Evolutionary Algorithm for the Problem of Parameters Optimization of Complex Technical Systems

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Abstract – **The problem of parameters optimization of complex technical systems has been considered and the possibility of application of the evolutionary algorithm for its decision has been investigated. The scheme of optimization system functioning based on the evolutionary algorithm has been resulted. The algorithm of the optimization problem decision based on the evolutionary approach is offered. The example of application of the offered algorithm for the problem of the shooting planning of the objects' group with the acceptable time expenditures with some criteria of the shooting optimization has been given.**

***Keywords** – technical system, optimization, parameter, evolutionary approach, evolutionary algorithm.*

I. INTRODUCTION

The purpose of this research is the application of evolutionary approach to the problem of parameters optimization of complex technical systems by means of development of the software tool containing the mathematical models and the evolutionary algorithms and providing the search of the optimum parameter values of the optimization problem, which must satisfy to the large number of requirements and restrictions, with the acceptable time expenditures.

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

II. THE EVOLUTIONARY APPROACH TO THE OPTIMIZATION PROBLEM

Evolutionary approach to specific optimization problems 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].

It is possible to mark out four main aspects which must be considered at the solution of the practical problems by means of the evolutionary algorithms:

- choice of a way of the decision representation (coding);
- choice (development) of the evolutionary operators;
- determination of laws of the decision survival;
- generating of the initial decision population.

The universality of the evolutionary approach is that only criteria of search depend on the specific optimization problem. All other actions in the case of application of the evolutionary algorithms for the optimization problems are realized similarly, but with the use of various evolutionary operators [2].

In the case of application of the evolutionary approach it is possible to present an optimization problem in the form of the subject domain model integrated into the evolutionary algorithms. The subject domain model is understood as the representation of the set of the problem parameters, and also the criterion of its optimization in the form, acceptable for the use of the evolutionary algorithm.

III. THE OPTIMIZATION SYSTEM BASED ON THE EVOLUTIONARY ALGORITHM

The key input parameters of optimization system based on the evolutionary algorithm are the following: the number of the optimization parameters with the ranges of their possible changes, the fitness function, the population size, the number of populations, the initial values of the crossing probability and the mutation probability, the number of iterations of the evolutionary algorithm for the fitness function calculation.

As any evolutionary algorithms, the evolutionary strategies assume the generating of the initial population of chromosomes which is exposed to selection and the evolutionary operators impact to get the most adapted chromosomes.

The diagram of the optimization system based on the evolutionary algorithm is represented in Fig. 1.

The connection lines between the blocks on the diagram implement the following functions:

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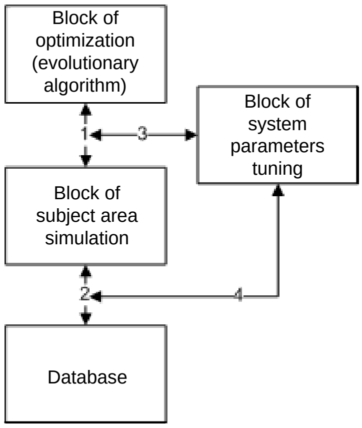

Figure 1. The diagram of the optimization system based on the evolutionary algorithm

- the connection 1 is the search of the decision on the base of the evolutionary algorithm;
- the connection 2 is the subject domain data presentation and the transfer of the received optimized parameter values by means of the optimization block;
- the connection 3 is the determination of the evolutionary algorithm search strategy;
- the connection 4 is the transfer of the optimized parameters values in the database by the evolutionary algorithm.

IV. The Evolutionary Algorithm for Solving the Optimization Problem

The evolutionary algorithm for solving the optimization problem is represented in Fig. 2.

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 mustl 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.

V. The Problem of the Shooting Planning of the Observation Object

For the functional testing of the evolutionary algorithm and the software optimization system the practical optimization problem of the covering with the shooting system of the observation objects was considered.

Previously, the planning of shooting of the observation objects was made for the chosen area with the purpose of receipt of the initial parameters values of the shooting of the observation objects.

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.

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

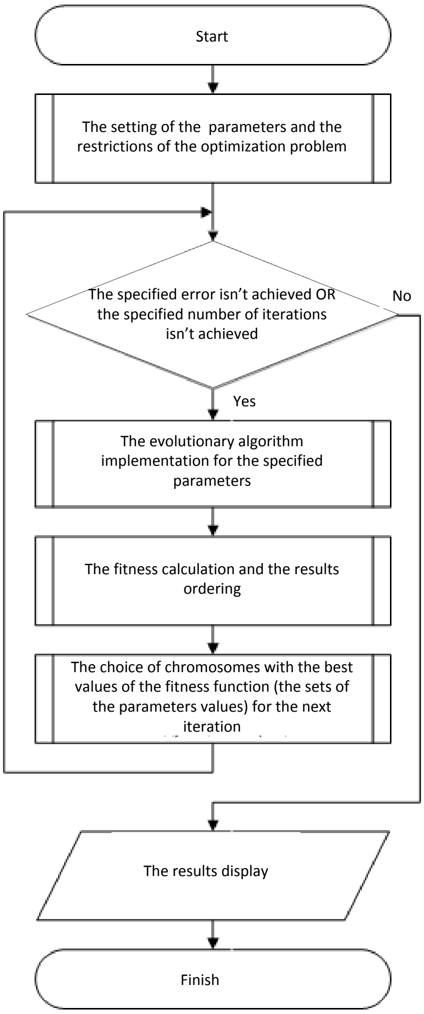

Figure 2. Evolutionary algorithm to solve the optimization problem

- 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.

When 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.

When 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 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:

$$S_s - S_{ob} \to min, \qquad (1)$$

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:

$$\left(S_s - S_{ob}\right) + N \cdot N_{kr} \to min, \qquad (2)$$

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:

$$((S_s - S_{ob}) + N \cdot N_{kr}) > 0. \qquad (3)$$

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.

The dependency of the values of the fitness function on the number of iterations of the evolutionary algorithm is presented in Fig. 3. A 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.

VI. Conclusions

The developed software optimization system based on the evolutionary algorithm is the instrument of searching of the optimum parameters values of the complex technical systems thanks to the representation of the optimization problem in the form of model of the subject domain integrated into the evolutionary algorithm. A 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.

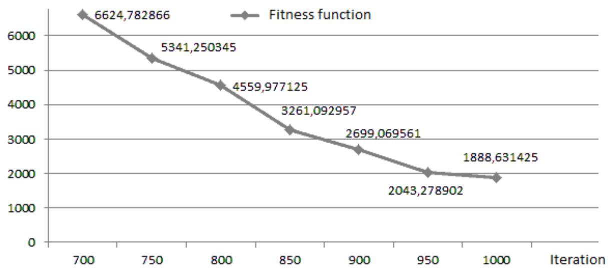

Figure 3. The dependency of the values of the fitness function on the number of iteration

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.

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

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