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Parameters Optimization of the Shooting on the Base of the Evolutionary Algorithm

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Abstract

The approach to solving the optimization problem of the covering of the observation object by means of the shooting system has been considered. It is offered to use the evolutionary algorithm to achieve an extremum of the fitness function under some additional restrictions. The example of application of the offered evolutionary algorithm for the problem of the parameters optimization of the shooting of the observation object with the acceptable time expenditures has been given.

Keywords: evolutionary algorithm, shooting system, optimization problem of the covering of the observation object

1 Introduction

The purpose of this research is the application of evolutionary approach to the problem of the parameters optimization of the shooting of the observation object. The solution of this problem is complicated by the need of the careful choice of the adequate fitness function. This problem demands to account a large number of the restrictions for the optimization parameters values, and, also, the restriction for the fitness function value. In particular, it is necessary to account such parameters as the latitude of the point of the shooting start, the longitude of the point of the shooting start, the time of the shooting start, the shooting duration, the speed of the image motion, the azimuth and the restrictions on their values.

In this case the problem of the parameters optimization belongs to the class of the multivariable one-criterion optimization problems of the parameters values, allowing reaching the greatest possible efficiency of the functioning of the shooting system.

Solving this optimization problem becomes more complicated by the fact that the initial parameters values from which it is necessary to start the search of the optimum set of the values aren't specified. Herewith, only the possible or admissible ranges of change of the parameters values are known.

Therefore, we suggest to develop the software tool containing the mathematical models and the evolutionary algorithms and providing the search of the optimum parameters values of the optimization problem with the acceptable time expenditures. These found optimum parameters values must satisfy to the large number of the requirements and restrictions, specified in advance.

For the problem of the parameters optimization the use of the evolutionary approach, representing the perspective and dynamically developing direction of the intellectual data processing under the acceptable time expenditures, provides the possibility of the required decision finding with the minimum amount of the basic data.

2 The evolutionary algorithm for solving the optimization problem

The evolutionary approach allows applying the evolutionary algorithms (genetic algorithms, evolutionary strategies, evolutionary programming) as the optimization algorithms realizing the possibility of the simultaneous search among the several alternative solutions and choosing the best of them [1–3].

The evolutionary algorithm for solving the optimization problem is represented in fig. 1.

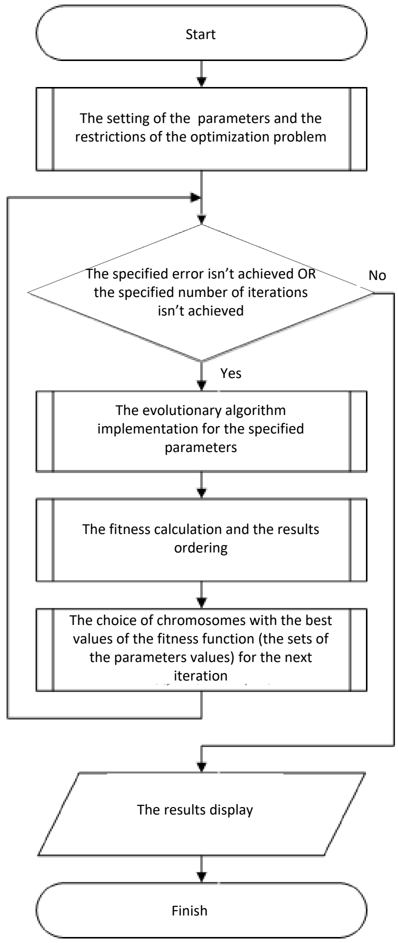

Fig. 1. The evolutionary algorithm to solve the optimization problem

The block of the algorithm called as "The setting of the parameters and the restrictions of the optimization problem" represents a problem definition stage at which it is necessary:

• to set the parameters the change of which must provide the maximum efficiency of the optimization problem decision in the context of obtaining of the optimum value of the used criterion (the fitness function);

• to set the criterion (the fitness function) which must allow reflecting the interrelation between the problem parameters and providing the accomplishment of comparison of the received decisions versions to determine the "best" of them;

• to set the variation ranges of the parameters of the optimization problem;

• to determine the extreme values of the parameters of the optimization problem by imposing the restrictions ("equality" or "inequality").

The block of the algorithm called as "The evolutionary algorithm implementation for the specified parameters" is responsible for implementation of the evolutionary optimization algorithm. In this block the sets of the values of the varied parameters are generated and the chromosomes after application of the evolutionary operators for the set number of iterations are determined.

The blocks of the algorithm called as “The fitness function calculation and the results ordering” and “The choice of chromosomes with the best values of the fitness function (the sets of the parameters values) for the next iteration” perform the fitness function calculation that allows comparing and choosing the “best” sets of the values of the optimized parameters with the aim to use them for the next iteration of the evolutionary algorithm. Besides, the check on the observance of all restrictions of the subject domain imposed on the values of the varied parameters and the fitness function is made here.

The block of the algorithm called as “The results display” is responsible for output of the values list of the fitness function which provide the achievement of the optimization criterion goal) and sets of the values of the optimized parameters and restrictions corresponding to this values list of the fitness function.

3 The shooting optimization of the observation object

Let we have the practical optimization problem of the covering with the shooting system of the observation objects.

Previously, the planning of the shooting of the observation object must be made for the chosen area with the purpose of the receipt of the initial parameters values of the shooting of the observation object.

The initial values of the optimized parameters of the shooting and the corresponding rangers of the permissible parameters values for one of the observation objects are given in table 1.

Table 1. The initial values of the shooting parameters and the ranges of the permissible parameters values

The shooting parameter	The initial value	The range of the permissible parameters values
The latitude of the point of the shooting start, degrees	62.5856	(61; 62.6)
The longitude of the point of the shooting start, degrees	– 163.171	(– 165; –162)
The time of the shooting start, second	7888174	(7888150; 7888200)
The shooting duration, second	11.8483	(5; 15)
The speed of the image motion, meters per second	60	(45; 75)
The azimuth, degrees	0	(0; 360)

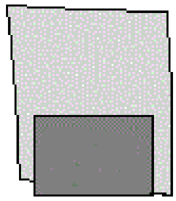

Fig. 2. The boundaries of the shooting, according to the calculated initial values of the parameters

The boundaries of the shooting calculated with the use of the initial values of the shooting parameters are schematically presented in Fig. 2 (the dark rectangle is the object; the light polygon is the shooting capture).

The criterion of the optimum covering of the observation object is the minimum value of a difference between the covering area and the object area.

It is necessary to find the values of the shooting parameters providing the optimum covering of the observation object. To solve this optimization problem the evolutionary algorithm described above is applicable.

A herewith, previously it is necessary to implement the representation of the subject domain of the optimization problem using the evolutionary algorithm terminology. The required decision of the optimization problem of the covering with the shooting of the observation object can be presented in the form of a chromosome in which the parameters, such as the latitude and the longitude of the initial shooting point, the shooting start time, the shooting duration, the image motion speed and the azimuth, which are the points in the search space, are coded.

The population with n decisions can be written down as:

$$\begin{aligned} &P_1 = \left(nshir_1, ndolg_1, ontel_1, dlit_1, sdi_1, azim_1\right), \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &P_n = \left(nshir_n, ndolg_n, ontel_n, dlit_n, sdi_n, azim_n\right), \end{aligned} \tag{1}$$

where P_i is the *i*-th chromosome ($i = \overline{1, n}$); $nshir_i$ is the latitude of the point of the shooting start; $ndolg_i$ is the longitude of the point of the shooting start; $ontel_i$ is the time of the shooting start; $dlit_i$ is the shooting duration; sdi_i is the speed of the image motion; $azim_i$ is the azimuth; *n* is the population size.

For each gene in the chromosome P_i ($i = \overline{1, n}$) according to the restrictions imposed by the subject domain of the optimization problem the range of the permissible parameters values are defined as:

- $61 < nshir_i < 62.6$;
- $-165 < ndolg_i < -162$;
- $7888150 < ontel_i < 7888200$;

- $5 < dlit_i < 15$;
- $45 < sdi_i < 75$;
- $0 < azim_i < 360$.

If the latitude and the longitude of the initial shooting point, the shooting start time, the shooting duration, the speed of the image motion and the azimuth will be considered as the genes (the atomic elements of a genotype), then the respective set (option) of the values of the shooting parameters will represent the phenotype.

Then, the aim of the evolutionary algorithm is the search of the optimum values of the shooting parameters: $nshir$, $ndolg$, $ontel$, $dlit$, sdi, $azim$.

In solving the optimization problem of the covering with the shooting system of the observation objects using the evolutionary algorithm it is expedient to apply:

• the several populations of the fixed size;

• the fixed size of population corresponding to the number of the decisions of the optimization problem representing the sets of the values of the shooting parameters;

• the fixed length (digit capacity) of chromosomes, equal to six, to match the number of the optimized parameters;

• the identical combinations of strategies of selection and formation of the next generation in the each population;

• the random selection of chromosomes for the crossing;

• the single-point crossover (crossing) and the single-point mutation.

In implementing the crossing in the evolutionary algorithm, at first, the random choice of parents (two chromosomes) is carried out, then the crossing point is randomly selected and, at last, the crossing (exchange of parts) of chromosomes-parents and receiving two chromosomes-descendants is performed.

In implementing the mutation in the evolutionary algorithm, at first, the mutation point for some chromosome-parent is randomly selected, and then the mutation and receiving the chromosome-descendant is performed.

Periodically (for example, through the assigned number of iterations of the evolutionary algorithm) the accidental exchange of chromosomes between the populations is made, that allows implementing the different type of the parallel evolutionary algorithm having some properties of the island model of the genetic algorithm.

The island model assumes the existence of the several populations of the identical fixed size; the fixed digit capacity of chromosomes; the possibility to use any combinations of the selection strategies and forming of generations in populations; the absence of the crossing and the mutation restrictions; the random exchange of chromosomes between the populations.

The analysis of the subject optimization problem of the covering with the shooting system of the observation objects, shows that initially the formula for the fitness function can be written down as:

$$S_s - S_{ob} \to \min, \qquad (2)$$

where S_s is the shooting area, S_{ob} is the object area.

It is necessary to provide the maximum approximation of the shooting area to the area of the observation object so that vertices of the observation subject were in the borders of the optimum shooting, and the shooting area differed from the area of the observation object at the minimum value. Therefore, the specified formula for the fitness function takes the form:

$$\left(S_s - S_{ob}\right) + N \cdot N_{kr} \to \min, \tag{3}$$

where S_s is the shooting area, S_{ob} is the object area; N is the number of vertices, which do not fall into the shooting boundaries; N_{kr} is the numerical value, which is much greater than the difference of areas and is required to achieve the significant deterioration in the fitness function in the case of non-compliance of condition of hit of all vertices of the object in the shooting area.

As the difference of the area of shooting and the area of the observation object will strive for the minimum value of the square kilometers, it is possible to accept the numerical value N_{kr} equal to 100000, that will allow increasing the difference of the areas of hundreds of times and will provide the rejection of decisions in which not all vertices of the object are captured.

As the shooting area must to cover the area of the observation object, it is necessary to provide the performance of the condition of positivity for the fitness function:

$$((S_s - S_{ob}) + N \cdot N_{kr}) > 0. \tag{4}$$

The optimization evolutionary algorithm of the covering with the shooting system of the observation objects can be described by the following sequence of steps.

1. To form *M* initial *n*-size populations with the chromosomes P_i $(i = \overline{1, n})$.

2. To make the random choice of the chromosomes parents from populations, if the current number g of iterations of the evolutionary algorithm iterations is less than the maximum number G of iterations, and then to the go to the step 3 is carried. To go to the step 6, if maximum number G of iterations is achieved.

3. To make the crossing and mutation operators in each population, if the current number g of iterations is not a multiple of some number I ($I < G$). To choose randomly from *M* populations T $(T \le M/2)$ pairs of populations, if the current number g of iterations is a multiple to number *I*, to create in the each pair of populations the pair of chromosomes with the best values of the fitness function, and to apply the crossing operation for this pair of chromosomes.

4. To form the intermediate population from the parents and the descendants. To calculate for each chromosome the value of the fitness function calculating using the formula (2) and to check the restriction (3).

5. To form the new n-size population by an exception of chromosomes with the worst values of the fitness function. To go to the step 2.

6. To choose the “best” chromosome (with the smallest value of the fitness

function (2)), which defines the set of the parameters values. To output the received set of the parameters values.

When the execution of the evolutionary algorithm is over it is recommended to use the decision received by means of this algorithm (the set of the found values of the shooting parameters values) or to increase the number of iterations of the evolutionary algorithm for the further search.

The calculation with the use of the offered evolutionary algorithm of the optimum values of the shooting parameters for the observation objects for the specified set of the values of the initial parameters and specified set of the values of the restrictions was done.

Herewith, we used following data: the set of the initial values of the shooting parameters (Tab. 1); the restrictions imposed on the values of the shooting parameters (Tab. 1); the number of iterations of the evolutionary algorithm – 1000; the errors of achievement of a minimum of the fitness function – 0.0001; the number of populations – 2; the number of descendants in the crossing operators – 2; the population size – 20.

The boundaries of the shooting calculated with the use of the found optimum values of the shooting parameters are schematically presented in fig. 3 (the dark rectangle is the object; the light polygon is the shooting capture).

The dependency of the values of the fitness function on the number of iterations of the evolutionary algorithm is presented in fig. 4. Herewith, the improvement (decreasing) of the fitness function in the case of increasing of the iteration number is shown.

The obtained results demonstrate the feasibility of application of the evolutionary algorithm for solving the optimization problem of the covering with the shooting of the observation object when the difference between the area of the object and the area of the shooting shall be minimum and the area of the shooting shall cover the area of the object with the specified number of iterations of the algorithm.

Fig. 3. The boundaries of the shooting, according to the calculated optimal values of the parameters

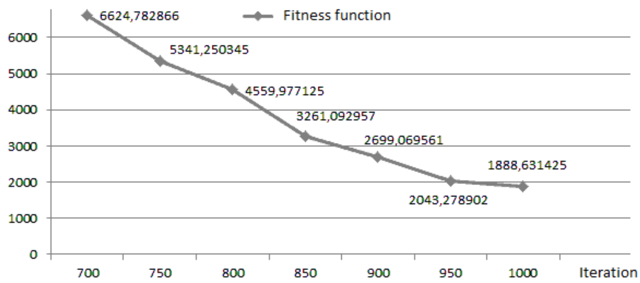

Fig. 4. The dependency of the values of the fitness function on the number of iteration

4 Conclusions

The developed software optimization system based on the evolutionary algorithm is the instrument of searching of the optimum parameters values of the shooting system thanks to the representation of the optimization problem in the form of the model of the subject domain integrated into the evolutionary algorithm. Herewith, it is interesting to consider the possibilities of application, in particular, of the particle swarm optimization algorithm [4] in the context of solving the optimization problem as individually as in a hybrid, for example, with the genetic algorithm.

The reviewed practical example of the optimization problem of the covering with the shooting system of the observation object clearly shows the possibilities of the offered software optimization system and the prospects of its further development.

Improvement of the evolutionary algorithm in the context of the shooting optimization can be executed by means of modernization of the strategy and the way of generation of the populations and descendants, and, also, by means of selection of the optimum number of populations and the optimum number of descendants.

The shooting results, in particular, can be applied for the problems of the image segmentation [5] and the objects identification [6].

The purpose of the further researches on application of the evolutionary approach is the development of the model of the subject domain of the problem of the optimum planning of the shooting for the objects group with the acceptable time expenditures with these or those optimization criteria of the shooting (the capture of the bigger number of objects, the minimization of the shooting costs, etc.).

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