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Decision-Making for Intelligent Transport Systems Using Genetic Algorithms

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Abstract

The purpose of research is to develop new mathematical models and new algorithms for intelligent devices to control in electric transport system. Models and algorithms are proposed for multi-criteria decision-making intelligent agent system. Main goal of research is energy saving for public electric transport. Mathematical model and genetic algorithm is proposed in the paper to solve multi-criteria optimization task minimizing idle time and electric energy used by public electric transport and maximize average speed of the flow in traffic jam. Paper presents a practical example to test proposed mathematical model and workability of genetic algorithm.
KEY WORDS: *genetic algorithms, intelligent agent, electric transport system*

1. Introduction

Authors propose to use electronic intelligent agent system to control traffic lights corresponding to the transport flow. The target is to minimize of total electric energy usage by electric transport [3] and total idle time for all transport flow participants using genetic algorithm for intelligent agents of traffic lights.

Paper describes the problem of decision-making for city transport control [6]. The decision making modelling for transport problems is described, using methods of decision making theory and process optimization in intelligent transport systems.

As the transport system is a cooperative system, where behaviour of one participant depends on other. That is why the negotiation process for intelligent agent is necessary [7]. Each agent controls his own object sending data to the superagent, which is responsible for optimization and coordination of negotiation process.

2. Problem Formulation

Nowadays transport flow in the city is growing and traffic jams become the common problem for most of big cities. Traffic lights that control the traffic work in constant mode independently from each other. In some cases traffic light modes do not correspond to the volume of the transport flow.

Public electric transport, such as trams and especially trolleybuses, uses more electric energy during frequent acceleration and braking in traffic jam. That is why, traffic light's green light should be synchronized with the schedule 2 of public electric transport. For all other participants of the transport flow the minimization of idle time in traffic jam is needed.

It is multi-criteria optimization task [5] with following criterions: minimization of electric energy and idle time and maximization of average flow speed .

The purpose of this paper is to define fitness function for genetic algorithm. Genetic algorithm is realized for intelligent superagent to optimize green and red light time. Fitness function should include normalized value of idle time and average speed for all transport participants in traffic jam and electric energy consumption.

3. Mathematical Model for Intelligent Agent

This part presents mathematical model for task solution

Input data:

Crossroad parameters:

- set of crossroads - K
- number of transport units – n_{jk}, where j – direction, k - crossroad;
- flow rate of crossroad (number of lines) – l;
- average speed of moving car (without stop) – v;

Parameter for i^{th} transport unit

- driver's average reaction time – r_i;
- acceleration time for one transport unit – a_i;
- length of a car - c_i;
- distance between cars in traffic jam - d_i;

- position in traffic jam - p_i;

Variables:
- green light time – x_k;
- red light time – y_k;

where k – crossroad.

Target functions:
- Average waiting time – $T = \Sigma t_i / \Sigma n \rightarrow \min$
- Average flow speed - $V = v_i \rightarrow \max$
- Electric energy - $E = \Sigma e_i \rightarrow \min$

Auxiliary functions:
- time of moving from position to the crossroad - $t_i = \frac{(p_i - 1)\cdot(c_i + d_i)}{v} + (r_i + a_i)\cdot p_i$
- flow rate of traffic light: $f = \frac{v \cdot x - c_i - d_i}{c_i + d_i + (r_i + a_i)\cdot v}\cdot l;\quad f \in \aleph$
- red light times (green light missing): $rt = p_i / f;\quad f \in \aleph$
- red light waiting time: $t_{ir} = rt \cdot y;$
- position before passing crossroad: $p'_i = p_i - t_{ir}\cdot(r_i + a_i);\quad f \in \aleph$

Fitness function for optimization:

$$T = \sum_{i=0}^{n} t_i(x,y) \Big/ \sum n = \left(\sum_{i=0}^{n} \frac{(p_i' - 1)\cdot(c_i + d_i)}{v} + (r_i + a_i)\cdot p_i' + t_{ir} + rt \cdot x \right) \Big/ \sum n \rightarrow \min \qquad (1)$$

Normalization functions

Let us assume, that maximal values of target functions are:
- $T_{max} = 3600$ s;
- $V_{max} = 50$ kmh;
- $E_{max} = 1000$ kWh.

According to this values normalization is:

- $T' = \frac{T_{max} - T}{T_{max}} = \frac{3600 - T}{3600};$
- $V' = \frac{V}{V_{max}} = \frac{V}{50};$
- $E' = \frac{E_{max} - E}{E_{max}} = \frac{1000 - E}{1000}.$

Let us assume the priorities for optimization parameters are
- $\alpha_T = 0.3$;
- $\alpha_V = 0.3$;
- $\alpha_E = 0.4$.

Fitness function for optimization:

$$F = \alpha_T T' + \alpha_V V' + \alpha_E E' \rightarrow \max \qquad (2)$$

4. Genetic Algorithm for Intelligent Agent

From genetic point of view the parameters of the problem are presented as genes of chromosome. Each chromosome presents problem solution. Each solution should be evaluated by fitness function. The goal of genetic algorithm is to find the chromosome with optimal value of fitness function [1].

In our case the chromosome contains green light time and red light time of each traffic light:

$$s = (x_1, y_1, x_2, y_2, \ldots, x_k, y_k)$$

Population in the task is presented as a set of traffic light working modes for all analyzed crossroads:

$$S = \{s_1, s_2, \ldots, s_p\}$$

Fitness function (2) will be used to evaluate each state s:

$$V_i = F(s_i)$$

General genetic algorithm for task solution is following:

Step 1: Initialize population: $S = \{s_1, s_2, \ldots, s_p\}$;

Step 2: Evaluate population: $V^S = \{F(s_1), F(s_2), \ldots, F(s_p)\}$;

Step 3: Arrange population by evaluation: $\overline{S} = \{\bar{s}_1, \bar{s}_2, \ldots, \bar{s}_p\}, \quad F(\bar{s}_1) = \max(V^S)$;

Step 4: Select best parents to elite $S_E \subset \overline{S}$;

Step 5: Select other parents for crossover $S_C = \overline{S}$;

Step 6: Apply crossover, where $\bar{s}_i \Pi \bar{s}_j \rightarrow s'_i = s_{ij}; s'_j = s_{ji}, \quad i, j = \overline{1, p}$;

Step 7: Apply mutation, where $x_j^{s'_i} = x_j^{s'_i} + 1, \quad s'_i \in S', \quad j = rand(\overline{1,k}), \quad i = rand(\overline{1,p})$;

Step 8: Evaluate population: $V^{S'} = \{F(s'_1), F(s'_2), \ldots, F(s'_p)\}$;

Step 9: Arrange new population by evaluation: $\overline{S}' = \{\bar{s}'_1, \bar{s}'_2, \ldots, \bar{s}'_p\}, \quad F(\bar{s}'_1) = \max(V^{S'})$;

Step 10: Combining with elite: $S = (S_E + \overline{S}')$;

Step 11: Delete last: $S = S / \{s_{p+1}, s_{p+2}, \ldots\}$;

Step 12: IF $F(s_1) <> F(s_p)$ THEN Goto Step 2

ELSE End of Genetic Algorithm with solution s_1.

5. Practical Example

An abstract crossroad (Fig, 1.) is selected for a computer experiment. An experiment presents a modeling of intelligent electronic device [4] to control traffic light and optimize its green and red light time period.

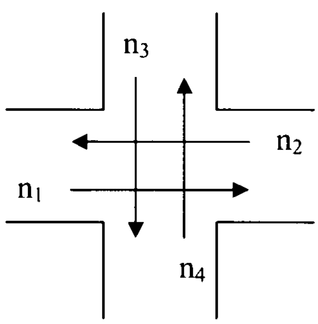

Fig.1. Schema of crossroad for computer experiment

Function (1) is optimized in this experiment with following parameters. Let us assume,

- number of vehicles on the first street: $n_1 + n_2 = 100$
- number of vehicles on the second street: $n_3 + n_4 = 200$
- number of lines: $l = 2$
- average speed of moving vehicle: $v = 25$;
- driver's average reaction time: $r_i = 1$;
- acceleration time – $a_i = 3$;
- length of a car: $c_i = 4$;
- distance between cars in traffic jam: $d_i = 0{,}5$;

Target is to minimize average waiting time for all vehicles by optimal traffic light regulation (1).

$$T(x, y) \rightarrow \min$$

Input data for genetic algorithm are presented on Fig. 2.

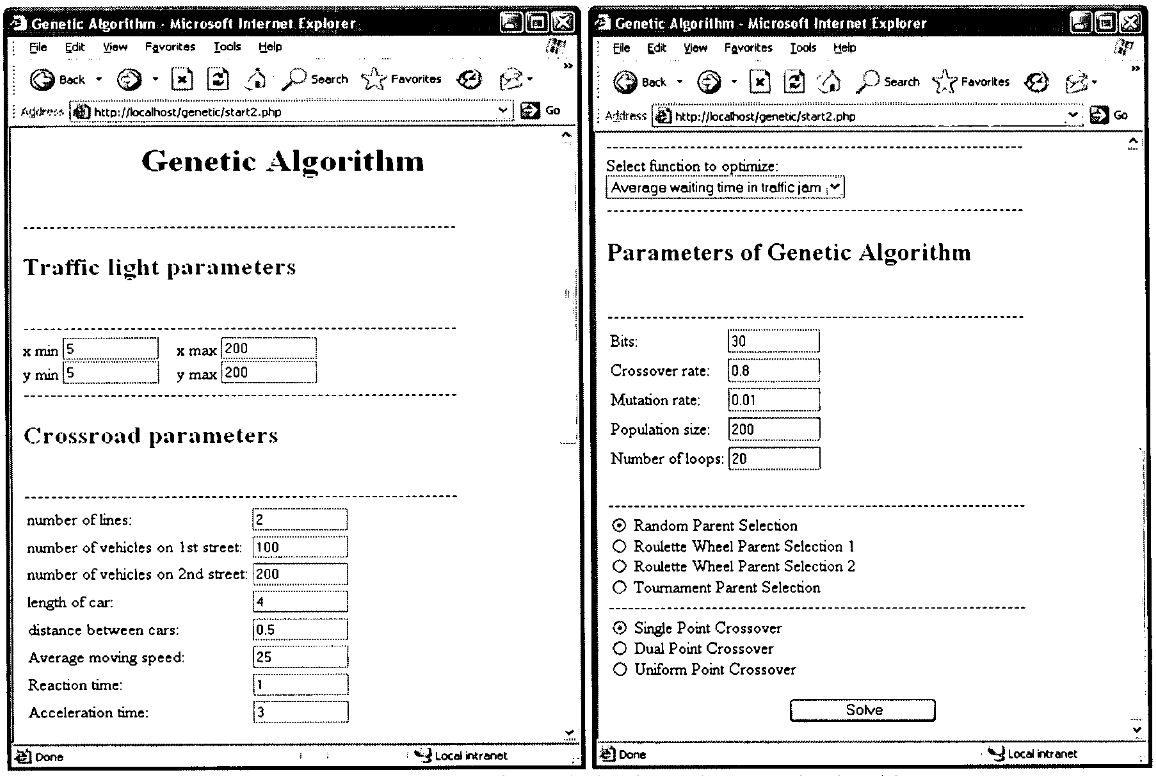

Fig. 2. Input parameters for optimization using genetic algorithm

Results of genetic algorithm are presented on Fig. 3.

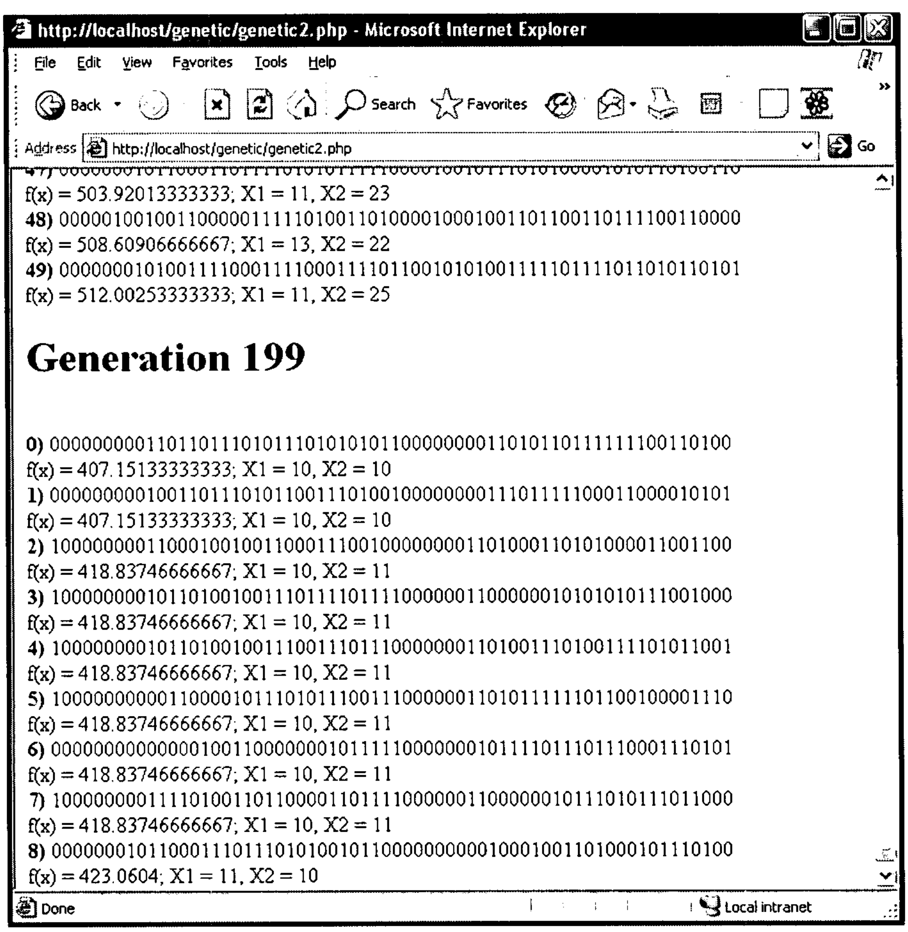

Fig. 3. Results of genetic algorithm

6. Conclusions

Results of practical examples on this stage of research prove that genetic algorithm is useful for traffic control task solution.

Genetic algorithm is very sensitive to its parameters. That is why is necessary to find out the most suitable algorithm of selection, crossover as well as number of bits, population size, number of loops and mutation.

Also minimal and maximal limits of variables x and y is very important. Experiment shows that in case of high maximal limit of green light, algorithm tries to switch on green light as long as possible to allow all vehicles to pass the crossroad. Otherwise, the minimal limit of green light is optimal.

Authors' further research is evolutionary software development using multi-criteria optimization for city electric transport. It is necessary to make model of several crossroads connected in intelligent traffic control network with a goal to reduce traffic jams.

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