EVOLUTIONARY TECHNIQUE OF SHORTER ROUTE DETERMINATION OF FIRE BRIGADE FOLLOWING TO FIRE PLACE WITH THE OPTIMIZED SPACE OF SEARCH

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Abstract: In this paper the technique of shorter route determination of fire engine to the fire place on time minimization criterion with the use of evolutionary modeling is offered. The algorithm of its realization on the base of complete and optimized space of search of possible decisions is explored. The aspects of goal function forming and program realization of method having a special purpose are considered. Experimental verification is executed and the results of comparative analysis with the expert conclusions are considered.

Keywords: Fire, Evolutionary techniques.

ACM Classification Keywords: H.4. Information systems applications

Introduction

The search of shorter passage is the discrete optimization problem. Thus determination of optimum route of fire engine following to the fire place has aspects which select him from the general row of such problems. So, practically, it is a problem which solves in critical terms, the still human lives rely on the rightness of its decision. The right chosen route is the necessary condition of prevention of technical and ecological catastrophes. In the conditions of resources deficit of time minimization for fire engine route is the deciding factor of prevention of negative consequences of fire. The far of scientific researches is devoted to solving this task.

The grounds of fire engine departure route are traditionally offered, coming from the criterion of minimization of arrival time of fire brigade to the fire place. In this paper [Pryanichnikov, 1988] the analysis of factors affecting emergency safety of roads is executed: width of carriageway and pavements, quantities of carriagestrips, radius of curvature, visibility, intensity of transport streams. It is offered to determine the coefficient of road terms on a formula:

$$D = \left[\sum_{i=1}^{n} \left(\prod_{j=1}^{m} k_{ij} \right) L_i \right] / L, \qquad (1)$$

where n – quantity of route areas, m – number of factors determining road terms k_{ij} – coefficient of importance of j-th factor of road terms on the i-th route area, L_i – length of i-th area L – general length of fire brigade. Departure of fire computation is assumed on a route having the most value D.

In many scientific publications similar approaches are considered. The necessity of consideration of the fixed, desirable complete set of possible routes is their failing, that practically is difficultly realized. Possibility for values varying of road terms factors importance is not foreseen, that in the conditions of road situation change, repair of road linen, weather terms results in distortion of the route supposed time. Development of adequate model of route time is needed, as dependences on meaningful factors, with possibility of its clarification and adaptation to the changing external terms.

Important to remark that development of time route model is the necessary condition of determination of shorter route for following to the fire place. A method which structurally will allow to define an optimum route is a sufficient condition. As the considered task has a combinatorial nature and, as a result, inevitable there is the problem of calculable complication of algorithm, it is necessary to foresee realization of technology which will allow to shorten the quantity of the analysed routes and optimize the calculations process.

Problem of optimum route determination for fire engine

Without restriction of generality we will assume that the structure of roads is rectangular (fig. 1). We will number every crossing in accordance with a central-radial chart. The location of fire brigade has a zero number, a most number has the farther-most "north-eastern crossing". Number of crossing is N. The matrix of distances between crossing $S=(s_{ij})_{i,j=0}^{N-1}$, where s_{ij} is distance from i-th one to the j-th crossing, corresponds with considered structure of roads. Knowing the middle rate of movement of fire brigade, the distances matrix can put in accordance the matrix of passage time between crossing $T=(t_{ij})_{i,j=0}^{N-1}$.

Factors influencing on a passage time, in a form the presentation of their values possible to divide into three groups: determined, probabilistic-statistical and subjective.

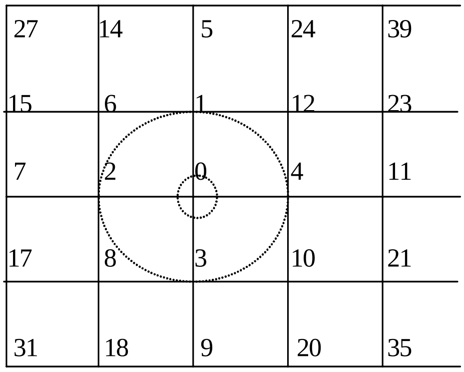

Fig. 1. Central-radial crossing numeration

The least number of crossing K on the passing way is the determined factor, its possible values – natural numbers equal to the number of quasi-concentric circumference (see the fig. 1) and increased fairly removal of crossing from fire station. Work-load of roads U is probabilistic-statistical factor which is characterized to statistical row distributing (tabl. 1), where in overhead part of table time intervals are found, in lower – relative frequencies of cars quantity on the road in these time intervals. Quality of road coverage V is a subjective factor and it is determined by the membership function, which can be both continuous or discrete. Its construction is carried out to one of two methods, the first from which is based on the pair comparisons executed by one expert [Rotshtein, 2002], second – on statistical treatment of experts group opinions [Zadeh, 1965].

Table 1

Statistical row

Intervals	$[t_0,t_1]$	$[t_1,t_2]$	...	$[t_{n-1},t_n]$
Relative frequencies	f_1	f_2	...	f_n

We will assume that the fire place H is found between two crossing n_1 and n_2. Then it is necessary to define an optimum route, that answers the decision of problem [Snytyuk, 2004]:

$$\min_t\{L_{on_1}+L_{n_1H};\,L_{on_2}+L_{n_2H}\} \tag{2}$$

where L_{ij} is route from a i-th point to j-th one. The values of matrices elements S; T; $K=(k_{ij})_{i=1,\ j=1}^{N\ \ 2}$ are basic data for the decision of problem (2) where k_{i1} – number of final crossing, k_{i2} – the minimal number of crossing, which is needed to pass by passage to k_{i1}; $G=(g_{ij})_{i=1,\ j=1}^{24\ \ 2}$, where g_{i1} – number of time interval (days are broken-down on 24 intervals: from 0 hours to the 1-th hour (1), from 1-th to the 2-th hour (2)...), g_{i2} – relative frequencies of cars quantity in a g_{i1}-th time interval, $\sum_{i=1}^{24} g_{i2}=1;\ \sum_{i=1}^{24} g_{i2}=1;,\ \sum_{i=1}^{24} g_{i2}=1;$, where $q_{ij}\in(0,1)$ – coefficients which determine quality of road coverage on an area from the i-th crossing to j-th one. We will remark that a matrix G can have not statistical, but subjective nature. If motion at one and the same time on different areas of road is uneven, the matrix will be three-dimensional, one of measuring of which will correspond to the number of road area a. Depending on the features of concrete city or situation, the quantity of matrices of values factors affecting to the rate of movement of fire brigade can be increase. We will mark that richly in content essence of consideration of other factors will not differ from already considered.

Preconditions for solving the optimum route determination problem by use the evolutionary modeling

The features of socio-economic development of countries are the direct motive for fire number increase and, as a result, death of people and causing of property losses. A personnel and material deficit is, from one side, by the cause of the uneffective extinguishing of fires, and with other – a stimulus to introduction of new information-analytical technologies, that allows to rise efficiency of fire brigade work. One of problems requiring application of intellectual models and methods, there is minimization of passage time of fire brigade to the fire place.

We will define initial preconditions its solving. We will remark that such problem has some general aspects with the known problem of traveling salesman. It is known, that the exact method of the given problem solving of any dimension, excepting complete look over of all variants, does not exist. Satisfactory results give the method of branches and scopes [Luger, 2002; Zaychenko, 2000], method of successive analysis of variants [Volkovich, 1993], search of optimum route with the use of the Hopfild's neural network [Wasserman, 1992]. However by application the last method an exact result is got, approximately, in 50% calculations, exactness of the first methods relies on problems dimension, also the hit in local optimums is high-probabilistic.

The feature of optimum route search problem for fire brigade is that the best decision is searched on the criterion of time minimum. Thus it is necessary to take into account the number of crossing on the passage way, work-load of roads (mean number of cars on the road in unit time), their quality. Consideration of other factors also is possible by their special meaningfulness and necessity. We will mark that technology of determination of passage optimum way of fire brigade to the fire place will be realized taking into account subjective and statistical factors. The evolutionary method of shorter route determination is its base element and it consists in the following.

Without limitation of community we will present (2) as a problem of finding

$$\min_{t} L_{0n_1}. \qquad (3)$$

It is obvious, that for the decision of problem (2) it is necessary twice to solve (3) and execute some clarifications of result. We will carry out the search of optimum way by application evolutionary algorithm (EA) of the special kind which allows to find global optimums, in the general case, undifferential functions. We will define its basic principles and base elements.

A general population is the basic concept EA – all set of possible decisions. In our case we will define a general population as set of vectors $X = (x_0, x_1, x_2, ..., x_k, x_n)$, where x_0 – place of fire station, x_n – number of nearest crossing to the fire place. Thus, the sequence of numbers of crossing which it is necessary to pass in order that to arrive in x_n is the values of elements of vector X. We will remark that the number of crossing, in the general case, is variable. The minimum value k is determined by the number of quasi-circumference (see fig. 1), on which lies the crossing x_n, its maximal value can be enough large. All x_i, $i = \overline{0,k}$ are different and neither of them coincides with x_n. On the face of it, optimum there will be those variants at which $x_i < x_j$ for all $i < j$, but implementation of such condition is not obligatory.

Model of goal function

The adequate application EA is related to transformations of number values from two scale of notation in decimal one and vice versa. Thus there is an informative redundancy, as not all two presentations have the analogues in decimal notation. In the general case, it bring to the necessity of enlisting of additional calculable resources and increase of problem solving time [Kislyakov 2000, 2001].

Foregoing facts are indicated on considerable labour-intensiveness and pointlessness of forming of general population. About belonging to it will testify the results of verification. Determination of selective population which must be a characteristic of representation is important procedure [Goldberg, 1989; Werbos, 1974; Isaev, 2000; Jensen, 2001]. The vectors of selective population can have a different number of elements, that it is related to the number of crossing on the passage way. Their generation takes place taking into account contens of matrix S. First and last elements of vectors are identical (crossing, where a fire station and nearest crossing to the fire place are found). Other elements are determined by accidental way, but taking into account implementation of condition, that from the place of fire station it is possible to get on one of the 4th crossing, and from each of them – already on one of the three. We will designate P – number of elements in a selective population.

For forming of goal function (fitness-function) is possible to apply two approaches. In the first case is necessary to have the sufficient set of the statistical data grouped in tab. 2, and to carry out identification of dependence

Table 2

Initial data structure for fitness-function identification

Length of way L	Number of crossing K	№ time interval g	Quality of road coverage q	Time of passage T

$$T = F(L, K, g, q), \quad (4)$$

where T – time of the following of fire brigade to the fire place, K – number of crossing which it passed, g – number of time interval, q – index of road coverage quality, which integrates in itself and weather terms. By correct formalization of problem carrying out identification (4) is simple. It is enough preliminary to execute data normalization and apply a least-squares method for construction of equation of linear regression [Nakonechniy, 1997], the Brandon's method – for nonlinear regression [Chavkin, 2001], methods of models self-organisation – for polinomial dependences (group method of data handling [Ivakhnenko, 1975] or method of successive simplifications [Vasilyev, 2001]).

In second case the goal function forming accomplishing empirically with the use of weighing and correction coefficients. The given matrices T are thus used. Mean time of passage from x_0 in x_n is determined on a formula (on one of routes):

$$T_{cp.} = \sum_{i=0} \sum_{j \neq i}^{n} t_{ij} \cdot \chi(s_{ij} \neq 0), \quad (5)$$

where $\chi(*)$ is function-indicator. As, on the average, time of passing of fire brigade is increased with the increase of number of crossing, we will specify (5):

$$T = w_1 \cdot k_{n2} \cdot T_{cp}, \quad (6)$$

where w_1 – weight coefficient which determines meaningfulness of number crossing parameter. Taking into account quality of road coverage function having a special purpose (5)–(6) is such:

$$T = w_1 \cdot w_2 \cdot k_{n2} \cdot \sum_{i=0} \sum_{j \neq i}^{n} t_{ij} \cdot q_{ij} \cdot \chi(s_{ij} \neq 0), \quad (7)$$

where w_2 – weight coefficient indicative on importance of quality road coverage parameter. As in a different time of days time of fire brigade passing to the fire place will be different, a model (7) must be specified:

$$T_v = \frac{\prod_{i=1}^{3} w_i}{g_{t2}} \cdot k_{n2} \cdot \chi(v = g_{t1}) \cdot \sum_{i=0} \sum_{j \neq i}^{n} t_{ij} \cdot q_{ij} \cdot \chi(s_{ij} \neq 0), \quad (8)$$

where w_3 – weight coefficient of importance of time intervals, v – number of time interval.

We will do the row of remarks. The value of function (8) must be calculated depending on time of fire. Weight coefficients are determined by experts empirically. Thus, the use of offered approach is sujective. Construction of function (4) is carried out analytically and, in most cases, can be in a theory grounded. Dependence (8) is got, coming from empiric deductions, and procedure of its verification is enough protracted. To the receipt of model rationally to take second approach at the small retrospective view of a priori data.

Evolutionary method of optimum route determination for fire brigade following

Taking into account that every top (crossing) is incident only to four other tops, and their common number is enough large (it is used for construction of matrices S and T), to apply traditional binary presentation of vector elements of population (chromosomes) in classic EA is inefficiently. Lets $X_1, X_2, ..., X_p$ – vectors of selective population (contained the great number of routes-crossing), regulated on the elements number, i.e. $|X_i| \leq |X_j|, i < j$. For each of them, calculating the value of function (4), we will get $T_1, T_2, ..., T_p$.

Using principle of the successive overcoming of uncertainty, *crossover* we will conduct on principle of successive selection [Vitkovski, 2003; Alguliev, 2004] in accordance with which large probability of participation in recombination have vectors with the less value of fitness-function. We will assume that it is necessary to define an optimum route to crossing № 39 (see fig. 1). For crossover vectors (0, 1, 5, 24, 12, 23, 39) and (0, 1, 12, 4, 11, 23, 39) are chosen. We determine, whether there are identical elements in these vectors, except for the first two and the last element. Such element is 12, it is the recombination point. Carrying out crossover, we will get two vectors-offsprings: (0, 1, 12, 23, 39) and (0, 1, 5, 24, 12, 4, 11, 23, 39). If identical elements are not present, we abandon one of vectors (with the minimum value of fitness-function) and by accidental appearance (with the use of proportion principle) we choose other vector from a selective population. A zero, one or two vectors, will be the result of crossover. Zero, if $\exists x_i, x_j : x_i = x_j, i \neq j$ in each of vectors; one – if in one; two, if the indicated terms are not executed not for one of vectors-offsprings.

Getting P descendants, among them and among P parents we choose the best vectors. Such selection is named an elite. Except for him, there are other methods of selection: selective, panmiksiya, selection with ousting [Isaev, 2000]. The practical design witnessed advantage of exactly elite selection, as at him optimum vectors-decisions are not lost. From all types of selection only for an elite it is proved [Harti, 1990]in a theory, that the iterative process of search of optimum decision meets.

For prevention of fitness-function hit in a local optimum the mutation procedure is foreseen. It uses with probability 0,01 on such chart. We consider uniformly distribute number on the set $\{1,2,...,P\}$. If $\xi = k$, we carry out the mutation in k-th vector of selective population. If the number of elements in it is d, we choose random number η from set $\{2,3,...,d-1\}$. The mutations are carried out at $\eta = L$ elements, what the random selection from two variants of $(L+1)$-th element is carried out for. Implementation of one the following terms is the criterion of search process ending of optimum decision:

- achievement of necessary value of fitness-function;
- selective population consists of identical elements;
- for any value $\varepsilon > 0 : \left|T_i - T_j\right| < \varepsilon, \forall i, j, i \neq j.$

If are executed the first or third condition, a vector will be the problem decision, the value of fitness-function which is the least.

Such method takes the advantages before classic EA and failing related to the features of problem. Considerable abbreviation of operations number is advantage, that is explained by no the application of transformation procedure of numbers in EA from decimal numeration in the two one and vice versa. Decimal presentation optimizes procedure of crossover due to reduction of forming time of vectors-offsprings. In offered method favour testifies also, that it is not “tied” to the rectangular structure of streets. If on some of them the repair is executed, in matrices S and T it is enough on the proper places to put zeros. To failing we will deliver the problem of selective population forming, that it is related to a different number of elements at vectors-representatives. In addition, procedure of determination of vector’s every next element requires the revision of matrix row of distances or time, that at a lot of crossing considerably multiplies time of algorithm work.

The offered technology is oriented to that the application module will work both in active, and in passive modes. In the passive mode for every time interval on the known matrices of crossing number on the fire brigade route and quality of road coverage an optimum route calculates and is written in a data-base. By the fire to fire brigade the order with two variants of routes to the contiguous crossing will be given out. By the change of parameters in one of determining matrices or origin of situation, which a necessity in urgent delivery of information about a route which is not present in a data-base, the system is translated in the active mode of operations and urgently decided a problem.

In the general case, the decision (8) is a local optimum, as a process of its search is determined by the choice of initial point and size of search step. Therefore there is the necessity to use of evolutionary methods which are invariant to such choice.

Optimization technology for space of problem solving search

In the modeling process two problems are exposed. First from them consisted that from every crossing, usually, are present routes to the four other. At the same time, in the matrix of distances, at least, on an order anymore variants, therefore there is a considerable calculable redundancy. Other problem consists in rational presentation of chromosomes-decisions. In particular, a priori it is impossible to define, what length must be had by a chromosome, the number of elements of which answers the number of crossing which must be passed by fire brigade following to the fire place.

For solving the indicated problems such procedure is offered. In accordance with a fig. 1 and the matrix of distances we build a matrix $N = (n_{ij})_{i,j=1}^{4\ m}$ (table of directions, which crossing contiguous to fixed are shown in) and matrix $L = (l_{ij})_{i,j=1}^{4\ m}$ (table of distances from the fixed crossing to contiguous) (tabl. 3). Obviously, that to the fixed crossing there are a lot of routes, each of which passes through a different number of the intermediate crossing. The least number of such crossing is determined by the number of quasi-concentric circumference passing through the final crossing. The maximal number of crossing is determined by an expert way and, more frequent all, does not exceed the triple number of the minimum crossing in the critical case, and double – in the regular situations.

Table 3

Table of directions

crossing	0	1	2	3	4	5	6	7	8	9	10	11	12
to the left	2	6	7	8	0	14	15	*	17	18	3	4	1
straight	1	5	6	0	12	*	14	15	2	3	4	23	24
to the right	4	12	0	10	11	24	1	6	3	20	21	*	23
backwards	3	0	8	9	10	1	2	17	18	*	20	21	4
Table of distances between crossing													
crossing	0	1	2	3	4	5	6	7	8	9	10	11	12
to the left	1	3	3	5	6	3	2	*	3	2	4	4	2
straight	9	1	1	3	7	*	2	3	1	2	2	3	3
to the right	6	2	1	4	4	2	3	3	5	1	2	*	3
backwards	3	9	1	2	2	1	1	2	1	*	2	3	7

We will define crossing as final № 39 (see fig. 1). He belongs to the fourth circumference, therefore the least length of chromosome is evened four and she will be such:

$x(1)$	$x(2)$	$x(3)$	$x(4)$

There is a starting point (station) $x(1) = 0$ in a chromosome and $x(4) = 39$ – final point. We will set maximal length of chromosome to equal eight. Parallel with implementation of the traditional operations EA, in the offered procedure it is necessary to adhere to such steps. During initialization of selective population it is necessary to provide the even representative of chromosomes of a different length. For this purpose we choose a random evenly distributed number from the set {4, 5, 6, 7, 8} which answers length of chromosome. If this number is 4, first and the last its fragment already known. An auxiliary chromosome consists of four genes. First two genes encode direction of motion from $x(1)$ (accordingly: 00 – to the left, 01 – straight, 10 – to the right, 11 – backwards), other two – from $x(4)$. On admission of decision indicates implementation of limitation which determines that crossing $x(2)$ and $x(3)$ are neighbouring. For longer chromosomes such procedure is recurrent executed.

Analysis of modeling results

Time of experimental modeling without implementation of procedure of search space narrowing on the Pentium 2,0 GHz computer made, on the average, 12-16 minutes. If in the search algorithm auxiliary procedure is executed, time of optimum decision search to 0,8-1,1 minutes diminished due to abbreviation of incorrect steps. If dependence (8) with preliminary set by an expert way weight coefficients is a function having a special purpose, time of passage to the fire place on a route definite by means of modeling, on 7-10% is less, than time, which corresponds with the route offered by experts (by the chiefs of fire brigades) or coincides. Verification of this fact is achieved by the calculation of goal function on two offered routes by the permanent values of weight coefficients determining the feature of passage.

Inference

The method of determination of shorter route for fire brigade following to the fire place with optimization of search space is technology allowing to evade still human victims and shorten material harm. His effective application supposes the presence of informative base, containing data about the number of crossing, state of roads and road situation, and also its update in the real-time mode. The multiplied number of “corks” on the road underlines actuality of the offered method. The change of information supposes the count of optimum route.

Calculable complication of evolutionary algorithms grounds the necessity of development of the methods directed on the increase of computations speed by unchanging exactness. That is why development of the optimized models of goal functions and procedures of reduction of informative surplus of initial data are perspective. Important to remark that the offered models possess property of openness, i.e. they assume consideration and other meaningful factors, and expediently to divide weight coefficients into local (characterizing areas of roads) and global, being the attributes of road situation on the whole.

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INFORMATION TECHNOLOGIES OF THE DISTRIBUTED APPLICATIONS DESIGN

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Abstract: *The questions of distributed systems development based on Java RMI, EJB and J2EE technologies and tools are rated. Here is brought the comparative analysis, which determines the domain of an expedient demand of the considered information technologies as applied to the concrete distributed applications requirements.*

The Distributed Systems' Design Conception

Distributed system, from the information systems point of view, consists of several independent computing devices. The state of distribution concept shares and belongs to data warehouses, hardware and software in equal parts. The application program, whose program code, data warehouses and computing resources are distributed, is called a distributed application. The composite parts of a distributed application interacts between themselves using information telecommunication technologies of seven-level OSI model, where TCP/IP sockets used on lower levels and remote access tools like DCOM, CORBA, RMI on higher levels.

The next problems can appear during the distributed applications design [1-4]: *telecommunications reliability*- communicational tools must provide a reliable interaction between the objects which execute severs and clients functions; *interface dependence*- client and server interfaces have and influence on the queries and answers; *object activation*- during the application execution the necessity of server object activation by client's request can appear; *create and remove*- during the application execution the necessity of object creating and removing can appear; *transaction support*- the control of operations set which executes by the distributed application objects, if at least one operation of the current set cannot be executed then the rest of operations must be also cancelled.

The distributed applications are based on possibility to send objects from one application program to another and to allow an invocation by one application program of object methods, which are located in anther application program. The processing of user's interaction with the database in realized in four levels: web browser, database client and database server. The user's level contains web browser, which displays web pages and collects information for processing. The middle level contains web server and application server, which are the client programs for database. The lowest level contains database servers.

The Technologies of the Distributed Applications Design

The interest to distributed applications is explained by increased requirements to modern program tools. The major of them are:

- *application scalability*- the capability for an effective maintenance of any quantity of clients at the same time;
- *application reliability* to the client application errors and communication failures;