Research on Intelligent Signal Timing Model Optimization Based on Deep Learning Thought

Xin Zhang¹, YinghuaSong², DanLiu³

¹School of Safety Science and Emergency Management, Wuhan University of Technology, Wuhan, Hubei, 430000, China
²School of Safety Science and Emergency Management, Wuhan University of Technology, Wuhan, Hubei, 430000, China
³School of Safety Science and Emergency Management, Wuhan University of Technology, Wuhan, Hubei, 430000, China

*Corresponding author’s e-mail:1300491634@qq.com

Abstract. Aiming at the problem of traffic congestion and traffic jams at intersections, this paper proposes an optimized control system for automatic timing of traffic lights. Based on big data and deep learning ideas, the number of vehicles parked at intersections in a signal cycle and the signal cycle time are used to calculate the number of vehicles parked at intersections in the next cycle. According to the number of vehicles parked, the green time of the signal light is obtained, and an optimization model of the signal light is established. The model aims to maximize the traffic capacity at the intersection and minimize the delay time. Finally, the model is simulated by python, and the obtained data is compared with the data under the control of traditional signal lights.

1. Introduction
With the rapid development of society, urban traffic problems have become increasingly prominent, and daily traffic jams have become a daily life of people. Urban traffic lights are an important way to improve the operation of urban traffic. The traditional traffic light control system uses a relatively fixed traffic light timing scheme.[1] The traditional timing control algorithm obviously cannot adjust in time according to the changes in traffic flow. It is likely that there is no vehicle passing in the green light direction and there are many traffic jams in the direction of the red light. Resulting in a waste of a lot of transportation resources.[2]

There are many researches on transportation at home and abroad. Among all types of traffic accidents, rear-end collisions are the most frequent.[3] Therefore, traffic lights are very important in traffic. However, traffic lights make the speed of cars at the forks greatly reduced, so a reasonable design of the lights must be carried out.[4] This article has done two main tasks: (1) Obtain the number of vehicle stops and the green light time in the next cycle based on the number of vehicle stops and the time period of the signal lights to establish a traffic signal timing model; (2) Establish a traffic signal timing model and use python to optimize the obtained data and the original. The data are compared for conclusions.
2. Intelligent signal timing model based on deep learning

2.1 Intelligent signal light timing model flow
This article focuses on the timing of signal lights at single intersections, assuming that no pedestrians cross the red light, drivers are driving in accordance with traffic rules, the response time is basically the same, and the vehicle acceleration is also basically the same. Under the above assumptions, based on the time data under the control of previous cycle lights combined with deep learning ideas, a traffic signal timing model is established from the vehicle accumulation and data of the previous cycle, and the green signal ratio of this cycle is obtained. Use the same method to wait for the signal timing of the subsequent cycle.

2.2 Intelligent signal light timing model principle

2.2.1 Parameter setting. Set the following parameters:
- \(x_{k1}/x_{k2}\) — represents the number of straight/left lanes waiting for traffic on the kth intersection,Vehicle.
- \(x_{nk1}/x_{nk2}\) — represents the number of vehicles on the straight/left-turn lane at the kth intersection of the nth batch,Vehicle.
- \(v_{k1}/v_{k2}\) — represents the amount of passage on the straight/left road in the direction of the k intersection, Vehicle.
- \(C\) — represents the duration of the previous cycle, seconds.
- \(t_{min}\) — represents the minimum transit time of the intersection, seconds.
- \(t_{max}\) — represents the maximum transit time of the intersection, seconds.
- \(x_{min}\) — represents the corresponding car throughput at the minimum transit time, Vehicle.
- \(x_{max}\) — represents the corresponding car throughput at the maximum transit time, Vehicle.

2.2.2 Model establishment. The model in this paper adopts unilateral traffic mode, and the straight lane and left-turn lane can assist each other. When the traffic volume in the straight lane is excessive, some straight vehicles can use the left-turn lane to go straight, or when the traffic volume in the left-turn lane is excessive, some left-turn vehicles can use the straight lane to turn left. Therefore, under this kind of traffic mode, the number of traffic in the straight lane and the left-turn lane is approximately equal to \(v_{k1} \approx v_{k2}\). Then the traffic volume and travel time at the kth intersection:

A. When the green light of k-1 intersections is over, there will be 3 seconds of yellow light duration, and the right of passage will be handed over to the kth intersection. Before the k junction starts, there are \(x_{1k1} \) and \(x_{1k2}\):

\[
x_{1k1} \approx \frac{x_{k1} + x_{k2}}{2} + \frac{(\Sigma_{i=1}^{k} t_{i} + 3(k-1))v_{k1}}{C}
\]

\[
x_{1k2} \approx \frac{x_{k1} + x_{k2}}{2} + \frac{(\Sigma_{i=1}^{k} t_{i} + 3(k-1))v_{k2}}{C}
\]

B. When \(x_{1k1} \) (\(x_{1k2}\)) is all started, there are \(x_{2k1} \) (\(x_{2k2}\)) vehicles parked:

\[
x_{2k1} \approx \frac{(x_{1k1} - 1)t_{0}v_{k1}}{C}
\]

\[
x_{2k2} \approx \frac{(x_{1k2} - 1)t_{0}v_{k2}}{C}
\]

C. When \(x_{2k1} \) (\(x_{2k2}\)) is all started, there are \(x_{3k1} \) (\(x_{3k2}\)) vehicles parked:

\[
x_{3k1} \approx \frac{(x_{1k1} - 1)t_{0}^{2}v_{j1}^{2}}{C^2}
\]

\[
x_{3k2} \approx \frac{(x_{1k2} - 1)t_{0}^{2}v_{j2}^{2}}{C^2}
\]

D. And so on, when \(x_{(n-1)k1}(x_{(n-1)k2})\) is all started, there is \(x_{nk1}(x_{nk2})\). The car is parked:

\[
x_{nk1} \approx \frac{(x_{1k1} - 1)t_{0}^{(n_{k1} - 1)}v_{j1}^{(n_{k1} - 1)}}{C^{(n_{k1} - 1)}}
\]

\[
x_{nk2} \approx \frac{(x_{1k2} - 1)t_{0}^{(n_{k2} - 1)}v_{j2}^{(n_{k2} - 1)}}{C^{(n_{k2} - 1)}}
\]

E. When \(t_{0}v_{k1} \geq C\) (or \(t_{0}v_{k2} \geq C\)), it means that the parked vehicle gradually grows, at this time \(x_{k1} \approx x_{k2} = x_{max}\); when \(t_{0}v_{k1} < C\) (or \(t_{0}v_{k2} < C\)), the stopped vehicle gradually decreases. When
\( x_{nk1} < 1 \), the green light ensures that all vehicles before \( x_{nk1} \) (or \( x_{nk2} \)) pass, then there is:

\[
\begin{align*}
\frac{(x_{1k1} - 1)}{C_{(nk1-1)}} &< 1 \\
\frac{(x_{1k2} - 1)}{C_{(nk2-1)}} &< 1
\end{align*}
\]

\[
\begin{align*}
x_{nk1} &\simeq \frac{(x_{1k1} - 1)_{0}^{(nk1-1)}}{C_{(nk1-1)}} \\
x_{nk2} &\simeq \frac{(x_{1k2} - 1)_{0}^{(nk2-1)}}{C_{(nk2-1)}}
\end{align*}
\]

\[
\begin{align*}
nk1 - 1 > -\frac{\ln(x_{1k1} - 1)}{2n0v_{k1}} \Rightarrow nk1 - 1 = \left[ 1 - \frac{\ln(x_{1k1} - 1)}{ln(t_0v_{k1})} \right]
\end{align*}
\]

\[
\begin{align*}
nk2 - 1 > -\frac{\ln(x_{1k2} - 1)}{2n0v_{k2}} \Rightarrow nk2 - 1 = \left[ 1 - \frac{\ln(x_{1k2} - 1)}{ln(t_0v_{k2})} \right]
\end{align*}
\]

At the same time, the number of passing vehicles \( x_{nk1} \) and \( x_{nk2} \) at the kth intersections 1 and 2 are:

\[
\begin{align*}
x_{k1} &\approx x_{1k1} + x_{2k1} + \ldots + x_{(n-1),j,1} = \left( \frac{(x_{1k1} - 1)(1 - \frac{t_0v_{k1}}{C})}{1 - \frac{t_0v_{k1}}{C}} \right) + 1
\end{align*}
\]

\[
\begin{align*}
x_{k2} &\approx x_{1k2} + x_{2k2} + \ldots + x_{(n-1),j,2} = \left( \frac{(x_{1k2} - 1)(1 - \frac{t_0v_{k2}}{C})}{1 - \frac{t_0v_{k2}}{C}} \right) + 1
\end{align*}
\]

F. Therefore, the number of vehicles to be used in the 1st and 2nd channels of the kth intersection are:

\[
\begin{align*}
x_{k1} &\approx \left( \frac{(x_{1k1} - 1)(1 - \frac{t_0v_{k1}}{C})}{1 - \frac{t_0v_{k1}}{C}} \right) + 1 & t_0v_{k1} < C \\
x_{k2} &\approx \left( \frac{(x_{1k2} - 1)(1 - \frac{t_0v_{k2}}{C})}{1 - \frac{t_0v_{k2}}{C}} \right) + 1 & t_0v_{k2} < C
\end{align*}
\]

G. The total traffic volume and green letter ratio of the 1st and 2nd road junctions:

1) When \( x_{k1} < x_{k2min} \), the green light duration is \( t_{min} \), and the approximate number of roads in the first and second roads are:

\[
\begin{align*}
\frac{x_{k1}'}{C} &\approx x_{1k1} + \frac{tk_{1min}}{C}, \\
\frac{x_{k2}'}{C} &\approx x_{1k2} + \frac{tk_{2min}}{C}
\end{align*}
\]

2) When \( x_{max} \geq x_{k1} \geq x_{min} \) and \( x_{max} \geq x_{k2} \geq x_{min} \), the number of passes of the 1, 2 roads are:

\[
\begin{align*}
x_{k1} &\approx \left( \frac{(x_{1k1} - 1)(1 - \frac{t_0v_{k1}}{C})}{1 - \frac{t_0v_{k1}}{C}} \right) + 1 & t_0v_{k1} < C \\
x_{k2} &\approx \left( \frac{(x_{1k2} - 1)(1 - \frac{t_0v_{k2}}{C})}{1 - \frac{t_0v_{k2}}{C}} \right) + 1 & t_0v_{k2} < C
\end{align*}
\]

After the longest \( t_{min} \), the number of remaining vehicles is:

\[
\begin{align*}
x_{k1} &\approx x_{k1} - x_{min}, \\
x_{k2} &\approx x_{k2} - x_{min}
\end{align*}
\]

Re-allocation time: \( t_{k1}' = \frac{x_{k1} t_{min}}{x_{min}}, t_{k2}' = \frac{x_{k2} t_{min}}{x_{min}} \)

Then 1,2 road green light is: \( max(t_{min} + t_{k1}, t_{min} + t_{k2}) \).

3) When \( x_{max} < x_{k1} \), the green light duration is \( t_{max} \), and the road traffic of 1, 2 is
approximately $x_{max}$.

### 2.2.3 Objective function.

1. The total period duration in the period is: $C_n = t_{east} + t_{south} + t_{west} + t_{north} + 12$

2. Total traffic during the period of the intersection: $x = \sum_{k \in \{e,s,w,n\}} (x_{k1} + x_{k2})$

### 3. Simulation and comparative analysis

#### 3.1 Data collection

A set of numerical values is simulated according to the rules of the daily life of urban residents as shown in Figure 1. In the morning and evening rush hours, vehicle traffic at various intersections in the city increased significantly. In the rest of the time, the traffic volume of urban vehicles remained basically stable.

#### 3.2 Fixed-time signal light timing model simulation

Fixed timing data under real traffic signal control by python simulation, as shown in Figure 2. In the figure, the abscissa indicates the time change of the traffic light, the vertical coordinate indicates the traffic volume of the vehicle, the blue line indicates the throughput of the vehicle traveling south, the orange color indicates the throughput of the vehicle traveling west, and the gray indicates the throughput of the vehicle traveling north. Indicates the passing vehicle that drives the vehicle eastward. It can be seen from the figure that during the peak period of commuting, vehicle traffic is obviously congested, and the vehicle traffic rate is low.
3.3 Intelligent signal light timing model simulation
Optimize the traditional signal data through the intelligent signal timing model to get a new set of data, as shown in Figure 3. By observing Figure 3, it can be clearly seen that the number of vehicles passing through during the peak hours of commuting has increased significantly.

![Figure 3: Time and vehicle traffic after traffic signal optimization](image)

3.4 Comparative analysis
Through the above analysis of vehicle traffic rates under the control of traditional traffic lights and intelligent traffic lights, we can find that when the vehicle stops a lot, especially during the rush hour, under the control of traditional traffic lights, the vehicle passing rate is significantly lower. It can be found that when the vehicles are parked more, especially during the peak hours of commuting, under the control of traditional traffic lights, the vehicle passing rate is significantly lower. And the optimized intelligent traffic signal model is about 2.5 times that under the control of traditional traffic lights. At night or when there are fewer vehicles parked, intelligent traffic lights can save the waiting time of the vehicle and improve the efficiency of vehicle passing.

4. Conclusion
This article mainly intelligently optimizes the traffic lights at intersections, establishes an intelligent optimization model for traffic lights, and uses python for simulation. Through comparative analysis, it can be seen that the intelligent optimization of traffic lights can alleviate certain pressure on the traffic system, save people's waiting time and improve traffic efficiency.

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