Application of Artificial Neural Networks for Forecasting of Characteristics of Transport Streams and Adaptive Regulation at Crossroads.

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Abstract

This is a continuation of a research on adaptive management of the traffic light object. It is known that for successful usage of adaptive regulation it is necessary to watch characteristics of a transport stream and to operate phases on various algorithms [8]. Application of neural networks for forecasting of characteristics of a stream will allow using more difficult and effective control algorithms.

1 Introduction

The main sites of a high system of a city are crossroads. On them the greatest losses as usage of a road are observed. The analysis of traffic conditions shows that intensity of transport streams on approaches to a crossroads are not constant, and are subject to changes within days with the strongly pronounced peak periods (one or two). Besides, even at constant intensity, movement of cars has casual character; there are oscillations among the cars approaching to a crossroads for the identical periods of time.

At slow change of intensity optimal duration of a cycle and the phases, calculated for conditions of the peak period, for the rest of the time of days appear non-optimal, as a rule, too big, leading unjustified transport delays.

Rigid program regulation is not capable to consider short-term casual fluctuations among the cars approaching to a crossroads. Recently various systems which allow considering changes in transport streams more and more actively develop. One of directions of development of such systems is application of neural networks for the decision of a problem of regulation [6].

2 Problem statement

The purpose of the given work is the analysis of possibility of creation of system of the adaptive regulation using neural networks for forecasting of the future intensity of movement of transport streams and calculation of phases of work traffic lights object (TLO) during the following moment of time. At adaptive regulation formation of a transport stream is carried out, basically, not adjusting factors, and under the influence of other factors not connected with regulation at a crossroads. The problem of adaptive regulation, in that case, is reduced to imposing on the generated streams of such regulation which would give a minimum of losses.

Adaptive control by the TLO represents the concept in which by means of sensors definition of intensity of transport streams on the way to a crossroads is made. On the basis of this data it is necessary to construct the forecast about crossroads work during the following moment of time and to bring updating in duration of phases traffic regulations. Thus, there is a calculation optimum duration of phases of work of a traffic light on the basis of the found out volumes of the traffic. It in a mode of real time allows to react to change of volumes of vehicles that leads to reduction of a delay of vehicles, reduction of turns, and also to waiting time reduction in turn.

Work of any adaptive system is critically connected with a good subsystem of detection of characteristics of a transport stream. Reliability and accuracy of decision-making on adaptive regulation cannot be reached without enough qualitative system of detecting of transport [7].

In the given work use as detectors of transport of system of the detecting using video detectors is supposed. Various algorithms of digital processing of images and computer sight allow to find out precisely enough for today vehicles and to measure characteristics of a transport stream. In aggregate with application of neural networks for forecasting of intensity of a stream during the following moment of time, reception of minimization of losses of vehicles is possible.

3 Approaches for forecasting of intensity of transport streams

A difficult observable time series - finite and digital set of ranged data of the numerical nature of a uniform informational rank [5]. Movement of vehicles in time to a crossroads represents a difficult observable time series. This time series depends on set of factors and changes eventually very strongly. In traffic fluctuations as on the long periods of time – winter, summer, on averages – within days of week, and on short – during the day are observed.

For reception of values of the given time series it is offered to use video detectors as gauges of a transport stream. On the basis of the analysis of images received they carry out measurement of intensity of a transport stream [4]. Algorithms of digital processing of frames allow finding time correspondence between detected objects from a frame to a frame. Time identification of the selected areas of the map is thus provided and the appropriate information on objects in observable allowed band, namely, a trajectory, speed and a movement direction is defined. From the specified parameters there is an intensity of transport streams necessary for forecasting.

Intensity of a transport stream is defined as follows:

$$q = \frac{n}{t},$$

where

n – quantity of vehicles cleared road section in time t.

The transport stream can be characterized three key parameters: intensity q, average speed V and density D. These parameters are linked by the main equation of a transport stream: q = DV.

Graphically this equation represents the main diagram of the transport stream which general view is shown on fig. 1.

For adaptive regulation and calculation of duration of phases forecasting of a time series – dependences of intensity of movement on time is necessary.

For forecasting of such time series it is possible to use neural networks. The forecasting task is formalized through the pattern recognition task. The data about a predicted variable for some period derivates an image which class is defined by value of a predicted variable in some instant outside of the given interval, that is a value through a predication interval.

Collection of known values of a time series derivate the learning sampling which dimension equals m. For forecasting of time rows the method of "a sliding window" is used [2]. It is characterized by length of a window n which equals to quantity of units of the time series simultaneously submitted on a neural network. It defines structure of a neural network which consists from n distributive neurons and one output neuron.

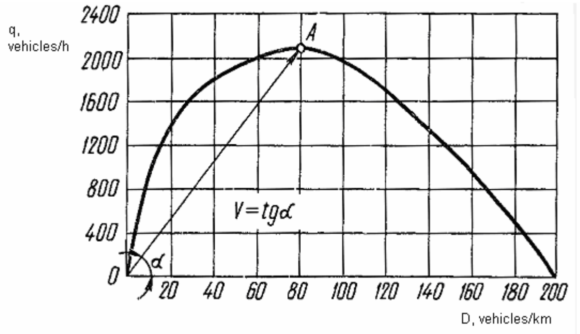

Figure 1: The main diagram of a transport stream.

Such model corresponds to linear auto-regression and is described by following expression:

$$\overline{x(n)} = \sum_{k=1}^{n} \omega_k x(p-n+k-1),$$

where $\omega_k, k=\overline{1,n}$ — the synaptic weights of the network; $\overline{x(p)}$ — estimation of value of a time series $x(p)$ in time p.

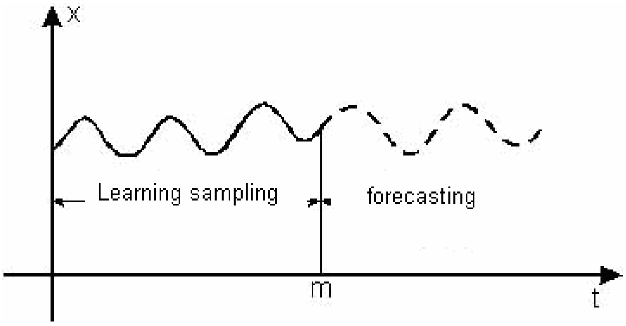

Figure 2: Forecasting of a time series.

The forecasting error is defined, how $e(p) = x(p) - \overline{x(p)}$.

Thus, for training of a neural network to forecasting sampling of known terms of the series is used. After training the network should predict a time series on a look-ahead period.

Having received intensity of a transport stream on the following period for TLO it is necessary to calculate new duration of phases.

Duration of «a green signal» for a mainstream:

$$t_{T1} = \frac{q_1 * C_{\min}}{q_{n1} * x_{\lim 1}},$$

where

q_1 – intensity of movement of a mainstream for the given lane, vehicles in a second,

q_{n1} – stream of saturation for the given transport stream, vehicles/s,

C_{min} – the minimum duration of a cycle for transition of pedestrians, second,

x_{lim1} – limiting value of a loading factor of a lane for a mainstream.

Duration of «a green signal» for a direction of secondary direction:

$$t_{T2} = \frac{q_2 * C_{\min}}{q_{n2} * x_{\lim 2}},$$

where

q_2 – intensity of movement of a stream for the given lane, vehicles in a second,

q_{n2} – stream of saturation for the given transport stream, vehicles/s,

C_{min} – the minimum duration of a cycle for transition of pedestrians, second,

x_{lim2} – limiting value of a loading factor of a lane for a stream of the second direction.

Having received for crossroad new values for regulation phases it is necessary to transfer them to the controller. As neural networks allow achieving high degree of correlation of the forecast with the real data, the received values of duration of phases will allow generating the schedule of switching of phases on some time interval forward. With reduction of an error of the forecast, crossroads work will adapt as much as possible under existing road conditions.

For forecasting of time series it is possible to use various types of neural networks [2]:

- The Linear neural network
- The Heterogeneous neural network (sigmoid activation function, logarithmic function of activation)
- Recurrence neural networks (model of Elman, Jordan's model)

Proceeding from [7], as transport stream in time – the difficult time series, the most preferable architecture for forecasting heterogeneous neural networks with logarithmic function of activation and recurrent on the basis of model of Elman [1] and Jordan [3] look. Results of forecasting by neural networks on the basis of the resulted architecture allow approximating difficult time series with fine precision.

3 Conclusions

There are various algorithms of functioning of adaptive regulation. The most simple and widespread provide possibility of change of duration of signals of a traffic light cycle depending on a state of a transport stream at present time, in the given concrete cycle. In the approach offered in given operation the situation is predicted on one or the several traffic light cycles forwards that provides handle by more difficult criteria, such at least losses at a crossroads, including stops and delays. Application in the given approach for forecasting of neural networks, with their possibilities on generalization of the data and prolongation of results, allows to consider at adaptive control of oscillation of intensity of a transport stream as during the durable periods of time, a time of year, and during daily changes (fig. 2).

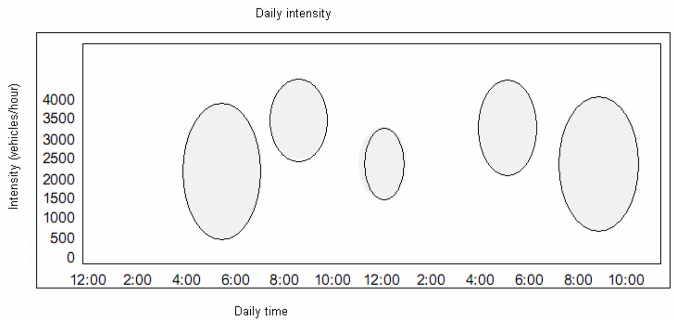

Figure 3: Daily oscillations of intensity of a transport stream.

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

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