

# Approach to the problem of the parameters optimization of the shooting system

L A Demidova<sup>1,2\*</sup>, O R Gazizova<sup>1</sup> and N A Petrova<sup>3</sup>

<sup>1</sup>Ryazan State Radio Engineering University, Ryazan, Russia

<sup>2</sup>Moscow Technological Institute, Moscow, Russia

<sup>3</sup>Branch of JSC „SRC „Progress” – Special Design Bureau „Spectr”, Ryazan, Russia

\*E-mail: demidova.liliya@gmail.com

**Abstract.** The problem of the parameters optimization of the shooting system has been considered and the possibility of application of the evolutionary algorithm for its decision has been investigated. It is offered to use the evolutionary algorithm to achieve an extremum of the fitness function under some additional restrictions. The scheme of optimization system functioning based on the evolutionary approach is resulted. The algorithm of the optimization problem decision based on the evolutionary approach is offered. Also, the idea of hybridization of the proposed evolutionary algorithm and the differential evolution algorithm is presented. This hybridization will allow reducing the time expenditures for the desired solution receiving. The example of application of the offered evolutionary approach for the problem of the parameters optimization of the shooting system for the observation object has been given.

## 1. Introduction

The purpose of this research is the application of evolutionary approach to the problem of 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. A 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.

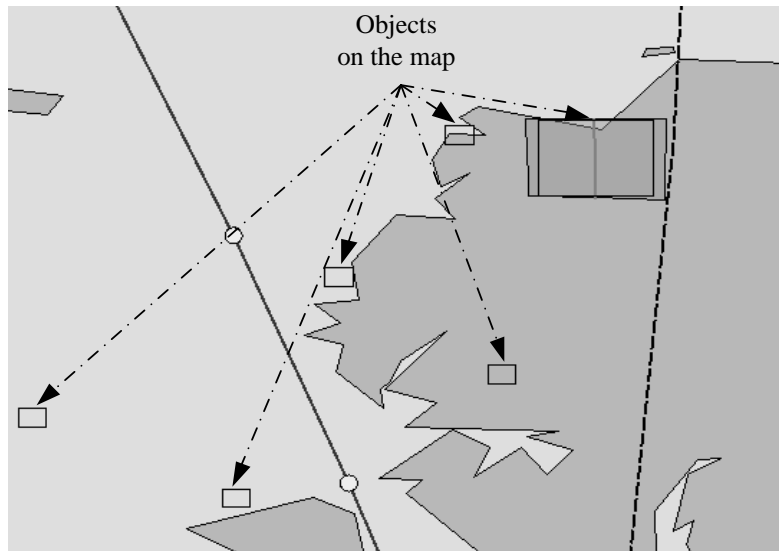
For the problem of the parameters optimization the use of the evolutionary approach, representing the perspective and dynamically developing direction of the intellectual data processing under the acceptable time expenditures, provides the possibility of the required decision finding with the minimum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

Figure 1 shows the simulated group with 6 objects and the result of optimization of the biggest informative object. Further the aspects of the parameters' optimization of the shooting system for the chosen object will be considered.



## 2. The optimization system based on the evolutionary algorithm

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].



**Figure 1.** The group of objects and the result of optimization of the chosen object

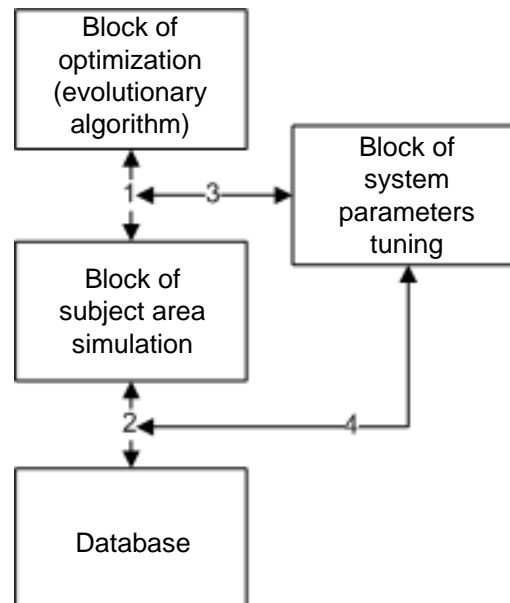
In the case of application of the evolutionary approach it is possible to present an optimization problem in the form of the subject domain model integrated into the evolutionary algorithms. The subject domain model is understood as the representation of the set of the problem parameters, and also the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

The diagram of the optimization system based on the evolutionary algorithm is represented in figure 2. The connection lines between the blocks on the diagram implement the following functions:

- 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.

The software optimization system based on the evolutionary algorithm provides:

- the search of the sets of the parameters values of the optimization problem according to the subject domain model;
- the determination of the set of the “best” parameters values of the optimization problem among all decision composition received for a certain number of iterations;
- the work with the database on extraction of the initial information and the transfer of the obtained data.



**Figure 2.** The diagram of the optimization system based on the evolutionary algorithm

### 3. The evolutionary algorithm for solving the optimization problem

The evolutionary algorithm for solving the optimization problem is represented in figure 3.

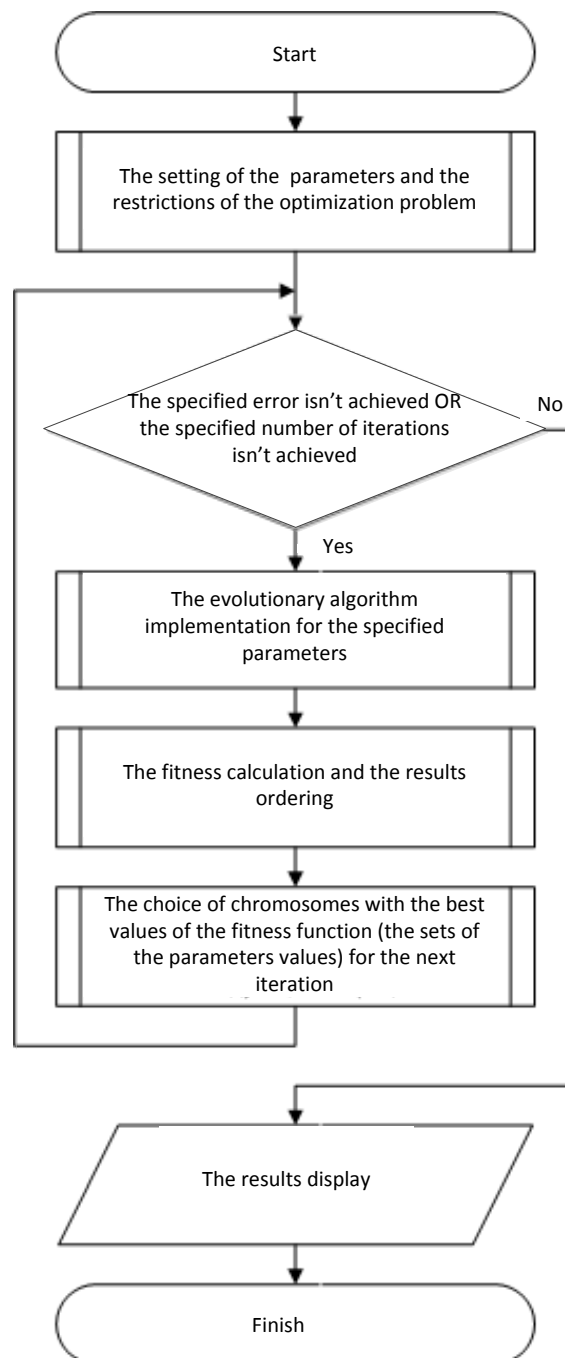
The block of the algorithm called as “The setting of the parameters and the restrictions of the optimization problem” represents a problem definition stage at which it is necessary:

- to set the variation ranges of the parameters of the optimization problem;
- 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 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.



**Figure 3.** The evolutionary algorithm to solve the optimization problem

#### 4. The shooting planning of the observation object

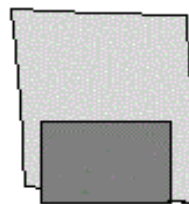
For the functional testing of the evolutionary algorithm and the software optimization system the practical optimization problem of the covering with the shooting system of the observation objects was considered.

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 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)

The boundaries of the shooting calculated with the use of the initial values of the shooting parameters are schematically presented in figure 4 (the dark rectangle is the object; the light polygon is the shooting capture).



**Figure 4.** The boundaries of the shooting, according to the calculated initial values of the parameters

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:

[illegible]

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 image motion speed 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:  $nshir$ ,  $ndolg$ ,  $ontel$ ,  $dlit$ ,  $sdi$ ,  $azim$ .

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 [5]:

- 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 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:

$$S_s - S_{ob} \rightarrow \min, \quad (2)$$

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:

$$(S_s - S_{ob}) + N \cdot N_{kr} \rightarrow \min, \quad (3)$$

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:

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

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  $T$  ( $T \leq M/2$ ) 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 (3) and to check the restriction (4).
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 (3)), 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 boundaries of the shooting calculated with the use of the found optimum values of the shooting parameters are schematically presented in figure 5 (the dark rectangle is the object; the light polygon is the shooting capture).



**Figure 5.** The boundaries of the shooting, according to the calculated optimal values of the parameters

In the figure 6 the dialog box of a program system of optimization on the basis of an evolutionary algorithm containing sets of values of the optimized parameters 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.



Nº	nshir	ndolg	ontel	clit	sdi	azim	critery
1	61.816773	-163.255575	7888186.670213	9.363442	46.3462000000	148.5623520000	<b>418715.7100570000</b>
2	61.818249	-162.823117	7888157.266762	8.154576	67.5397480000	279.6447270000	<b>407836.2113080000</b>
3	62.504235	-162.480783	7888195.047214	7.304150	71.8934460000	285.4823840000	<b>315983.4104090000</b>
10	61.855858	-164.277911	7888150.000000	7.808385	75.0000000000	360.0000000000	<b>306721.1514520000</b>
25	62.514322	-163.385874	7888167.129805	7.336645	48.8520060000	129.9758580000	<b>304702.9382410000</b>
33	62.065589	-163.341501	7888158.894363	14.730092	71.7532770000	20.5389080000	<b>224191.2960920000</b>
36	62.118106	-163.041501	7888153.918413	15.000000	74.7540120000	0.0000000000	<b>123294.7567710000</b>
37	62.121650	-163.027151	7888150.000000	15.000000	75.0000000000	0.0000000000	<b>122673.7145140000</b>
64	61.738804	-163.309796	7888190.324009	14.999542	74.9999360000	0.0000000000	<b>40492.5442300000</b>
68	61.908213	-163.265190	7888184.717135	15.000000	74.2594840000	0.0000000000	<b>35498.0617800000</b>
88	62.138298	-162.898079	7888196.581075	15.000000	57.4098750000	0.0000000000	<b>33414.8396480000</b>
90	62.125523	-163.211028	7888198.104074	14.753217	53.5008270000	0.0000000000	<b>30958.9335550000</b>
95	62.103974	-163.167388	7888179.090719	15.000000	49.2356210000	7.0135780000	<b>20206.3263300000</b>
97	62.127923	-163.166698	7888179.457011	15.000000	48.2390300000	7.2525360000	<b>19754.8110080000</b>
131	61.901521	-163.195808	7888174.880735	15.000000	48.1051140000	7.0684070000	<b>18749.5530950000</b>
149	62.188046	-163.878543	7888182.335692	15.000000	45.0000000000	25.8839130000	<b>18657.0021780000</b>
152	62.306716	-163.427403	7888168.289559	15.000000	53.6290040000	15.3226360000	<b>17910.9289600000</b>
167	62.124908	-163.224806	7888181.042297	13.443936	48.6072960000	0.0000000000	<b>17070.0463590000</b>
221	61.938540	-163.100831	7888164.921802	12.721874	58.9198280000	3.4721340000	<b>15906.1941750000</b>
222	62.123653	-163.482754	7888162.606270	12.515203	57.2464630000	11.7791860000	<b>13923.8397460000</b>
224	61.982604	-163.161357	7888169.366041	14.077281	45.3399530000	0.0000000000	<b>13755.9515210000</b>
233	61.985274	-163.173268	7888169.306965	14.073842	45.4150190000	0.0065520000	<b>13741.5476530000</b>
247	62.221774	-163.129564	7888153.953973	12.913411	48.5367010000	0.0000000000	<b>9574.6553220000</b>
253	62.225932	-163.060849	7888160.699695	12.467293	45.0000000000	0.0000000000	<b>8815.7210630000</b>
258	62.304696	-163.178060	7888155.549695	12.162382	45.0000000000	0.3804950000	<b>7455.0224630000</b>
282	62.352688	-163.258505	7888150.233818	11.461740	45.0000000000	0.0000000000	<b>5794.5432690000</b>
304	62.329513	-163.246263	7888150.000000	11.247300	45.0000000000	0.0000000000	<b>5490.5681300000</b>
320	62.444091	-163.152520	7888158.627272	10.200376	45.0000000000	1.6319570000	<b>5191.9325600000</b>
360	62.429137	-163.135614	7888157.185106	9.909490	45.0000000000	1.6148180000	<b>4737.8583300000</b>
370	62.433325	-163.123473	7888156.797799	9.568921	45.0000000000	1.3670490000	<b>4382.0959170000</b>
415	62.447246	-163.134960	7888155.977683	9.218921	45.0000000000	1.2052660000	<b>3638.5422100000</b>
451	62.474317	-163.155690	7888155.001798	8.590308	45.0000000000	0.9687240000	<b>2883.6437040000</b>
485	62.491403	-163.154547	7888153.611036	8.706600	45.3608740000	1.0634660000	<b>2856.8779820000</b>
555	62.499137	-163.168288	7888154.921723	8.284917	45.0000000000	0.9485360000	<b>2541.2611400000</b>
622	62.511109	-163.182943	7888150.000000	8.366665	45.0000000000	0.6587600000	<b>2194.7998160000</b>
751	62.514427	-163.183399	7888150.000000	8.136138	45.0000000000	0.6917650000	<b>1891.7579870000</b>
875	62.514326	-163.186968	7888150.001363	8.065554	45.0000000000	0.7031500000	<b>1888.7377550000</b>
1025	62.515149	-163.187151	7888150.000000	8.075942	45.0000000000	0.7091540000	<b>1888.5250950000</b>

**Figure 6.** The dialog box of the program system of optimization on the basis of the evolutionary algorithm containing the sets of values of the optimized parameters

Application of the program system for optimization the values of parameters of shooting has allowed to reduce initial value of the optimization criterion (3) more, than by 221,7 times.

The execution of 1025 iterations was performed in 34 seconds using the computer on the basis of Intel Core i7 processor with a clock speed of 3.07 GHz and RAM of 1.99 GB.

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. A herewith, the realization of technologies of self-adapting of the evolutionary algorithm is of considerable interest.

In addition, it is expediently to implement the hybridization of the already existing evolutionary algorithm with the differential evolution (DE) algorithm [6–8]. Nowadays, books have been published on theoretical and practical aspects of using DE in parallel computing, multiobjective optimization, constrained optimization, and the books also contain surveys of application areas. A basic variant of the DE algorithm works by having a population of candidate solutions (agents). These agents are



moved around in the search-space by using simple mathematical formulae to combine the positions of existing agents from the population. If the new position of an agent is an improvement it is accepted and forms part of the population, otherwise the new position is simply discarded. This algorithm is easier to implement than the evolutionary one.

In the DE algorithm, the source of noise is not the external random number generator, but the “internal” generator, realized as the difference between randomly chosen vectors of the current population.

In case of falling into a ravine, the “cloud” of solutions takes the form of this ravine and the distribution of points becomes such that the mathematical expectation of the difference of two random vectors turns out to be directed along the long side of the ravine. This ensures the rapid movement along the narrow elongated ravines. An important feature of the DE algorithm is the ability to dynamically simulate the features of the topography of the optimized function, adjusting the distribution of the “built-in” noise source for them. This explains the ability of the DE algorithm to pass the complex ravines quickly, providing the efficiency even in the case of complex terrain. More advanced DE variants are also being developed with a popular research trend being to perturb or adapt the DE parameters during optimization. We plan to use this algorithm with the evolutionary algorithm simultaneously to find the best solution with the minimal time expenditures. In this case, one part of populations will develop on the basis of the proposed evolutionary algorithm, and the other part will develop on the basis of the DE algorithm. At the beginning, the populations will develop independently from each other for some number of generations, and then they will exchange by the best solutions. This process will be repeated until the algorithm halts. It is proposed to vary the number of populations of each type (evolutionary algorithm type and DE algorithm type) depending on their success in the current generation in the context of minimizing the criterion (3).

## 5. 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 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.

The shooting results, in particular, can be applied for the problems of the image segmentation and the objects identification [4, 9, 10].

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 bigger number of objects, the minimization of costs, etc.).

## 6. References

- [1] Krus P K and Ölvander (Andersson) J 2013 *Engineering Optimization* **45**
- [2] Afonin P V 2009 *Proceedings of the XV-th International Conference “Knowledge-Dialogue-Solution”* **1**.
- [3] Younis A and Dong Z 2010 *Engineering Optimization* **42**.
- [4] Demidova L , Nikulchev E and Sokolova Y 2016 *International Journal of Advanced Computer Science and Applications (IJACSA.)* **7** 16-24.
- [5] Demidova L Petrova N and Nikulchev E 2017 *Contemporary Engineering Sciences* **10** 253-262
- [6] Storn R and Price K 1997 *Journal of Global Optimization* **11**.
- [7] Chakraborty U K 2008 *Advances in Differential Evolution*

- [8] Rocca P, Oliveri G and Massa A 2011 *IEEE Antennas and Propagation Magazine* **53**
- [9] Novikov A I., Yukin S A, Loginov A A, Nikiforov M B, Muratov Y R and Sablina V A 2015 *Proceedings The 5th International Workshop on Computer Science and Engineering (WCSE 2015)*
- [10] Efimov A I, Novikov A I, Sablina V A 2016 *5<sup>th</sup> Mediterranean Conference on Embedded Computing (MECO) Proceedings*. Budva, Montenegro.