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OPTIMIZING THE MANAGEMENT OF TRAFFIC LIGHT OBJECT BASED ON NATURAL ALGORITHMS

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The article proposes an adaptive control method for traffic lights, which operates at the strategic level of management. The algorithm uses data on changes in the intensity during the day, which provides forecasting module (for the experiments used neural network prediction). An adaptive algorithm is based on finding the minimum of delay at the crossroad, based on genetic algorithm and the method of 'swarm of bees'.

Keywords: traffic light, adaptive control, genetic algorithm, artificial bee colony algorithm

1. Introduction

Crossroads are the most important nodes of the road network of the city. The largest losses are observed by the use of the roadway. The main parameter that characterizes the management of traffic lights is the average delay of transport at crossroads. The minimizing of this parameter leads to an improvement quality of service at the crossroads.

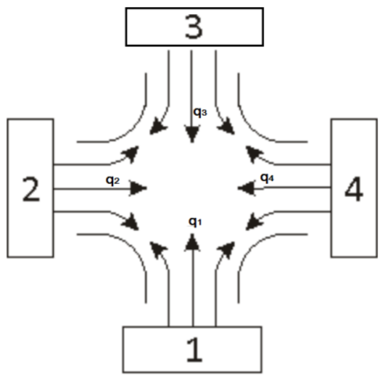

Figure 1. The scheme of traffic light object

Scheme of a typical traffic light object is shown on Figure 1.

The optimization problem consists in the fact that to choose a number and duration of cycles in a controlled cycle in which the delay for traffic would be minimal. To calculate the delay formula can be used [1]:

$$e'_{ti} = 0.45 \cdot \left(\frac{C \cdot (1-\lambda^2)}{1-\lambda x} + \frac{x^2}{q_i \cdot (1-x)} \right), \text{ s/vehicle,} \tag{1}$$

where C – duration of the traffic light cycle, s;

λ – proportion of the green signal for the direction in the cycle;

q_i – traffic volume in this direction, vehicle/s;

x – coefficient of loading.

Then the target function for the optimization task is as follows:

$$f = \sum_{i=1}^{m} w_i e'_{ti} \rightarrow \min, \tag{2}$$

where w_i – weighting factor of importance (priority) direction of optimization.

The coefficients w_i are determined at the design stage. It is also possible that at which these values will change during the day. If all values are equal to one, then the intersection is considered to be equivalent for each of the directions of optimization.

Thus, a complex target function f depends on many parameters t_{zi}. It is required to find such values t_{zi}, which satisfy (2).

To solve the problem of optimization methods were chosen:

1) the genetic algorithm,
2) the method of 'swarm of bees'.

2. Application of Genetic Algorithm for Adaptive Management at the Crossroads

Genetic Algorithms – adaptive search methods, which in recent times are often used for solving a functional optimization. They are based on the genetic processes of biological organisms: biological populations evolve over several generations, subject to the laws of natural selection and the principle of "survival of the fittest", an open Charles Darwin. Genetic algorithm is a simple model of evolution in nature, implemented by the algorithm. It is used as an analogue of the mechanism of genetic inheritance, as well as an analogue of natural selection. This preserves the biological terminology in a simplified form.

To simulate the evolutionary process, initially generated by a random population i.e. some individuals with a random set of chromosomes (numeric vectors). A genetic algorithm simulates the evolution of this population as a cyclic process of crossing individuals and change of generations.

The life cycle of the population – a few random crossings and mutation, which resulted in a population, is added to a number of new individuals. The selection of a genetic algorithm – it is the process of forming a new population from old one, after which the old population is removed. Following the selection of a new population again used the operation of crossover and mutation, then again there is a selection, and so on (Figure 2).

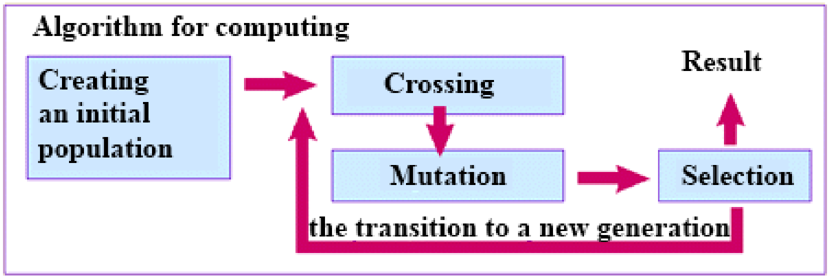

Figure 2. Steps of genetic algorithm

Step 1 – Create the initial population.

Each member of the population consists of a set of chromosomes t_{zi}, $i = \overline{1, m}$.

tz1	tz2	tz3	. . .	tzm	f

Figure 3. A set of chromosomes of an individual with a fitness function

I member of the population of chromosomes contains a value t_{zi}, which is equal to the duration of the *i*-th phase of the traffic light cycle, if the value is zero, then this phase is not in the cycle of regulation. The value of the genome for each chromosome is in the interval (t_{min},t_{max}). Number of phase's m and variations of flow are defined at the design stage of the system. At this stage, as well as during crossing check the admissibility condition of existence of this individual. Testing is to analyse all phases and check on the condition that the entire cycle of time allocated for each direction of motion. If this condition is not satisfied, the fitness function is calculated with an error, so not to waste time on the calculation of this set of chromosomes varies.

Step 2 – Crossing.

The selection of a genetic algorithm is closely related to the principles of natural selection in nature as follows:

- The fitness of the individual – the value target function (fitness function) for this individual.
- Survival the most adapted – the population of the next generation is formed in accordance with the target function. The more adapted an individual, the greater chance of his participation in the crossover.

Model selection defines how to build the next generation population. As a rule, the probability of an individual's participation in crossing is taken proportional to its fitness. Thus, each successive generation will be on average better than the last. The probability of involvement of *i*-th member of the population as a crossing is determined by:

$$P_i = \frac{1}{m-1}\left(1 - \frac{f_i}{\sum_{j=1}^{m} f_j}\right), \qquad (3)$$

After determination of individuals i.e. members crossing, the operation itself is executed crossover.

Single-point crossover works as follows. First, randomly select a point of discontinuity (break point – the area between adjacent values in a row.). Both the parent structure is broken into two segments at this point. Then, corresponding to different segments of the parents stick together and produce two offspring genotypes; can be applied to multi-point crossover or uniform crossover. In uniform crossover, each gene is inherited by the first parent first child with a given probability; otherwise it is passed to the second child.

Step 3 – Mutation.

After the end stage of the crossover, mutation operators are performed. For each of the individual is subjected to mutation of each gene with probability *Pm*. The population obtained after mutation overwrites the old one. The mutation changes the value for the individual genome t_{zi} to some value in the range [–5,5].

Step 4 – Selection.

At this stage there is the sorting of all genotypes of the objective function; and the inclusion of the next generation of individuals with the best target function values (Eq. (2)). Just switch on parental genotypes are there with the best values of f, in accordance with the principles of "elitism". The use of "elitism" cannot lose a good interim solution.

Then the steps of the algorithm are performed again starting from the second. So occurs the limited number of epochs (an acceptable calculation time), resulting in the best option solving the optimisation problem is chosen. Genomes of the options will be used to specify the structure and duration of phases for the traffic light cycle.

Genetic algorithm is a combined method of iterate and gradient descent. The mechanisms of crossover and mutation, in a sense part of the implement then iterative method, and the selection of the best solutions – gradient descent.

3. The Method of "Swarm of Bees" for the Solution of the Optimisation of Management at the Crossroads

One of the newest varieties of genetic algorithms is the search algorithm for 'swarm of bees'. The algorithm for finding the global extrema of functions of complex multidimensional emerged relatively recently. In [2] first described the basis of the method Particle Swarm Optimization.

Every bee in the swarm is considered as a particle or agent. All swarm particles act individually in accordance with one control principle: to move towards the best personal and global best position, constantly checking the value of the current position.

The position coordinates of the bees in the study is *m*-dimensional space.

The personal best position (BPP) is a position with the best value of the target function, discovered by a bee. Each bee has its own BPP. At each point along the path of the bee compares the value of the target function at the current position with a value of BPP. If the current position is set to the suitability of the above, the importance of BPP is replaced by the value of the current position. The global best position (BGP) is defined as the position with the best value of the target function, found all the swarm. Information about the value of BGP is available for each individual bee. If in the process of moving from a bee finds a position with the best target function replaced by the current position of the BGP of the bees.

Description of the algorithm for finding the optimal solution using the 'swarm of bees' method is given below.

Step 1.

Similarly, the genetic algorithm creates a population of bees, each of which contains *m* coordinates and the current value of the optimality of *f* (which is determined by the formula (2)). Also, there is given a random initial speed of movement. Each coordinate corresponds to the duration of some phases in the traffic light cycle t_{zi}.

Step 2.

Each bee in the swarm moves in a new direction in accordance with its position and speed. Checks exit bee's solutions of bounds, and limit the actions required are performed.

Step 3.

For each bee we calculate the value of the objective function in its new position. Comparing this value with the value of the BPP bees, and if necessary, replace the BPP's current position. Comparing this value with the value of BGP swarm, and if necessary, replace the current position of the BGP.

Step 4.

For each bee calculate new speed of movement in accordance with the equation:

$$v_i^{j+1} = w \cdot v_i^j + c_1\psi_1(p_i - t_{zi}) + c_2\psi_2(g_i - t_{zi}), \tag{4}$$

where v_i^j – speed of the bees in the measurement of *i* to *j* iteration;

w – inertia weight, the number (located in the interval [0,1]) reflects the extent to which the particle retains its original speed;

p_i, g_i – value of the *i* position, respectively, for the BPP and the bees swarm of BGP;

ψ_1, ψ_2 – random value in the range [–1, 1];

c_1, c_2 – constant weighting factors determining the attraction of its own BPP and BGP of swarm.

The parameter c_1 determines what effect on the particle has its memories of BPP, and c_2 determines what effect on the particle has the rest of the swarm. These factors are sometimes considered as a cognitive and social factor.

Step 5.

Checking the termination condition of the algorithm (5) if the search is completed, executed the transition to Step 3.

As an estimate of the current state of the search process is proposed to use the average value for the swarm of Euclidean distance ε from each bee to the centre of gravity of the cluster:

$$\varepsilon = \frac{1}{k}\sum_{j=1}^{k}\sqrt{\sum_{i=1}^{m}\left(t_{zi}^j - \tilde{t}_{zi}\right)^2}, \tag{5}$$

where *k* – population size;

$\tilde{t}_{zi}$ – centre of gravity of the swarm in the coordinate *i*:

$$\tilde{t}_{zi} = \frac{1}{k}\sum_{j=1}^{k} t_{zi}^j. \tag{6}$$

The search result is a swarm of BGP. The value of the response function at this point in relation to the known value of global optimisation determines the accuracy of search results. An important advantage of this method for finding the optimal solution is its robustness, i.e. it keeps performance at rather complex response surfaces, as well as the presence of the stochastic component in the measured value of the response function.

4. Results of Testing Algorithms

For the beginning let's generate the intensity of the 8 tests of 15 minutes, equivalent to 2 hours. Table 1 shows the intensity of the input streams at a crossroads.

Table 1. Initial intensity for adaptive algorithms

№	The intensity of the *i* phase, 15 min			
	1	2	3	4
1	157	86	162	124
2	142	153	165	112
3	145	157	167	114
4	157	135	159	126
5	156	138	166	130
6	144	116	174	120
7	140	116	161	114
8	166	122	145	117

At received intensities using adaptive algorithms obtain the duration of the phase traffic light cycle. These data are summarized in Table 2 for the genetic algorithm in Table 3 for the algorithm 'swarm of bees'.

Table 2. Duration of the phases of the genetic algorithm

№	Duration of the *i* phase of the traffic light cycle					
	1	2	3	4	1+3	2+4
1	32	0	23	0	0	14
2	21	29	0	0	14	14
3	18	0	32	0	0	28
4	27	0	0	0	14	14
5	19	0	0	21	14	24
6	39	27	0	0	26	14
7	16	0	35	0	22	14
8	38	32	0	0	23	14

Table 3. Duration of the phases of the algorithm of bee swarm

№	Duration of the *i* phase of the traffic light cycle					
	1	2	3	4	1+3	2+4
1	18	0	0	0	14	14
2	27	0	32	0	0	14
3	0	23	30	0	14	14
4	0	0	0	0	39	19
5	0	0	0	0	31	24
6	28	0	38	14	19	14
7	0	0	31	0	14	17
8	0	0	0	0	17	14

The inputs to the algorithm are the intensity, where for five phase equals the amount of the intensities of the first and third, and 6 phase – the second and fourth.

Figure 4 shows the dynamics of the queue number 2 for the rigid control and adaptive, based on genetic algorithm.

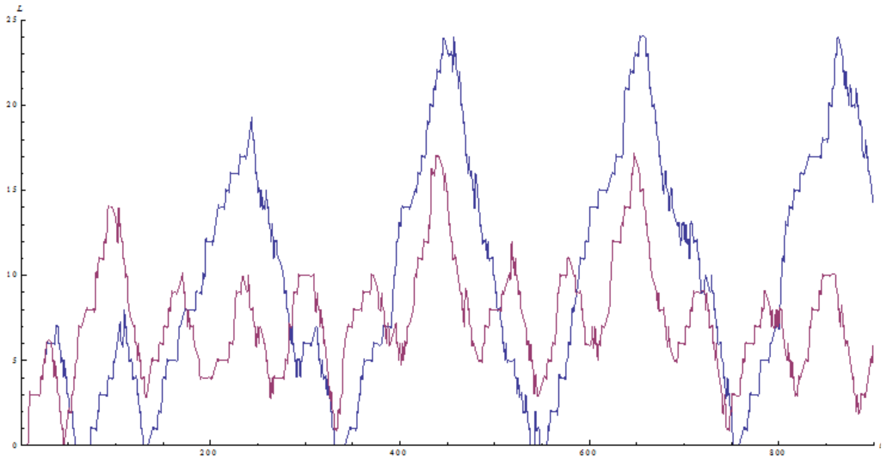

Figure 4. The dynamics of the queue for the genetic algorithm

Figure 5 shows the dynamics of the queue number 2 for the rigid control and an adaptive algorithm based on 'swarm of bees'.

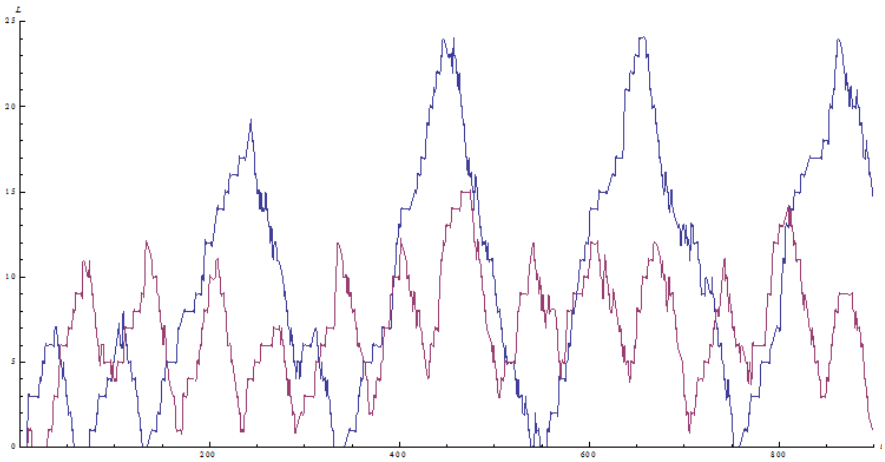

Figure 5. The dynamics of the queue for the algorithm bee swarm

Comparison of changes in the length of the queue of two adaptive algorithms is shown on Figure 6.

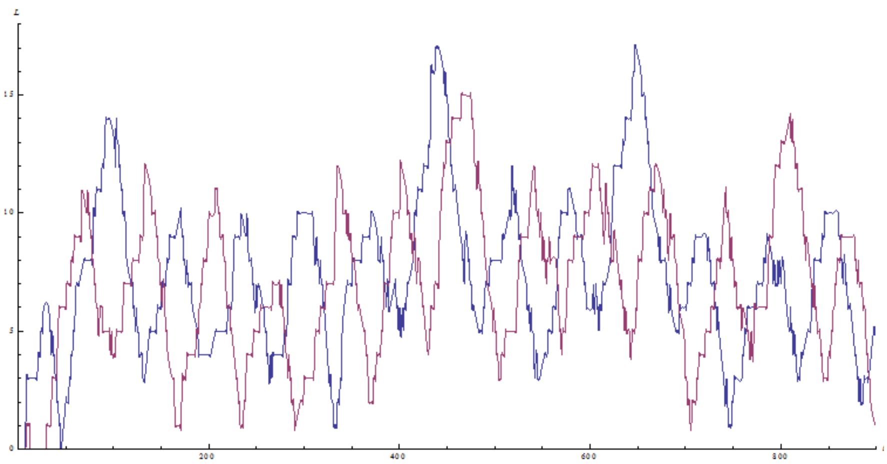

Figure 6. The dynamics of the queue adaptive algorithms

Statistics on the queue for the first 15 minutes is shown in Table 4.

Table 4. Statistics queues for the first 15 minutes

№	**Number of queue**	**The maximum value of queue**	**The average value of queue**	**Average time in queue**
Rigid algorithm				
1	Queue1	22	7,726	45,298
	Queue 2	10	1,598	34,097
	Queue 3	23	8,088	44,732
	Queue 4	19	5,8	40,85
The genetic algorithm				
2	Queue1	15	4,14	24,014
	Queue2	9	1,482	30,507
	Queue3	16	5,35	30,205
	Queue4	16	5,285	39,44
The algorithm of 'swarm of bees'				
3	Queue1	9	1,108	6,45
	Queue 2	6	0,902	18,259
	Queue 3	12	4,711	25,363
	Queue 4	11	3,276	23,411

5. Conclusions

The article considers the option to optimise the management of traffic lights at the level of strategic management.

The proposed methods: genetic algorithm and the method of 'swarm of bees' are methods for solving the optimisation problem in traffic management, its effectiveness in comparison with a rigid management mode is shown. Since the information for calculating the parameters of traffic lights cycle continuously enters to the adaptive control module, it allows responding in a quicker way to the current transport situation at the crossroads. Method of 'swarm of bees' shows better performance in comparison with the genetic algorithm.

These methods belong to a class of strategic management and are a synthesis of control algorithms for a sequence of phases and the calculated algorithm for determining the duration of the cycle and phases.

References

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