# Calculation of intersection signal timing based on electronic police passing data

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## ABSTRACT

The passing data from the electronic police are increasingly used for traffic state identification and signal optimization. Obtaining the specific settings of signal timing is very important for refined traffic analysis. In this paper, traffic signal timing settings are directly calculated from the passing data of electronic police equipment to solve the problem of not being able to obtain signal timing for various reasons in practice. In the experiment, the bidirectional sliding window was used to evaluate the probability of the signal light indication at each time, and the evaluation probability for each time of the sliding range was added up to obtain the overall green probability of the sliding range. The experiment shows that the electronic police data can not only calculate the intersection signal timing effectively, but also eliminates the influence of abnormal vehicles.

**Keywords:** Electronic police, passing data, signal timing, sliding window, probabilistic assessment

## 1. INTRODUCTION

Traffic signal timing optimization has always been one of the most direct and effective means to improve road traffic, and one of the most important works of road traffic management departments[1]. Most of the existing signal optimization relies on traffic signal machines, such as SCOOT and SCATS[2-3]. At present, it is almost impossible to obtain the timing parameters directly from the traffic signal machines. However, obtaining the intersection signal timing parameters from the traffic control department not only requires some effort, but also usually results in a signal timing schedule which can be difficult to update due to some specific reasons why the traffic police have manually adjusted the phase durations. It is not a simple task for traffic control departments to collect time sequence information of large-scale urban signals. In practice, it is common to fail to obtain signal timing due to various reasons.

To solve the problem that the signal timing cannot be obtained in practice due to various reasons, Ban et al.[4] proposed to use the intersection delay model to estimate the signal timing parameters. When the fleet encounters the red-light phase, the vehicle cannot pass the intersection. By correlating the vehicle delay time with the red-light duration, the intersection timing parameters can be roughly estimated. Hao et al.[5] collected the travel time of vehicles from the upstream to the downstream of the intersection and correlated the travel time with signal timing changes to estimate signal timing parameters. In recent years, GPS trajectory data of taxis[6], buses[7], and commercial vehicles[8] can be used to deduce the cycle length and phase duration of intersection signal lights. With the development of vehicle detection technology, massive detection data have been used to diagnose signal parameters, such as mobile navigation data[9], mobile sensor data[10], and even simulated data[11-12], etc. However, due to the relatively low sampling rate of data, the accuracy of calculated signal lamp timing parameters is not high.

Based on the characteristics of electronic police[13] with a high sampling rate and easy access to traffic passing data, this paper makes use of bidirectional sliding Windows to evaluate the probability of signal indication at each moment and effectively calculates the timing parameters of intersection signals.

## 2. ELECTRONIC POLICE TRAFFIC PASSING DATA ACQUISITION

The electronic police is an off-site law enforcement system in the intelligent traffic management system, mainly used to capture various vehicle violations and generally installed upstream of the intersection stop line, with its camera pointing to the rear of the vehicle. When the vehicle passes the stop line, the electronic police device will recognize the license

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plate and record the information such as the lane where the vehicle is located, license plate number, and time stamp[14]. The installation diagram of the electronic police is shown in Figure 1. Whether the traffic flow passes the stop line or not is determined by the periodic change of the colour of the traffic signal light. For different directions of traffic, the light colour display obtained at a certain moment is different. Figure 2 shows the periodic change of the traffic light colour in a classical four-phase. Traffic passing data is one of the most important data contents provided by electronic police equipment, and it is also the main data used in the research. At present, more and more vehicle passing data is used for trajectory data acquisition, traffic state identification and accident detection, etc., and has become an important traffic information collection method.

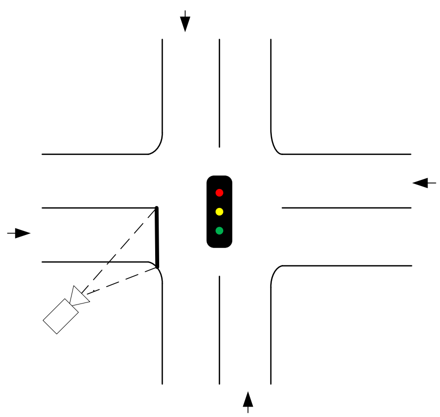

Figure 1. Schematic diagram of electronic police installation.

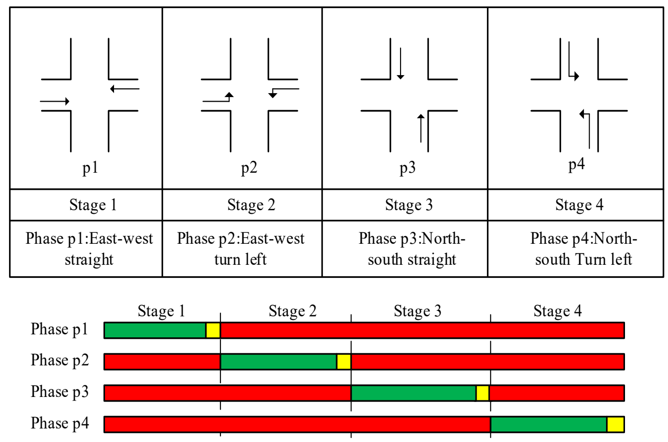


Figure 2. Four phases at intersection.

At present, the mainstream electronic police will identify all vehicles passing the stop line, not just illegal vehicles. The main format of traffic passing data is shown in Table 1.

Table 1. Main formats of traffic passing data.

| | License plate ID | Equipment ID | Lane ID | Timestamp |
|---|---|---|---|---|
| 1 | 5B**099 | D1001 | 65-1-1 | 2021-03-08 09:08:35.32 |
| 2 | —— | D1007 | 65-3-2 | 2021-03-08 09:08:45.32 |
| 3 | 7FGM710 | D1003 | 65-7-1 | 2021-03-08 09:09:35.32 |

The equipment ID is the electronic police equipment number, the lane ID is the number of the lane where the vehicle is, and it is composed of three IDS: intersection ID- road ID- lane number. For example, 65-1-1 represents the first lane of the No. 1 entrance road at intersection 65. The license plate of the second car in the form was not be recognized, and the electronic police equipment would fail to recognize or misrecognize the license plate under the conditions of low light and license plate occlusion. The data that fails to correctly identify the license plate can still provide important information and can be compensated by some means. In addition, the electronic police can also record the colour of the license plate, the type of vehicle, etc., and can further divide buses, police cars, etc. through the license plate library comparison.

## 3. DATA PRE-PROCESSING

The data set selected for the experiment came from the left-turn lane of Zhong guan Road-Donghuan North Road-Northeast Entrance in Zhenhai District, Ningbo City on March 8, 2021. The statistical time interval is 5 minutes, and a total of 1560 sets of data were collected, as shown in Figure 3.

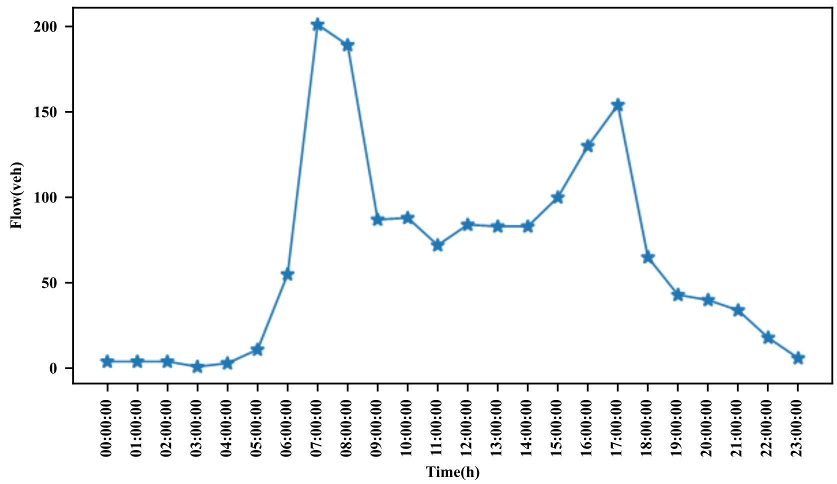


Figure 3. Changes in the traffic flow over time.

As can be seen from the changes in the traffic flow of the day, the lane has two peak traffic times, with the morning peak time around 7 a.m. to 8 a.m. and the evening peak time around 5 p.m. In the experiment, the period from 7:50:00 to 8:10:00 am was selected to record the time of each car passing the stop line and draw the passing time chart as shown in Figure 4. In this period, when a vehicle passes the stop line at a certain moment, the moment is recorded as 1, otherwise, the moment is recorded as 0.

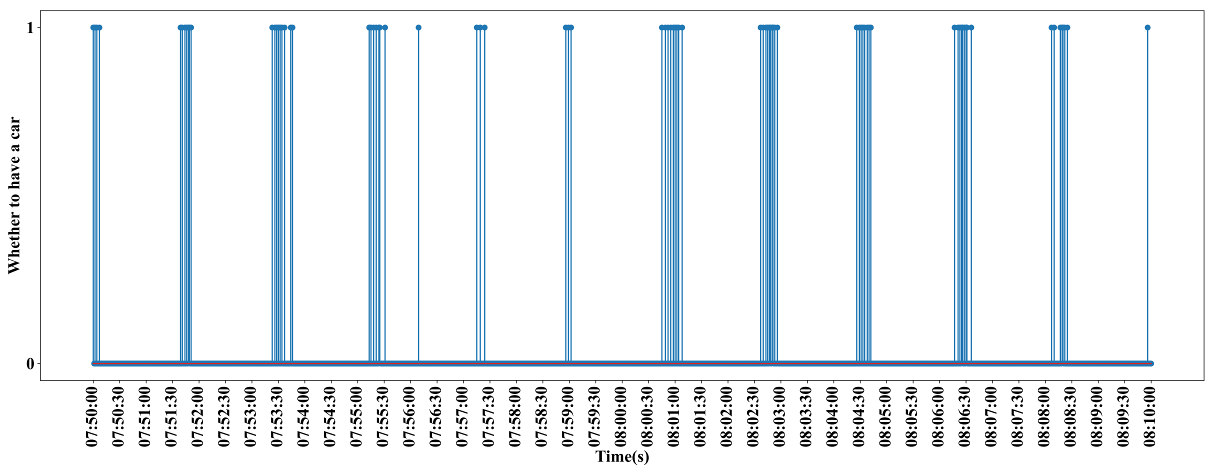


Figure 4. Time for vehicles to pass the stop line.

Due to the influence of the signal lights, vehicles can only pass the stop line to gain access at the green light time, and the passing time is subject to a cyclical cluster pattern of traffic signal colour changes. During peak traffic hours, without the loss time of all critical traffic flows in its signal phase being considered, the time of each cluster is approximately equal to the green light duration of that phase, and the duration of two consecutive clusters is approximately equal to the period length of the signal light. However, there will be individual abnormal data such as 07:56:00-07:57:30 in the experiment, caused by incorrect driving behaviours at this moment, which will interfere with the estimated signal timing parameters. This experiment not only calculates the signal timing of the intersection based on the passing data of the electronic police but also eliminates the vehicles with abnormal driving behaviours.

## 4. EXPERIMENTAL DESIGN

As the intersection is affected by traffic lights, if there is a continuous vehicle passing through the stop line in a certain period, it is likely to be a green phase during this period, and the vehicle will get the right of way. If no vehicle passes the stop line during this period, this phase is likely to be a red-light phase and the vehicle will not be able to obtain the right of way. In the peak traffic period, starting from a certain time, within the time interval T before and after this time, the closer a vehicle passes the stop line to this time, the greater the possibility that the time passing the stop line is the green light time; the further away from the moment there is a vehicle passing the stop line, the less the probability that the moment passing the stop line is a green light. The overall green light probability for time interval T can be obtained by summing the green light probabilities at each moment in time interval T.

The experiment takes the time of 7:50:00 as the starting point of the front sliding, T=20s as the sliding window, and the sliding window slides forward at the speed of one second, and we get [7:50:00, 7:50:00+T], [ 7:50:01, 7:50:01+T] … such a front sliding interval. Taking the time of 8:10:00 as the starting point of the rear sliding, the sliding window slides backward at the speed of one second to get [8:10:00-T, 8:10:00], [8:09:59-T, 8:09:59] … such a rear sliding interval. The experiment calculates the overall green light probability $P_{front}$ of the front sliding interval and the overall green light probability $P_{rear}$ of the rear sliding interval respectively, as shown in Formula 1.

$$P_{front}=\sum_{j=1}^{T-1}\left(\frac{T-j}{T}*j^*\right)^2 \quad \begin{cases} j^* = 1 \ \ A\ car\ passes\ the\ stop\ line\ at\ time\ j \\ j^* = 0\ Others \end{cases}$$

$$P_{rear}=\sum_{i=1}^{T-1}\left(\frac{i}{T}*i^*\right)^2 \quad \begin{cases} i^* = 1 \ \ A\ car\ passes\ the\ stop\ line\ at\ time\ i \\ i^* = 0\ Others \end{cases} \tag{1}$$

During the front sliding process, the latter ending time will not reach T, which is supplemented with 0 in the experiment. During the rear sliding process, the start time does not satisfy T, again supplemented with 0. The green light probability map of the sliding interval as shown in Figure 5 is obtained.

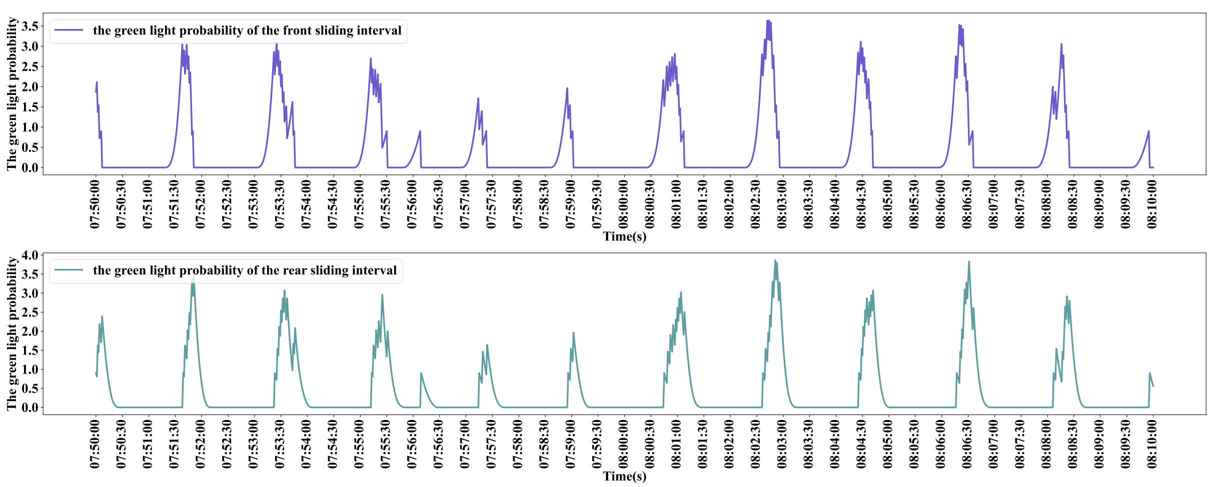


Figure 5. The green light probability for the sliding interval.

In the green light probability map of the front sliding interval, the right side of each probability interval perfectly fits the passing time diagram, but the left side expands the range of green light probability; In the green light probability map of the rear sliding interval, the left side of each probability interval fits well with the passing time diagram, but the right side also expands the range of the green light probability. Combine the green light probability of the front sliding interval with each interval corresponding to the green light probability of the rear sliding interval, as shown in Figure 6.

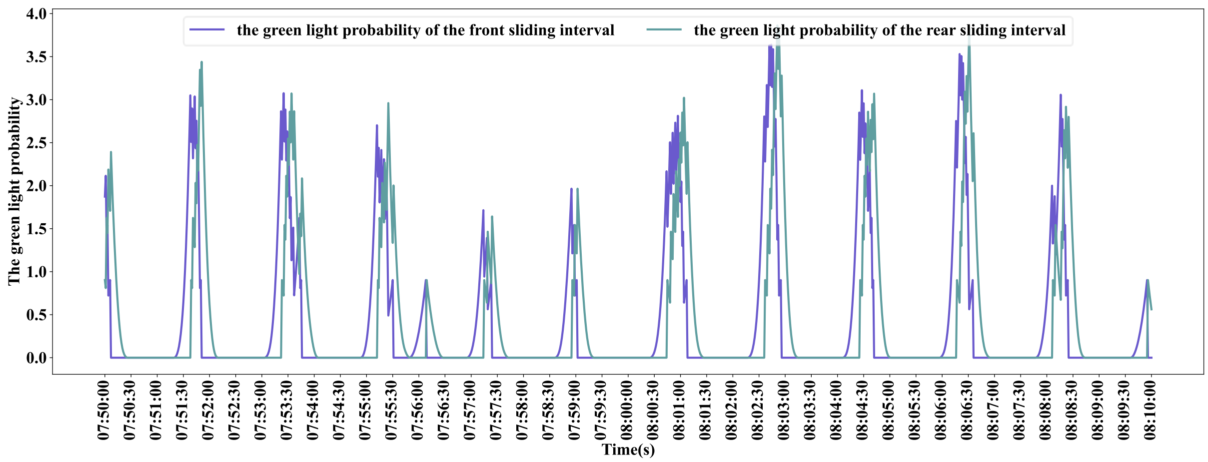


Figure 6. The green light probability for the two-way sliding interval.

It can be seen from the figure that, after setting the green probability of the front sliding interval and the green probability of the rear sliding interval to smaller values in each corresponding interval, the green probability P that matches the passing time diagram can be obtained, as shown in Formula (2).

$$P = \min(P_{front}, P_{rear}) \tag{2}$$

The green light probability $P$ of each interval is shown in Figure 7.

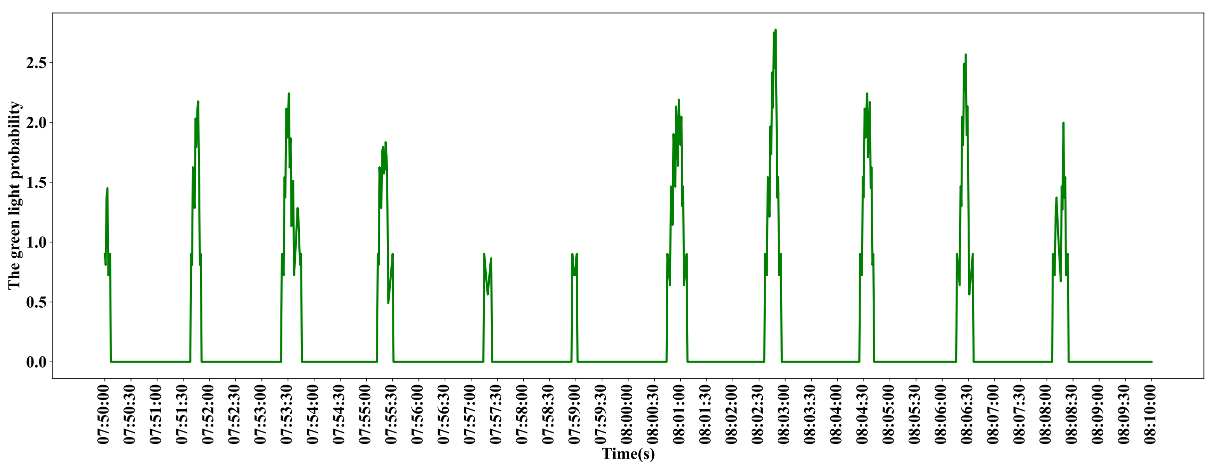


Figure 7. Interval green light probability.

As can be seen, the green light probability of each interval perfectly conforms to the passing time in Figure 4, and the green light probability of both sides of the interval is low and relatively high in the middle. This is exactly the effect pursued by the green light interval evaluation probability. When the time interval between adjacent vehicles before and after a car passes the stop line is smaller, the possibility of the green light at that time is higher. The greater the time interval between adjacent vehicles passing the stop line, the less likely it is to be green at that time. Since the experiment takes the smaller value of the corresponding interval between the front sliding interval and the rear sliding interval each time, individual abnormal data is eliminated after this operation.

## 5. CONCLUSION

This article proposes a method for calculating intersection signal timing based on electronic police passing data. The experiment uses a two-way sliding window to evaluate the probability of green light at each moment and takes the minimum value of the green light probability in the front sliding interval and the green light probability in the rear sliding interval. Finally, the obtained time series green light probability figure is basically consistent with the passing time figure, and the interference of individual abnormal data is also automatically eliminated, which has a certain practical value for solving the problem that signal timing cannot be obtained due to various reasons in practice.

The paper focuses on peak hours of traffic, and the signal timing in non-peak hours cannot be accurately evaluated, so the generalization capability is relatively weak. It is difficult to infer signal timing parameters when the intersection with variable phase and bus signal priority is encountered, and further research is needed in the future. In addition, the reasoning model can also be extended to multi-phase, and the timing parameters of intersection signals can be further accurate through the comparison of multi-phase vehicle passing time. At the same time, the control of abnormal data is clearer.

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