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ROAD TRAFFIC PARAMETERS PREDICTION IN URBAN TRAFFIC MANAGEMENT SYSTEMS USING NEURAL NETWORKS

Summary. The article reviews neural networks applications in urban traffic management systems and presents a method of traffic flow prediction based on neural networks. It describes neural networks features, which allows them to be used to solve, optimisation tasks involved in designing optimal road traffic control strategies in urban traffic systems (UTC systems). In presented examples neural networks estimate road infrastructure throughput and length of waiting vehicles queue.

PREDYKCJA PARAMETRÓW RUCHU Z WYKORZYSTANIEM SIECI NEURONOWEJ W INFORMATYCZNYCH SYSTEMACH ZARZĄDZANIA RUCHEM MIEJSKIM

Streszczenie. Artykuł przedstawia przegląd zastosowań sieci neuronowych w systemach zarządzania ruchem miejskim oraz propozycję metody predykcji natężenia ruchu opartą o sieci neuronowe. Na wstępie opisane zostały cechy sieci neuronowej, które mogą być przydatne w rozwiązywaniu zadań optymalizacji związanych z opracowywaniem optymalnych strategii sterowania w miejskich systemach sterowania ruchem (UTC systems). W przedstawionych przykładach sieci neuronowe wykorzystane zostały do obliczania przepustowości dróg oraz długości kolejki pojazdów.

1. INTRODUCTION

Nowadays, traffic congestions are most cities growing problem. Silesian Agglomeration with Katowice despite continuing modernisation of road infrastructures (also faces traffic congestion problems)/(is no exception). Rapid increase of number of vehicles causes rapid increase of road traffic intensity. Due to limited capacity of urban transportation infrastructure in times of growing traffic intensity many difficulties occur in vehicles circulation. The road throughput and traffic regularity decreases, travelling time grows and what is more the vehicles maintenance costs increase.

The Urban Traffic Management System (UMTS) partially solves the above problems. The system utilizes fast and efficient methods for optimalisation of road traffic control strategies. It collects the information about road traffic from various sources and allows processing it and utilizing it to improve traffic control. Improved traffic control leads to increase of traffic security, increase of road throughput and reduction of emitted pollutions.

The example of modern traffic management system scheme is presented on Fig. 1. Such systems are being developed for over 50 years. First system of this type served in Toronto [1]. Till recently many types of management system models were designed [4, 5, 6] however due to high complexity and dependency on local conditions the universal system model was not found.

Due to this most of proposed solutions focus on a particular system module or a specific algorithm.

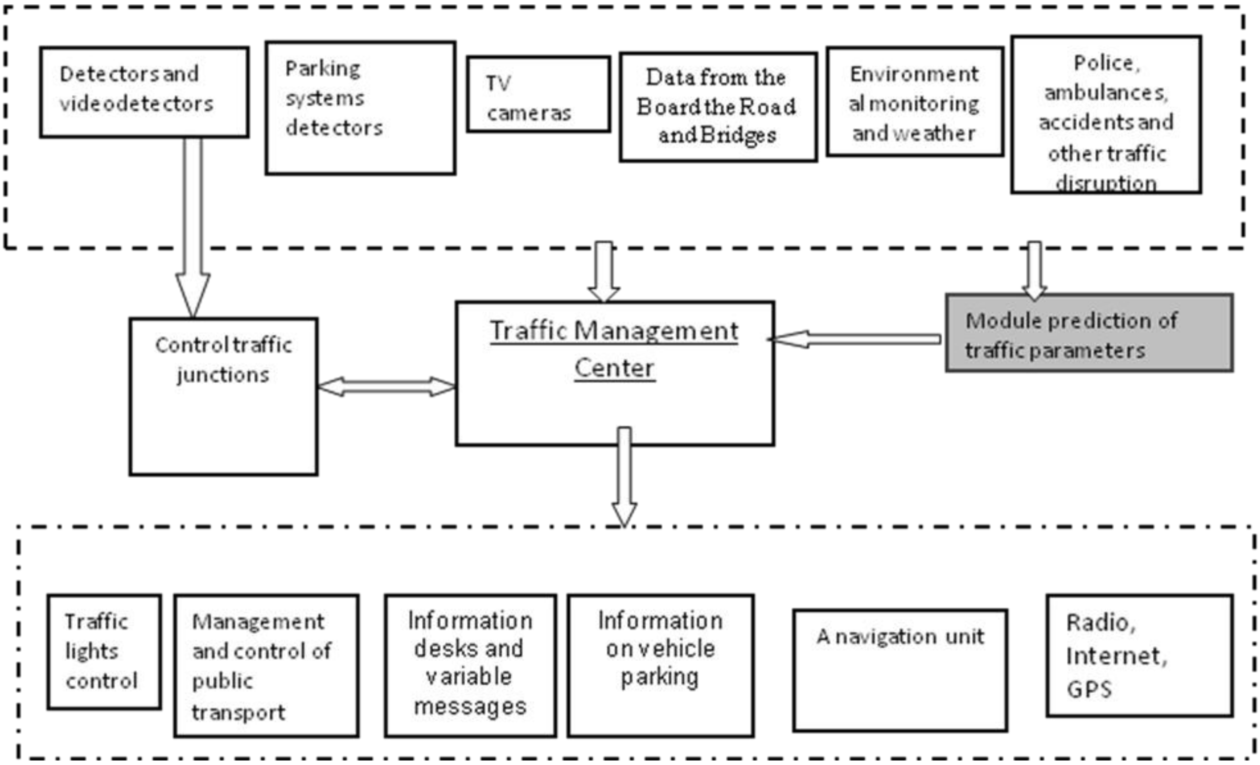


Fig. 1. Traffic management system scheme
Rys. 1. Schemat systemu zarządzania ruchem

Modern management systems utilise telecommunication technologies, computer science methods and transportation management methods (schemes). Such systems are called Intelligent Transportation Systems (ITS). Name ITS was accepted on the first world ITS congress held in Paris in 1994. Later, in United States, ITS systems requirements were specified. Final ITS specification version was published in January 2007.

Traffic management systems should consider the following elements:

- existing road infrastructure,
- prediction of changes in traffic intensity for the monitored area,
- prediction of changes in traffic due to changes in traffic organization caused by for example: mass events, road accidents and other unusual incidents disturbing traffic fluency,
- roads and streets throughput between the road junction,
- road junctions throughput,
- level of traffic security,
- influence of traffic organization changes on group of different road users, with special consideration of public transport users,
- investments and maintenance costs of urban traffic management systems,
- traffic capacity of the monitored area.

Parameters describing traffic fluency and infrastructure throughput can also be taken into consideration in optimalisation of traffic control and management. Traffic fluency depends on the following parameters:

- time losses on each road junction,
- number of vehicles halts,

- vehicles queues lengths at road junctions,
- distribution of time losses (e.g. standard deviation),
- distribution of vehicle queues lengths.

Recently, very often, traffic management algorithms employ artificial intelligence methods such as fuzzy logic [1], genetic algorithms [2] or neural networks [3, 4].

The neural networks features, which could be used/implemented/employed for computations in various elements and modules of intelligent urban traffic management systems, are presented below:

- classification and recognition – the network through learning process starts to recognise basic pattern features and basing on the achieved information classifies the patterns,
- approximation – neural network can approximate multivariable functions,
- association – the network remembers group of patterns in such a way that after comparing its elements with new incoming patterns it is able to find the most similar ones,
- data grouping – the network detects similarities existing in processed data,
- prediction – prediction of future realizations or statistic features of stochastic process.
- low noise sensitivity in the group of data – in classical software a single data error usually results in an erroneous output, the network, on the contrary is able to discard wrong/strange/incorrect/(out of order) data,
- ability to recover from partial network damages, e.g. removal of few neurons or some neurons interconnections (in case of hardware solution).

2. EXAMPLES OF NEURAL NETWORKS APPLICATION IN TRAFFIC CONTROL AND MANAGEMENT SYSTEMS

2.1. Assumptions

The most commonly used neural network feature is the ability of prediction of various road traffic parameters, such as: throughput, intensity and length of vehicle queues, basing on historical data. 1st generation traffic control systems, e.g. TRANSYT utilize set of control strategies, which parameters were determined offline basing on the particular time of the day. 2^{nd} generation traffic control systems perform online optimalisation based on predicted changes in traffic intensity, 5-10 minutes, before employing new control strategy, e.g. RTOP (constant period). 3rd generation traffic control systems allows also online optimisation but basing on analysis of traffic intensity monitored 3-6 minutes before employing new control strategy (variable period). Finally in 4th generation systems the control plans are changed with the change in traffic intensity and not as in other cases according to the previously made predictions (or if needed according to the predictions done in few seconds period).

SCOOT is the example of such system. To predict the length of vehicle queue on next road junction it utilizes traffic intensity profiles (time losses and vehicles halts) which are updated each few seconds. Through the variation of splits, offsets and analysed period lengths the vehicles queue length is minimized.

In three level, adaptive urban road junction networks control system UTOPIA-SPOT the optimalisation is based on thorough estimation and prediction of traffic streams. The estimation and prediction is done with 3 types of detectors.

The highest level of the system is UTOPIA, which is responsible for monitoring, performing diagnostics and supervision over optimalisation of control of network of road junctions. Next layer is the superior controller SPOT and the lowest layer, the local controller.

2.2. Determination of the length of the queue at the junction output with use of neural networks

The authors assumed, that the queue length in time t+1+j can be described by the following function:

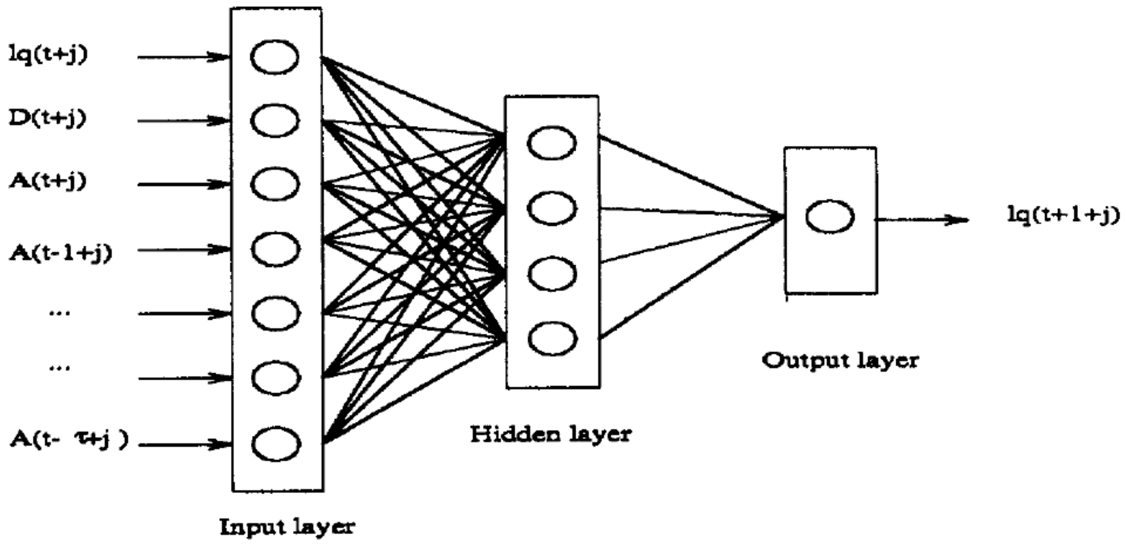
$$lq(t+1+j)=f(lq(t+j), A(t+j), A(t-1+j),..., A(t-\tau+j), D(t+j)) \quad (1)$$

where:
lq(t+j) – length of queue at juction input in time t+j,
D(t+j) – intensity at junction output in time t+j,
A(t+j) – intensity at junction input in time t+j,
A(t-1+j) , ..., A(t-τ+j) – intensity at junction input in precedeing time period t,
t – intitial value of time window H,
j – length of time window.

Variables lq(t+j), D(t+j), A(t+j), A(t-1+j),..., A(t-τ+j) are neural network input nodes.

Function value (output of the neural network) - lq(t+j+1) is a predicted length of the queue in time t+j+1.

Neural network acts as a multi variable function approximator. A schematic of neural network used to determine the queue length is shown on Fig. 2 [3].



Rys. 2. Neural network predicting queue length schematic
Rys. 2. Schemat sieci neuronowej do predykcji długości kolejki

2.3. Using neural networks to estimating capacity of multilane road – HCM2000 method variation

This time the neural network was used to estimate the throughput of multi lane road. It was assumed that such throughput depends on minimal and maximal number of lane changes, the speed of non disrupted vehicles flow, length of investigated road segment and number of lanes. The structure of the neural network is presented on Fig. 3 [4].

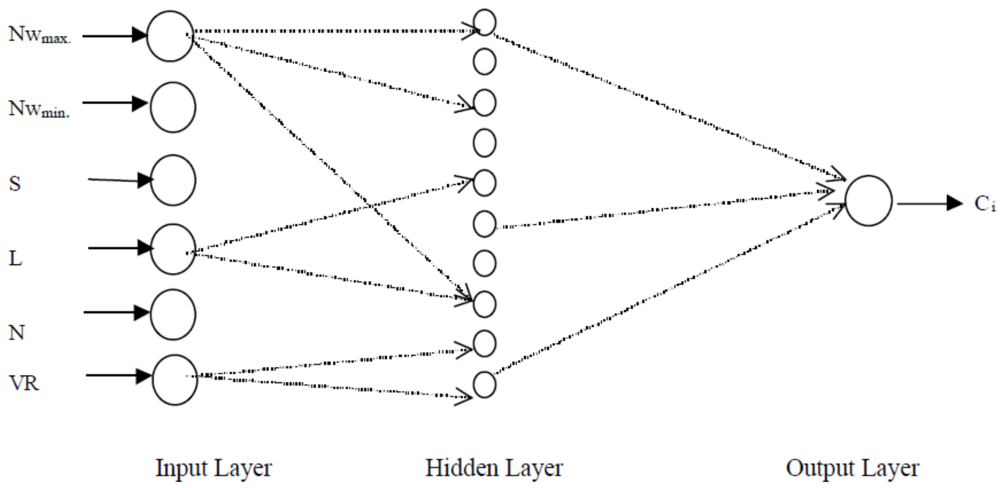


Fig. 3. Neural network estimating capacity schematic
Rys. 3. Schemat sieci neuronowej do obliczania przepustowości

- Network input nodes

Nw_{min} – minimal number of lanes changed,
Nw_{max} – maximal number of lanes changed,
S – the speed of not disrupted vehicles flow,
L – the length of weaving segment in meters,
N – number of lanes,
VR – coefficient representing the relation between number of lane changes and maximal number of lane changes for the investigated road segment, takes values in the range 0,1-0,8.

- Output – c (capacity of weaving segment in pc/h).

2.4. Road traffic parameters prediction module

The prediction module place in urban traffic management system is filled in grey colour in Fig. 1. To predict traffic intensity it employs neural networks.

The following assumptions were defined:

- road traffic parameters are measured in between equal time periods thus can be regarded as time series,
- if the values in the series are following a cyclical pattern then basing on this pattern one may predict future, not yet measured, values,
- time window - historical data which could be used for prediction of next series value,
- short-term prediction – one or few next values,
- long-term prediction – considers longer measurements periods.

The neural network allows achieving fast short-term prediction (5s), which strongly impacts the way of controlling the urban traffic.

It was assumed that traffic intensity in the investigated segment is similar on Monday, Tuesday, Wednesday and Thursday. On Saturday due to shopping the traffic intensity is different than on Sunday. It can be also observed that on Friday, due to weekend/(end of the week) migrations the distribution of road traffic is also different than on the other days of the week. Considering all these information 4 different neural networks, describing Saturday, Sunday, Monday and Friday were proposed.

Twenty-four hours cycles (day cycles) were divided into time windows of length 60 second with step 5 seconds what gives 12 values. The teaching cycle will comprise 1440 (24x60) time windows, containing 12 values each. Draft scheme of the proposed neural networks is presented on Fig. 4.

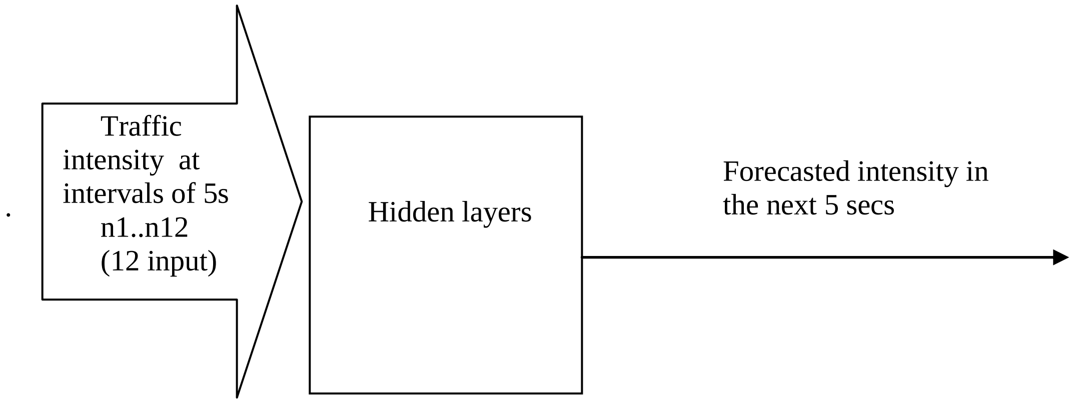


Fig. 4. Draft scheme of the proposed neural networks
Rys. 4. Poglądowy schemat zaproponowanej sieci neuronowej

3. CONCLUSIONS

Neural networks allow achieving very good short-term prediction results. Thus it can be employed in such traffic control and management systems which to optimise the control strategy need to consider recently/online measured parameters (e.g. intensity, queue length). Further research concerning utilisation of neural networks in traffic systems will be performed with use of the simulation model developed for the particular area in Katowice, in Vissum and Delphi environments. The research results will be presented in next article.

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