ARTIFICIAL NEURAL NETWORKS FOR ADAPTIVE MANAGEMENT TRAFFIC LIGHT OBJECTS AT THE INTERSECTION

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Key nodes of the road network of the city are the intersections. It is the greatest losses that are observed as the use of the roadway. Analysis of traffic conditions shows that the intensity of traffic on the approaches to the crossing is not constant, but subject to change during the day with a peak period (one or two). Furthermore, even with constant intensity, the movement of vehicles is random; there are variations in the number of cars approaching the intersection for the same periods of time.

If slow change of the traffic the optimal duration of the cycle and phases, calculated for the conditions of the peak period for the rest of the time of day are not optimal, are typically too large, leading to unnecessary support for transport.

In this regard, more actively developed various systems that adaptively take into account changes in traffic flows. One of the directions of development of such systems is the use of neural network approach to the management tasks. To implement adaptive management the authors suggest the following model of the adaptive system.

With video detectors read off on the state of traffic flow. Based on this information, the software module calculates the intensity of traffic flow $q$. In the operation of the intensity is continuously fed to the prediction module, where as a result of the module is the future value of intensity. Based on this value, calculated the length of the new traffic light cycle.

With strict regulation length calculation traffic light cycle is in the process of setting controller. The proposed model of a set of initial data for the calculation will be updated at iteration of the traffic light cycle.

Keywords: traffic light, adaptive steering, simulation, neural network, MLP

1. Introduction

The main road junctions of a city are crossroads. There are the greatest losses in use of the roadbed at the crossroads. The analysis of traffic conditions shows that the intensity of transport streams that approach to the crossroads is not constant, and subject to changes during the day with the strongly pronounced peak periods (one or two). Besides, even on condition of constant intensity, traffic has chance character and there are fluctuations of quantity of the cars approaching to a crossroad for the identical periods of time.

At slow change of the intensity optimal duration of a cycle and the phases, calculated for conditions of the peak period, for other time of the day appears non-optimal, as a rule, too long, that causes unwarrantable transport delays.

Rigid program regulation is not able to take into account short-term casual fluctuations of quantity of the cars approaching to a crossroad. In this connection various systems, which allow considering changes in transport streams are developing more and more actively. One of the directions of development of such systems is application of neural networks for the decision of a problem of regulation [1].

2. Setting of Task

The purpose of the present work is the analysis of the possibility to create a system of the adaptive regulation using neural networks for the forecasting the future traffic intensity and calculation of phases
of work traffic lights object (TLO) during the following moment of time. At adaptive control transport stream forms, mainly, not under the influence of regulation factors, but under the influence of other factors which are not connected with regulation at the crossroad. The main task of adaptive regulation, in this case, is to apply to the formed streams of such regulation, which would give minimum losses.

Adaptive control by the TLO represents the concept in which definition of intensity of transport streams on the way to the crossroad is made by means of sensors. On the basis of this data it is necessary to construct the forecast about crossroads work the next moment of time and to insert amendments into duration of phases of traffic regulations. Thus, the calculation of optimal duration of phases of work of a traffic light is made on the basis of the found volumes of the traffic. It allows in a mode of real time reacting to the change of volumes of vehicles that allow diminishing hold-ups of vehicles, decrease queues, and also to cut down the time taken to drive by the traffic lights.

Functioning of any adaptive system is strongly connected with a good subsystem of detection of characteristics of a transport stream. Reliability and accuracy of decision-making at adaptive regulation cannot be reached without enough qualitative system of detecting of transport.

In the present work is supposed to use as detectors of transport video detectors. Various algorithms of digital processing of images and computer sight allow today finding out vehicles enough precisely and to measure characteristics of a transport stream. In the aggregate with application of neural networks for forecasting intensity of a stream the following moment of time, reception of minimization of losses of vehicles is possible (it is possible to minimize quantity of undetected vehicles).

3. The Proposed Method of Solving the Problem

To implement adaptive management the authors suggest the following model of the adaptive system (Fig. 1).

![Figure 1. Model adaptive control](image)

With video detectors read off on the state of traffic flow. Based on this information, the software module calculates the intensity of traffic flow $q$. In the operation of the intensity is continuously fed to the prediction module, where as a result of the module is the future value of intensity. Based on this value, calculated the length of the new traffic light cycle.

With strict regulation length calculation traffic light cycle is in the process of setting controller [2]. The proposed model of a set of initial data for the calculation will be updated at iteration of the traffic light cycle.

Next is a mathematical description of the implementation of adaptive management based on this model.

Denote the traffic intensity for each transport stream (TS) $q_{i}$. Also for the calculation gives the minimum cycle time management for the transition pedestrians $C_{\text{min}}$. In the literature [3] recommended that $C_{\text{min}} > 20$ sec.
Then set the minimum duration of the cycle based on the recommended values of the load factor:

\[ t_{F1} = \frac{q_1 \cdot C_{min}}{q_{n1} \cdot x_{lim1}} \]  

(1)

where

- \( q_1 \) – the traffic of the main directions for the lanes, cars per second,
- \( q_{n1} \) – saturation flow for a given traffic flow, c/s,
- \( C_{min} \) – the minimum duration of the cycle to move pedestrians, second,
- \( x_{lim1} \) – limit load factor for the main line.

The duration of the "green signal" for the Secondary:

\[ t_{F2} = \frac{q_2 \cdot C_{min}}{q_{n2} \cdot x_{lim2}} \]  

(2)

where

- \( q_1 \) – the traffic of the secondary directions for the lanes, cars per second,
- \( q_{n1} \) – saturation flow for a given traffic flow, c/s,
- \( C_{min} \) – the minimum duration of the cycle to move pedestrians, second,
- \( x_{lim1} \) – limit load factor for the secondary line.

Thus, in calculating the value of time for each phase, the controller can send the new values to adjust the movement. Predicting changes in intensity with the help of a neural network allows calculating in advance and refining the values of the durations of phases of regulation, to smooth fluctuations in intensity and hence reducing the queues at the intersection.

As a neural network to predict the intensity of traffic flow \( q \) was chosen multilayer perceptron with the following structure: the input elements 400, 100 – hidden, 1 – output (Figure 2).

As the activation function of hidden neurons used sigmoid function, output – linear. Neural network training was carried out on these data, which are shown on Figure 3. The window size is selected...
400 values. The total square error for training is 0.01. Since the intensity of traffic flow undergoes diurnal variations, the training was formed three sample data: morning, afternoon, evening. At each of the samples had been trained by his copy of the neural network. More trained network predicted the intensity of traffic flow in the next moment in their daily range. This approach yielded significantly better results forecasting.

![Figure 3. Work module prediction](image)

Also separately trained and predicted the intensity of each direction. Figure 4 shows a diagram of an intersection indicating the direction.

![Figure 4. Architecture crossroads](image)

Each neural network was trained separately for each time interval.

Forecast of daily fluctuations in the intensity of traffic flow accurate and equal to a given error. In turn, the current prediction error value of the intensity was equal to 16%. This is due to the fact that traffic flow is a chaotic process with many parameters, it is influenced not only the daily movement of vehicles, but such random factors as accidents, drives the police car and ambulance enabled alarms, work nearby traffic light objects.

After unit testing, forecasting and video detection to determine the effectiveness of the adaptive approach in conjunction with these modules was carried out simulation of the intersection in the mode of adaptive management based on forecasting and on-line rigid regulation. The results are shown on Figures 5-6.
Figure 5. The difference in the average length of queues at the crossroads in the morning

![Figure 5](image1)

<table>
<thead>
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<th>Queue</th>
<th>Adaptive</th>
<th>Strict</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>19.586</td>
<td>26.046</td>
</tr>
<tr>
<td>#3</td>
<td>17.141</td>
<td>20.362</td>
</tr>
<tr>
<td>#1</td>
<td>20.881</td>
<td>25.609</td>
</tr>
<tr>
<td>#2</td>
<td>20.795</td>
<td>26.168</td>
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</table>

Figure 6. The difference in the average length of queues at the intersection in the afternoon

![Figure 6](image2)

<table>
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<tr>
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</tr>
</thead>
<tbody>
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<td>26.638</td>
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<tr>
<td>#3</td>
<td>20.514</td>
<td>22.695</td>
</tr>
<tr>
<td>#1</td>
<td>20.574</td>
<td>29.59</td>
</tr>
<tr>
<td>#2</td>
<td>21.154</td>
<td>27.07</td>
</tr>
</tbody>
</table>

Figure 7 shows the variations of one of the queues at the intersection for an hour of modelling adaptive and rigid regulation. You can see that at high loads at a crossroads, as in the case of time 17:00-18:00 (end of the day), with adaptive management is achieved by a significant decrease in the queue, and as a consequence, the waiting time at the intersection. Also worth noting that at low congestion on the crossroads, adaptive management shows the results of an average similarly strict control.

![Figure 7](image3)

Figure 7. Graphs of changes in the queue at the crossroads
4. Conclusions

There are various algorithms for operation of the adaptive control. The most simple and commonly include the possibility of changing the duration of signal traffic light cycle, depending on the state of traffic flow at a given time, in this particular traffic light cycle. In the proposed approach in this paper the situation is projected to one or more cycles of traffic lights ahead, which provides control for more complex criteria, such as minimum loss at the crossroads, including stops and delays. Application of this approach for the prediction of neural networks, with their capacity to synthesize data and prolong the results, allows for adaptive management to take into account fluctuations in the intensity of traffic.

As a result the offered approach to realization of the adaptive regulation at a crossroads will allow raising the quality of work of TLO in comparison with steering using rigid optimum duration of phases.

References