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APPLICATION OF SMART ROAD INTELLIGENT TRAFFIC CONTROL AS A DETERMINANT OF REDUCTION OF CO2 TO THE AIR

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ABSTRACT

The article presents a possibility of reduction of CO2 emission to the air through fluent traffic control within an urbanized area. Application of intelligent traffic control, except for reduction of pollution to the environment may also increase fluency of traffic within road junctions and partially solve the issue of economics and organisation of city transport. The presented method may be applied to a cause and effect analysis of bottlenecks occurring within a city. We will also present an analysis for future development research in which it will be possible to propose other methods of supporting city traffic control i.e. fuzzy sets or neural networks, hybrid methods and heuristics. Each, even the smallest improvement of vehicles passage in time perspective will ensure great benefits both to the environment and for our organization.

KEYWORDS

city logistics, system, transport

INTRODUCTION

Recently a problem of very high emission to the air of carbon dioxide and other harmful elements has become one of the vital issues of contemporary civilisation. The article focuses mainly on presentation of a method of reduction of emission of harmful substances to the air through making traffic of vehicles more fluent in an urbanized area. The most important element which improves traffic control is – and in principle are – traffic light signals. Time of rides, stops indicated by them, to a significant extent affect a flow

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of traffic, and also a degree of emission of harmful substances in city centres. Too limited traffic within road junctions impacts also economics and organisation of city transport [2].
Their development starts in 1868, when in London at crossroads of *New Palace Yard* and *Bridge Street* the first traffic lights were installed. These were manually controlled devices equipped with a gas lamp which sent green or red light. Unfortunately, several days after the explosion of the device, its application was ceased.
New attempts to implement equipment that would control road traffic were taken before the First World War in the USA where the first electrically controlled traffic lights were installed. Another stage was application of three colour lights and soon after in 1928 the first signalling device which was able to manage traffic based on a horn signal.
In Poland the first traffic lights appeared in 1926 in Warsaw, however the first fully accommodative traffic lights were introduced in the seventies.
Presently, year by year, more and more advanced technological progress lets us accept a challenge consisting in controlling a much higher intensity of road traffic than in the seventies or the eighties.
Depending on a situation we may choose the following signalling systems: cyclic system, accommodative system and their subtypes.
All values of individual components may be obtained through an appropriately considered model of road traffic as detectors making it possible to follow all changes occurring during motion of vehicles do not exist yet.
Road traffic control systems designed in this way should aim at obtaining the smallest value representing traffic intensity which may be easily calculated:

$$Q = v * k,$$

where Q is traffic intensity expressed in [P/h], v – average velocity of vehicles at a given section expressed in [km/h], k – traffic density expressed in [P/km]. For an accordingly small Q we may obtain a satisfactory fluency of vehicle motion or their complete stop.
Road traffic intensity to a great extent depends on how the very road junction is designed (e.g. how many lanes to drive straight, to turn left and right, it has) and also on how traffic lights located near our epicentre of traffic operate as we cannot allow a situation in which a traffic jam appears just after passing a road junction due to installation of a cyclic system of traffic lights just after our road junction. In such a situation, standing in a traffic jam in a road junction, despite seeing the green lights, we will be forced to wait in the same place due to lack of a free space on a lane onto which we want to get.
One of the desired results which we expect from intelligent systems managing traffic lights is fluent, more economical motion of vehicles in crowded places. We do not want to lead to a situation where a road is empty but due to traffic lights vehicles from other directions will unnecessarily wait for the change of traffic lights. Therefore we will, whether we want this or not, more and more often implement systems based on artificial intelligence, among others based on evolution algorithms which are suitable for solving optimisation problems.

1. OPTIMISATION OF TRAFFIC LIGHTS MANAGEMENT

In the research part the task of traffic lights management has been carried out using the author's method originating from the methodology of genetic algorithms.
Applying genetic algorithms, each activity may be presented in a form of a task, and its solution may be understood as searching for a possibly "best" solution in a given space. Depending on a space size various methods of solving a given problem are used. In the event of small space, classic solutions such as:…… are usually sufficient. Bigger space

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requires application of specialist methods of artificial intelligence, among which genetic algorithms may be distinguished.

A creator of genetic algorithms is John Holland. An inspiration to create such a method is evolution and genetics, and more precisely processes occurring in them. Individuals in a given population are probability of solution of an occurring problem. These individuals are subjected to a process of reproduction. Mixing genetic materials originating from both parents results in creation of a new generation - progeny. In a natural environment a chance to survive is given only to the strongest ones who are best adjusted to the environment.

Genetic algorithms are applicable in optimisation tasks such as:

- indicating a route,
- scheduling,
- transport tasks,
- travelling salesman problem,

For each task a genetic algorithm consists of such elements as:

- creating a basic database of probable solutions,
- selecting a method of creating an initial population of probable solutions,
- building an appropriate function,
- selecting appropriate parameters.

The research presented in this article aims at optimisation of a passage through road junctions. We want to enable a highest number of vehicles to pass road junctions at a possibly shortest time under the condition that none of them will have to wait too long for its turn. The aim is to reduce emission of harmful exhaust fumes to the air and indirectly to increase traffic capacity on the roads through elimination of bottlenecks in city road junctions.

In the research the author's model of genetic algorithm has been applied.

Using the markers we define formally correctness of the chromosome:

$$V_{i,j,k}\left(K\left(g_{ij}g_{ik}\right) \;\; != 1\right) \qquad (1)$$

Markings:

i – is a group's number

j, k – are indices of elements in a given group (k different than j)

If on i- lane there are in a given moment a_i of vehicles (it may also be a coefficient of traffic intensity on a given lane, obviously appropriately rescaled). Then the function of evaluation of C chromosome for a group of vehicles g:

$$E(C) = \frac{\sum_{k=1}^{n} \min[V \cdot t_k - \sum_{i \in Gk} a_i] - 0.1 \cdot |V \cdot t_k| - \sum_{i \in Gk} a_i}{\sum_{k=1}^{d} t_k} \qquad (2)$$

Where:

V - coefficient of a vehicle's velocity,

t_k – time of green light on for a given group *k* of vehicles

n – a number of groups

d – a number of all vehicles in a road junction

a_i – coefficient of occurrence of a given group of vehicles (0;1).

If a model analysing traffic within several road junctions including interactions among many road junctions *W* is described by the equation of evaluation of correctness of a chromosome:

$$E(C)=\sum_{o=1}^{W} E_o(C) \tag{3}$$

After replacing the template (2) to the template (3) we finally obtain the equation:

$$E(C)=\sum_{o=1}^{W} \frac{\sum_{k=1}^{n} \min[V \cdot t_{k,o} \sum_{i\in Gk,o} a_{i,o}] - 0.1 \cdot \left| \cdot V \cdot t_{k,o} \right| - \sum_{i\in Gk,o} a_{i,o}}{\sum_{k=1}^{d} t_{k,o}} \tag{4}$$

Finally we select such a cycle which generates the biggest continuity of traffic maximizing a value of the function of evaluation of the chromosome. We should add here that in the event of combining dependent road junctions we have an example of a sequential system which may be described successfully by a model combining fuzzy logic with a theory of mathematical evidence [1].
Selecting a priority of driving through a road junction is carried out using a classifier of impact force. A model of maximizing the distance from the reference point (i.e. a group of vehicles in a given lane).
Solution quality of β data is the equation:

$$\beta = \frac{D^2(x_0, y_0)E_0(C)}{D_{\max}{}^2(x_0, y_0)E(C)} \tag{5}$$

Where: $D^2(x_0, y_0)$ a quotient of the square of the length of a given vehicle from the traffic lights.
$D_{\max}{}^2(x_0, y_0)$ is the square of the length in a system of coordinates with the maximal number of dimensions.
Point quality is analogical to the notion of a set of shared variability in factor analysis.
Therefore a measurement of a strength of discrimination force of responses to questions in reference to traffic lights will be a classifier:

$$\forall p \in N,\ \ \forall \beta_p > 0.5,\ \ \lambda_p(X,Y) = \frac{D(x_p, y_p)E_0(C)}{\max\limits_i [D(x_i, y_i); E(C)]} \tag{6}$$

Where: $D(x_p, y_p)$ is the distance of the point (of the considered response) from the sample group and quality of this point.
This classifier determines force with which each point *p* is related to a given group of vehicles.

All statistical tests have been calculated at the relevance level alfa=0.05.

2. RESULTS OF THE RESEARCH

The research focuses on verification of the above described model using for this purpose a chain consisting of six road junctions and a random number of cars.
The results which have been obtained using the model with a genetic algorithm have

been compared with the classic and traditional model. The traditional model assumes that the data is fixed light cycles. Whereas the classic model assumes that control is carried out by application of motion sensors according to the algorithm relying on a principle of a queue fifo. A measure of fluency of motion and minimising of emission of carbon dioxide is an average time of stop of a vehicle in a given road junction. The obtained results are presented on the graph below:

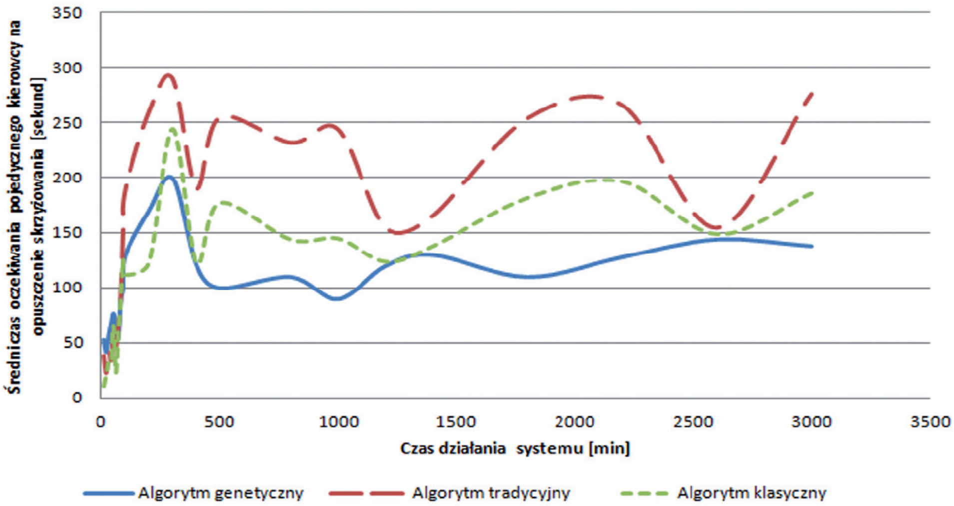

Fig. Graph of simulation of dependencies of average waiting time of a driver to leave a road junction depending on time of operation of the system acting based on a genetic and a classic algorithm

The obtained results of the research indicated that in the event of control of vehicles motion in a traditional manner with a fixed number of cycles, the average waiting time of a car at a road junction lasted 157+/-94 seconds. The time obtained using the classic algorithm was 123+/-67 seconds, whereas with the genetic algorithm the obtained time was ł 104+/-40 seconds.

The genetic algorithm in the first stage of control was learning the best solutions for traffic lights control and controlled the traffic lights in a weaker manner than the traditional method. Then, as presented on the drawing 1 in a longer time perspective intelligent control turns out to be more effective than the traditional method. In course of more detailed research and analysis it has been observed that the genetic algorithm makes it possible to increase fluency of traffic by circa 40% by a number of road junctions in comparison to the traditional method. Whereas comparing the results obtained with use of the genetic algorithm to the classic method circa 20% of improvement has been obtained. Therefore it may be assumed that the method based on intelligent control of traffic lights ensures better methods of traffic lights control than the ones available in the market. As a result it becomes an obvious fact that applying genetic learning methods we are able to contribute to reduction of emission of CO_2 to the air.

CONCLUSIONS

The developed models make it possible to increase fluency of passage of vehicles through road junctions. This increases traffic capacity in road junctions and fluency of traffic within road junctions, and partially it may solve the economics and organisation

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of city transport. The proposed method may be successfully applied to the cause and effect analysis of bottlenecks occurring within a city. Analysing the results it is possible to determine further directions of the research. Here we should focus on other methods supporting control i.e. fuzzy sets or neural networks as well as hybrid methods and heuristics. Each, even the smallest improvement of vehicles passage in time perspective will ensure great benefits both to the environment and to our organization.

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