions, and do not introduce the concept of stray vehicles. Pedestrian traffic is counted simply as the number of people passing through the crosswalk.

3.2. Split calculation

Figure 1 shows a schematic diagram of the spring model at a two-indication intersection used in this method. At the two-indication intersection, a spring model in which two springs are connected is assumed as in the case of the number of indications. Let SPLIT1 and SPLIT2 be the split values of the first and second presentations.

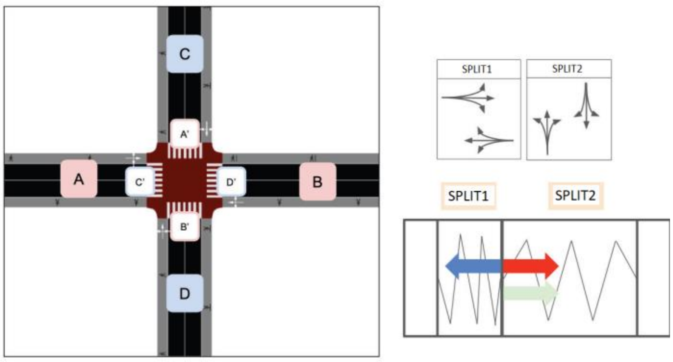

Figure 1. Schematic of the split model at the intersections

In the case of Figure 1, the direction of pedestrians $A-B$ corresponds to the first phase, and the direction of $C-D$ corresponds to the second phase. As for the sidewalk, A' and B' correspond to the first appearance, and C' and D' correspond to the second appearance. The arrows extending from the connecting part of the two springs represent the force exerted by the spring due to SPLIT1, the force exerted by the spring due to SPLIT2, and the external force, respectively. These interactions form a state of equilibrium similar to that of a physical spring.

Here, the external force on the mane is defined as the difference D between the traffic volumes in the east-west direction and the north-south direction. This traffic volume difference D is expressed using the traffic volume Q defined in Section 3.1. Specifically, when the vehicle traffic volume difference is D_v, this is the difference between the maximum east-west traffic volume $max(Q_{(A,v)}, Q_{(B,v)})$ and the north-south maximum traffic volume $max(Q_{(C,v)}, Q_{(D,v)})$ It is defined as the value divided by the sum. Note that $\{A, B\}$ and $\{C, D\}$ represent the roads to which the right of way is given to the first and second manifestations, respectively. The pedestrian traffic volume difference D_p is also defined in the same way.

The traffic volume difference D is defined as the force acting on the spring from the outside. It is expressed as when the constant is K:

$$X = \frac{D}{2K} \quad (2)$$

The split ratios SPLIT1 and SPLIT2 are calculated by adding and subtracting the value of the displacement X to the natural length of the spring while balancing so that the sum is kept at 1. In addition, the external force can be divided into vehicle force D_v and pedestrian force D_p calculated by the difference D.

Here, we introduce a coefficient that expresses the degree of consideration of pedestrians in control, and use the traffic volume difference D as

$$D = D_v + 1D_p \quad (3)$$

Note that when the value of the coefficient is 0, it is consistent with Ohno's control [Ohno 20], which does not consider pedestrian information at all.

4. Evaluation experiment

4.1 Experiment environment

In this experiment, a traffic simulator SUMO (Simulation of Urban MObility) is used. SUMO is open source developed by the German Aerospace Center. It is a micro-traffic simulator, and its main functions are the acceleration and speed of vehicles and pedestrians, 'driving route setting and road shape', 'traffic signal placement', and his parameter control of traffic lights. Furthermore, with a dedicated API called Traci, various information in the simulation space can be acquired in detail (Koti and Kakkasageri, 2021; Mathiane et al., 2022).

In addition, in this study, a radio wave radar, which is assumed to be used to acquire information on the roadway in the demonstration experiment, and an observation camera, which is assumed to be used to acquire information on the sidewalk, are used. Based on the settings in SUMO, information is acquired on SUMO.

The radio wave radar assumed in this study can acquire vehicle speed, vehicle position, and vehicle length as traffic information within a range of approximately 150 m from each intersection. The observation range is the entire crosswalk at each intersection, and the number of pedestrians crossing the crosswalk at a specific timing can be obtained.

Based on the above assumptions, only this information is handled in the simulation space when conducting experiments.

4.2 Experimental setup

In this experimental environment, we used a 5x6 road network configured on SUMO to verify the effectiveness of the split control based on the spring model that considers pedestrian information, as described in Section 3. External view of the experimental environment is shown in Figure 2. The simulation period is 14400 steps, and the cycle length at each intersection is fixed at 100 steps. The basic settings of the experiment are shown in Table 1. Note that the unit of time on SUMO is step, and 1 step corresponds to 1 second in real time. Table 2 shows the various settings of vehicles and pedestrians in the simulation, and Tables 3 and 4 show the inflow patterns of vehicles and pedestrians used in the experiment.

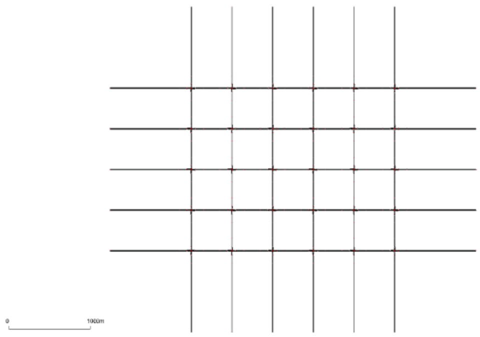

Figure 2. Network outside view

Table 1. Experimental settings

Seeting items	Set value
Cycle length	100 steps
Simulation period	14400 steps
Comparision method	Static method
Coefficient	0 to 1 (changes in 0.1 range)
Evaluation index	Average loss

Table 2. Various settings for vehicles and pedestrians

time	Vehicle	Pedestrian
Size	4.3 m	0.215 m
Maximum speed	180 km/h	5.4 km/h
Passing priority	low	high

Table 3. Vehicle inflow pattern from each inflow route

time	East [units/h]	East [units/h]	North-South [units/h]
0~3600	1800	2100	500
0~7200	1500	2100	500
0~10800	1200	2100	500
0~14400	900	2100	500

Table 4. Pedestrian inflow pattern from each inflow route

time	East [units/h]	East [units/h]	North-South [units/h]
0~3600	500	1500	1500
0~7200	500	1500	1200
0~10800	500	1500	900
0~14400	500	1500	600

For the inflow pattern of both vehicles and pedestrians, the flow rate is changed every 3600 steps, dividing the experimental period into four. Regarding the inflow of vehicles, the main traffic flow is set to the east-west direction, and the inflow from the east direction is reduced over time. It is set perpendicular to the vehicle. In addition, in this experiment, the value of the weighting factor l, which indicates the degree of consideration of pedestrian information, is varied in detail, and the time loss of vehicles and pedestrians at each stage is analyzed. 1, and a control experiment is performed when this interval is varied by a width of 0.1. In addition, in order to evaluate the effectiveness of the proposed method in this experiment, static control with a fixed split ratio and Ohno's control [Ohno 20], which does not consider pedestrians, were used as comparison methods.

4.3 Experimental results

Figures 3 and 4 show the average time loss of pedestrians and the average time loss of vehicles in the experiment.

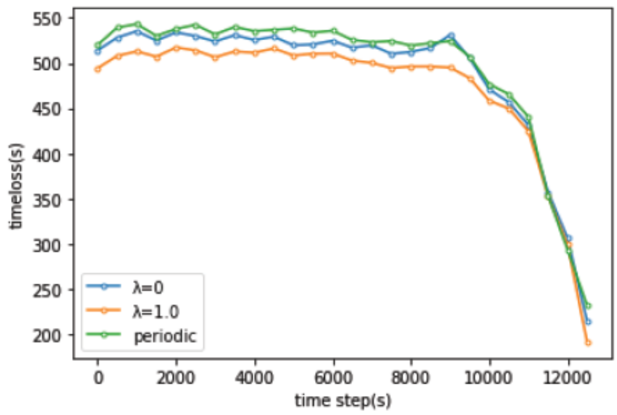

Figure 3. Comparision of pedestrian average loss

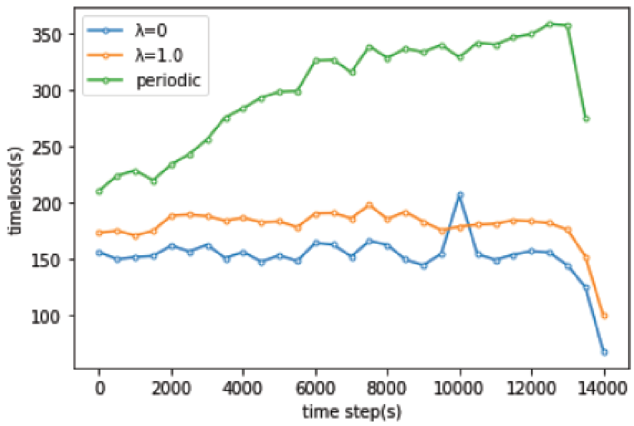

Figure 4. Vehicle average loss comparison

The results of control using a spring model that does not consider pedestrian information (l = 0), control results using a spring model that considers pedestrian information ($l = 1.0$), and control results using static control (periodic) are shown. Primarily, both with and without consideration of pedestrians it can be seen that the average loss time is greatly reduced compared to static control. Also, it can be seen that control that considers pedestrian information has the effect of reducing the average lost time of pedestrians and increasing the average lost time of vehicles.

Figure 5 shows the comparison of the cumulative vehicle loss time and pedestrian cumulative loss time in the experiment. The vertical axis represents the average time loss of pedestrians. As the value of the coefficient indicating the degree of consideration of pedestrians is changed, the lost time of pedestrians decreases/increases, and conversely, the lost time of vehicles increases/decreases. It can be understood that there is a trade-off relationship.

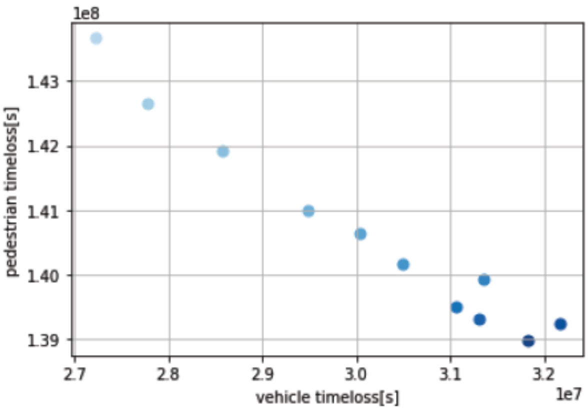

Figure 5. Comparison of vehicle cumulative loss and pedestrian loss

4.4 Inspection

Pedestrian traffic flow in the simulation is improved by control that considered pedestrian information, and the effectiveness of the proposed method that introduced pedestrian information into control based on a spring model is demonstrated.

On the other hand, it is also confirmed that the average loss of vehicles increased in inverse proportion as the average loss of pedestrians is reduced by increasing the degree of consideration of pedestrian information. This is thought to be due to the trade-off relationship between vehicles and pedestrians in determining the split ratio in signal control.

In addition, the average loss is improved compared to static control, regardless of whether pedestrians are considered or not. This is based on the premise that the spring model, which is flexible control for changes in traffic flow, has an average loss improvement effect compared to static control, and even if this effect is distributed to vehicles and pedestrians. It is considered that it does not fall below the static control.

The experimental results showed the trade-off between the lost time of vehicles and pedestrians, but if we want to calculate the optimal value of the coefficient that expresses the degree of consideration of pedestrians, we should consider the ratio of the value of vehicles and pedestrians. It is considered necessary to do so. For example, if the average number of people in a vehicle is 2, the value of the vehicle is simply determined as twice the value of the pedestrian. However, it is generally difficult to establish quantitative criteria for the value of vehicles and pedestrians. It is thought that it is necessary to take into consideration what kind of vehicles pass by depending on the road environment.

5. Conclusions and Future Outlooks

In this study, we proposed a traffic signal control method using a spring model that considers pedestrian information. We also confirmed that there is a trade-off between improving the traffic flow of pedestrians and vehicles.

As a future topic, when considering actual application as a signal control method, it is necessary to establish a more applicable control system that includes cycle length and offset as control parameters. It needs to be improved so that it can be applied to complex shapes existing in the environment.

In addition, we are preparing to conduct a demonstration experiment, and we would like to continue our research so that the method will be more suitable for operation in a real environment.

References

Akyol, G., Silgu, M. A., & Celikoglu, H. B. (2019). Pedestrian-friendly traffic signal control using Eclipse SUMO. In *Proceedings of the SUMO User Conference* (pp. 101-106).

Alegre, L. N., Ziemke, T., & Bazzan, A. L. (2021). Using reinforcement learning to control traffic signals in a real-world scenario: an approach based on linear function approximation. *IEEE Transactions on Intelligent Transportation Systems*.

Artal-Villa, L., & Olaverri-Monreal, C. (2019, April). Vehicle-pedestrian interaction in SUMO and unity3D. In *World Conference on Information Systems and Technologies* (pp. 198-207). Springer, Cham.

Han, G., Zheng, Q., Liao, L., Tang, P., Li, Z., & Zhu, Y. (2022). Deep Reinforcement Learning for Intersection Signal Control Considering Pedestrian Behavior. *Electronics*, *11*(21), 3519.

Koti, R. B., & Kakkasageri, M. S. (2021). Multi Agent Assisted Safety Information Dissemination Scheme for V2V Communication in VANETs: Intelligent Agent Approach. *International Journal of Intelligent Systems and Applications (IJISA)*, *13*(4), 49-62.

Malena, K., Link, C., Bußemas, L., Gausemeier, S., & Trächtler, A. (2022). Traffic Estimation and MPC-Based Traffic Light System Control in Realistic Real-Time Traffic Environments. In *International Conference on Vehicle Technology and Intelligent Transport Systems, International Conference on Smart Cities and Green ICT Systems* (pp. 232-254). Springer, Cham.

Mathiane, M., Tu, C., Owola, P. A., & Nawej, M. C. (2022). A SUMO Simulation Study on VANET-Based Adaptive Traffic Light Control System. In *Advances in Electrical and Computer Technologies* (pp. 225-237). Springer, Singapore.

Qu, D., Li, H., Liu, H., Wang, S., & Zhang, K. (2022). Crosswalk safety warning system for pedestrians to cross the street intelligently. *Sustainability*, *14*(16), 10223.

Sun, Q., He, C., Wang, Y., Liu, H., Ma, F., & Wei, X. (2022). Reducing violation behaviors of pedestrians considering group interests of travelers at signalized crosswalk. *Physica A: Statistical Mechanics and its Applications*, *594*, 127023.

Tomar, I., Sreedevi, I., & Pandey, N. (2022). State-of-Art Review of Traffic Light Synchronization for Intelligent Vehicles:

Current Status, Challenges, and Emerging Trends. *Electronics*, *11*(3), 465.

Trächtler, A. (2022). Traffic Estimation and MPC-Based Traffic Light System Control in Realistic Real-Time Traffic Environments. In *Smart Cities, Green Technologies, and Intelligent Transport Systems: 10th International Conference, SMARTGREENS 2021, and 7th International Conference, VEHITS 2021, Virtual Event, April 28-30, 2021, Revised Selected Papers* (p. 232). Springer Nature.

Wang, T., Cao, J., & Hussain, A. (2021). Adaptive Traffic Signal Control for large-scale scenario with Cooperative Group-based Multi-agent reinforcement learning. *Transportation research part C: emerging technologies*, *125*, 103046.