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Research Article

Genetic Algorithm Management Process with Artificial Neural Network Application in the Tasks of Imitational Model Structural and Parametric Synthesis of Great Discrete Systems with Set Behavior

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ABSTRACT:
Modern research in the field of artificial intelligence shows the feasibility of evolutionary procedure use in decision support systems within various subject areas. This approach has also proven itself in the problems of structural-parametric synthesis of large discrete systems with a given behavior. The use of genetic algorithms can significantly reduce the time of search for solutions and optimize the existing solutions. However, there is a problem in the simulation model synthesis tuning within large systems using this evolutionary procedure. The problem is associated with the intelligent system speed decrease when the element base of the models changes. This is due to the fact that the settings of operator types and parameters within the genetic algorithm depend on the element base and require manual editing by the expert. In this paper, we propose to consider the process of genetic algorithm management using artificial neural networks. For this purpose, they developed the models of evolutionary method management process using IDEF0 and IDEF3 methodologies. An artificial neural network manages the process of finding solutions by analyzing the population state. They propose to perform the analysis using pattern recognition, which are based on the graphs of minimum or maximum value of the objective function and the number of individuals with the objective function minimum or maximum value. The application of the proposed model will allow to avoid the attenuation of the genetic algorithm, to derive the population from local extremes, etc. Control is achieved by functioning parameter change or by the change of genetic algorithm operator types by their destructive capacity increase or decrease. This approach will allow to adapt the parameters of the genetic algorithm operator work without the involvement of experts in the intervals between the solution of structural-parametric synthesis problems, but also directly in the process of finding solutions. Thus, it is proposed to create a controlled genetic algorithm aimed at synthesis problem solution of large discrete systems with a given behavior.

Keywords: structural-parametric synthesis, evolutionary methods, artificial neural networks, genetic algorithms, large discrete system.

1. INTRODUCTION

The task of genetic algorithm adaptation is a complex process which is associated with the selection of operator types and the parameters of their functioning. Often, this kind of setting is performed by the experts who must have knowledge of evolutionary procedures and the subject area in intelligent decision support systems. The structural and the parametric synthesis of simulation models for large discrete systems is also applied to the tasks in which it is advisable to apply the evolutionary methods of this class [1]. However, these settings may lose their relevance, which may be due to the change in the element base and search criteria. This is related to the attenuation of the genetic algorithm, as well as to the loss of time due to the population falling into local extremes. In this case, the classical approach is the change of operator functioning parameters with the involvement of experts. This approach does not allow the evolutionary procedure to adapt to the search for solutions during the search process and it is rather laborious. Therefore, it is advisable to develop the methods that will allow you to manage the genetic algorithm directly during the search for solutions and during the intervals between them. For this purpose, it is proposed to use the mathematical apparatus of artificial neural networks.

2. *Methodology*

Each operator of a genetic algorithm has a different work type and parameter. At that the destructive ability is the basis for selection. That is, the initial binary line of species population can be modified to a greater or a lesser degree. Thus, when a population moves in a solution space, it is possible to control the trajectory by changing the rules of operator work. It is possible to use the neural network approach for this.

2.1 *Genetic Algorithms*

In modern research, the following main areas are distinguished in the field of genetic algorithms: canonical, genitor, intermittent equilibrium method, hybrid algorithm, SNS (Cross-population selection, Heterogeneous recombination and Cataclysmic mutation).

It is worth noting the parameters and the order of their operator operation as the main differences in this classification:

1. Operator selected by parents: panmixia; inbreeding; outbreeding; tournament selection; roulette selection.
2. Crossing-over operator: single point; two-point; multipoint; uniform crossing-over; triad crossing over; permutation crossing over; the crossing-over with fewer replacements.
3. Mutation operator: the increase of mutation likelihood; the reduction of mutation likelihood; binary mutation; mutation density change; a random gene attachment; a random gene insertion; a random gene deletion; the exchange by places.
4. Species selection operator for a new population: the selection by truncation; elite selection; the selection by displacement; annealing method (Boltzmann method).

Thus, one can state that the transition from one type of genetic algorithm to another is possible during the search for solutions, since the general structure of the evolutionary procedure does not change, that is they change only the working order, the type of operator used and the parameters of operator functioning.

2.2 *Artificial neural networks*

The mathematical apparatus of artificial neural networks is considered as an intellectual tool that is proposed to be used in this work. This tool has proven itself during the solution of management problems and pattern recognition. As well as the genetic algorithm, the neural network approach has received a large number of extensions and research trends [2, 3].

This paper proposes the use of such a class of networks as RAAM (Recursive Auto-Associative Memory) - Ellman's double network [4]. Such a network should be trained to recognize the state of the genetic algorithm on the basis of visualization, that is, lead to the solution of the “classical” problem.

3. *Problem solution*

3.1 *Problem statement*

It is required to describe the management processes by an adapted genetic algorithm using an artificial neural network, so that it is possible to control this process when you carry out the structural-parametric synthesis of large discrete system models with a given behavior.

3.2 The models of genetic algorithm control process

In order to solve the problem, it is advisable to consider the genetic algorithm through the parameters of its operators:

$$GA = \langle Psel_i, Tsel_j, Pcross_u, Tcross_r, Pmut_k, Tmut_l, Pred_o, Tred_m \rangle$$
,

where

- $Psel_i$ – the i-th parameter of the operator functioning;
- $Tsel_j$ – the j-th type of operator selection;
- $Pcross_u$ – the u-th parameter of the crossing operator functioning;
- $Tcross_r$ – the r-th type of the crossing operator;
- $Pmut_k$ – the k-th parameter of mutation operator functioning;
- $Tmut_l$ – the l-th type of mutation operator;
- $Pred_o$ – the o-th parameter of the reduction operator functioning;
- $Tred_m$ – the m-th type of reduction operator.

Based on this view, it is required to develop the models of genetic algorithm management process using the neural network approach.

IDEF0 and IDEF3 methodologies were used to build the models.

Figure 1 shows the context diagram of the process describing a controlled genetic algorithm.

As input parameters for this process, it is proposed to use the following ones:

- "Element base" (the models of elements on the basis of which the procedure of intellectual synthesis of a large discrete system with a given behavior will take place);
- "Search parameters" (tuple: input vectors, output vectors, intermediate states)

They consider the following as management:

- "SEL operator types" (the selection of parents);
- "Operator parameters" SEL;
- "Cross operator types" (crossing);
- "Cross operator settings";
- "MUT operator types" (mutation);
- "MUT operator parameters";
- "RED operator types" (reduction);
- "RED operator parameters";
- "Management Rules" (the set of rules that allow you to select a desired control signal).

The following mechanisms are proposed:

- "Artificial Neural Network";
- "Intellectual system";
- "Expert".

"Search Results" are in the end of the considered process.

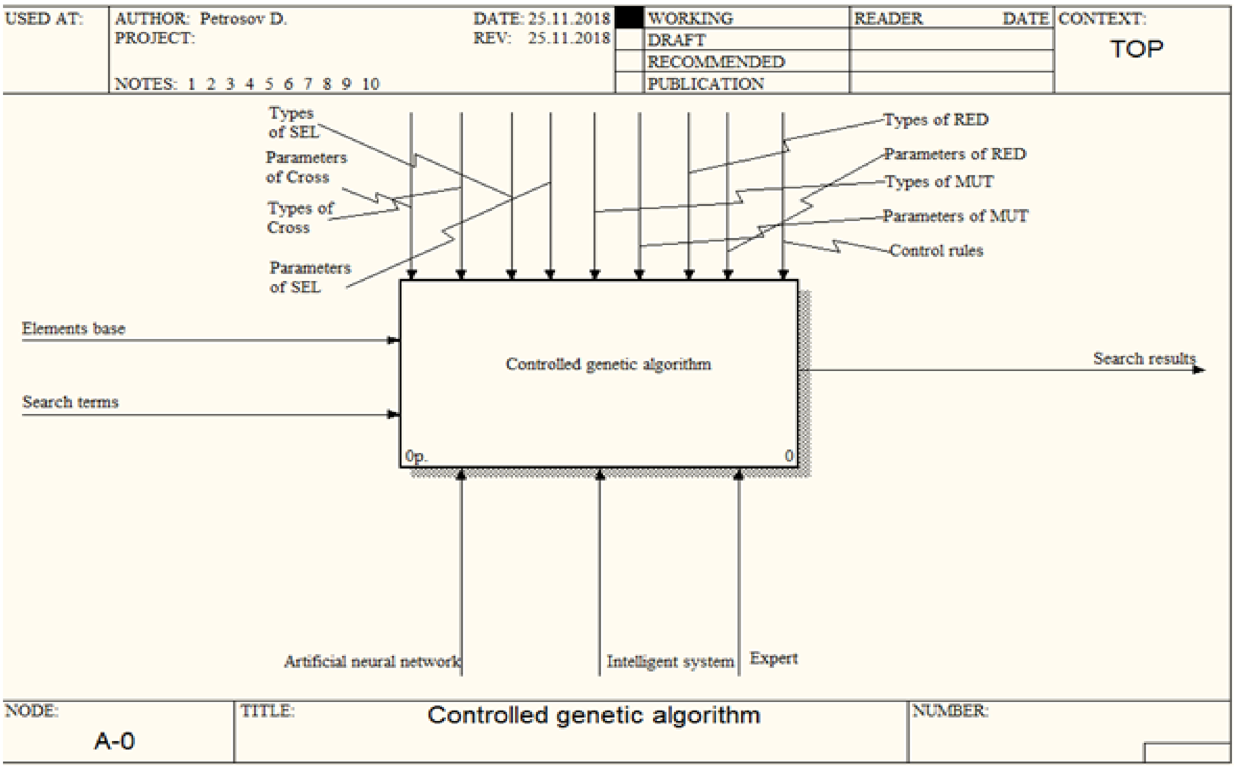

Figure 1 - The context diagram of the controlled genetic algorithm

The decomposition of this process is shown on Figure 2.

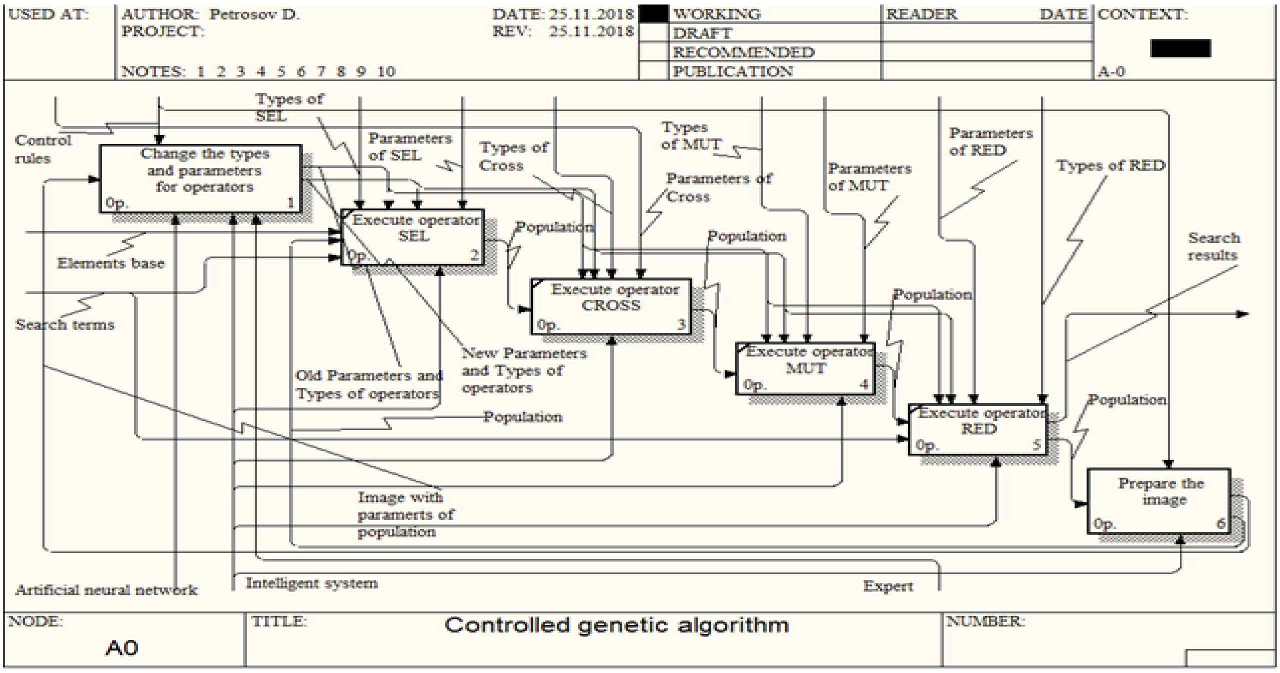

Figure 2 – The decomposition of the controlled genetic algorithm process

In this model they proposed to consider the controlled genetic algorithm through the following subprocesses:

- "To change the types and the parameters of operator functioning";
- "Run SEL";
- "Run CROSS";
- "Run MUT";
- "Run RED";
- "To perform image preparation".

The main difference from the classical representation of the genetic algorithm is the presence of two processes: "The change of operator functioning types and parameters" and "To perform image preparation". The first is the process of image preparation. It generates an image that displays the population state (the process decomposition is shown on Figure 3).

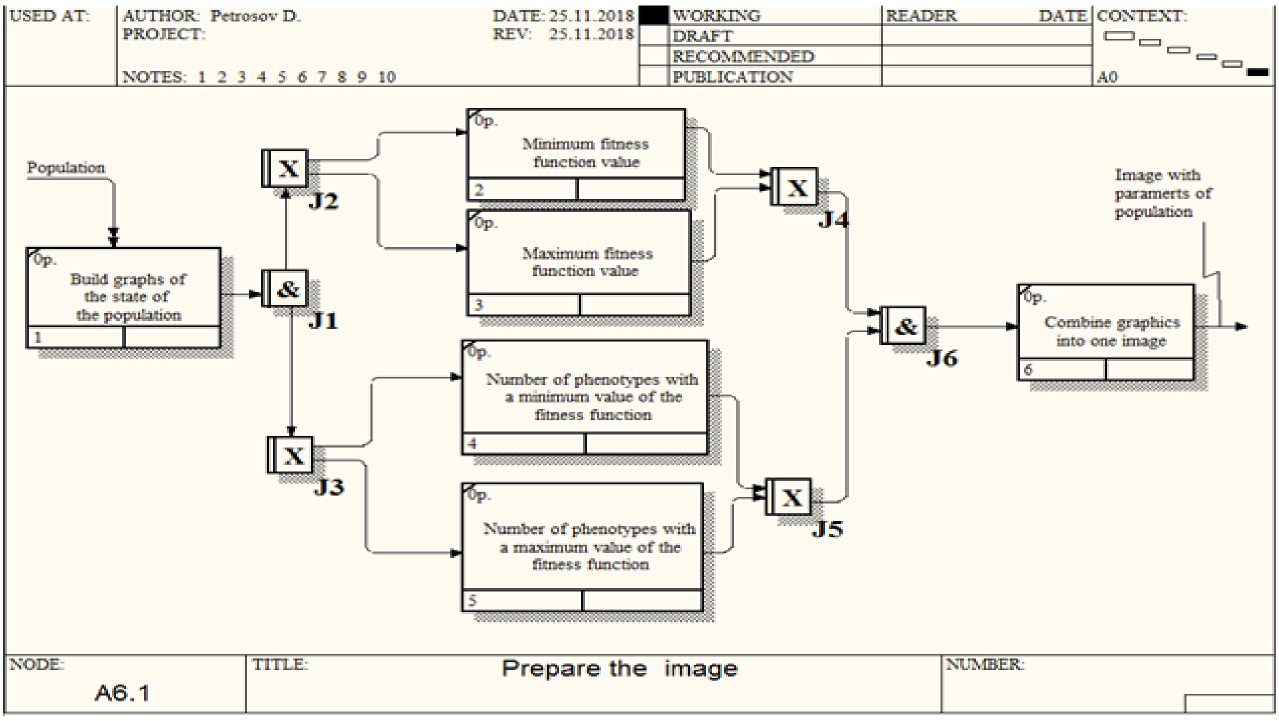

Figure 3 – The decomposition of the process "Prepare an image"

The task of this process is to prepare an image, on the basis of which Elman's artificial neural network will decide on the change of operator functioning types or parameters of the controlled genetic algorithm.
Figure 4 shows a prepared image example. The image consists of two parts: in the upper part the graph demonstrates the minimum values of the objective function, in the lower part - the number of individuals with the minimum value of the objective function. This figure allows the neural network to assess the population state. As can be seen from the figure, there is the tendency of convergence in the genetic algorithm, since the number of individuals with the minimum value of function (equal to zero) increases.

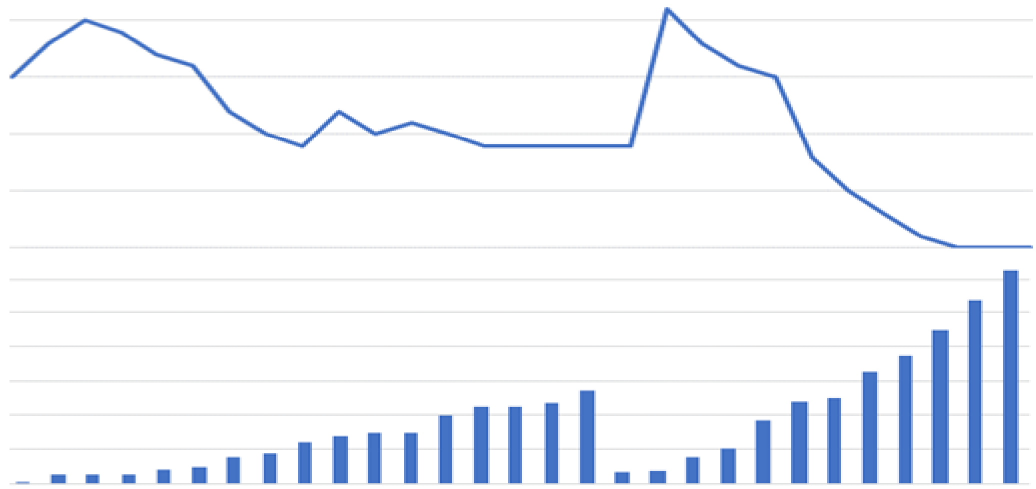

Figure 4 - The example of a prepared image for Elman's neural network (the tendency to convergence)

Figure 5 shows the image on the basis of which the neural network must decide to change the parameters of genetic algorithm operator work.

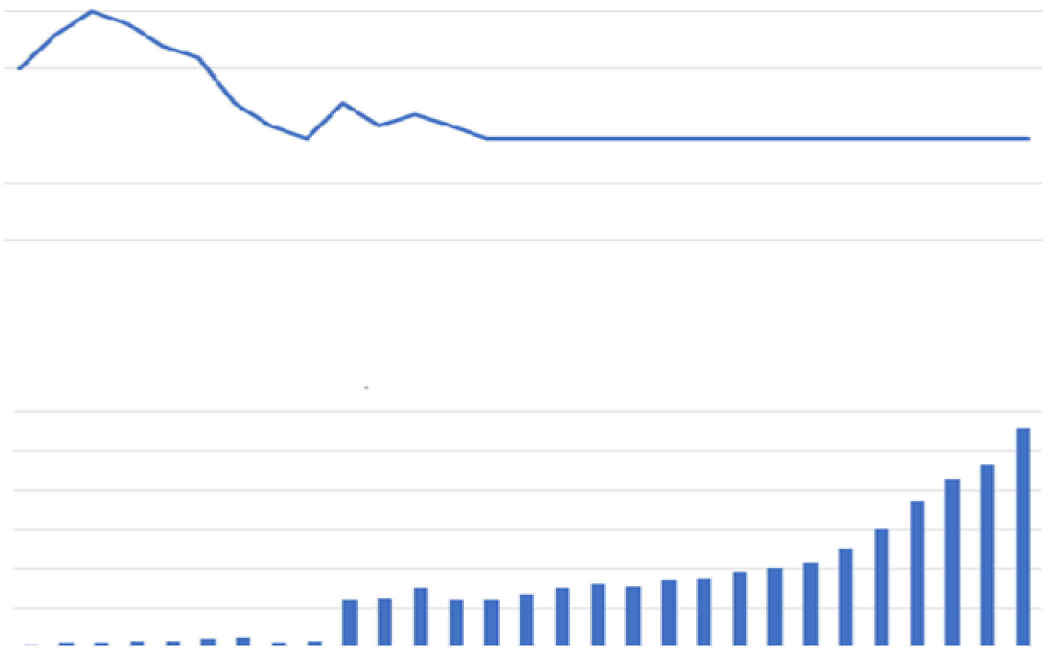

Figure 5 - The example of the prepared image for Elman's neural network (genetic algorithm attenuation)

The attenuation tendency is determined by the network, since the number of individuals with a minimum fitness function value other than zero increases, and the very minimum fitness function value is not changed during the processing of a large number of populations.
Figure 6 shows the decomposition of another subprocess: “Change the types and the parameters of operator functioning”.

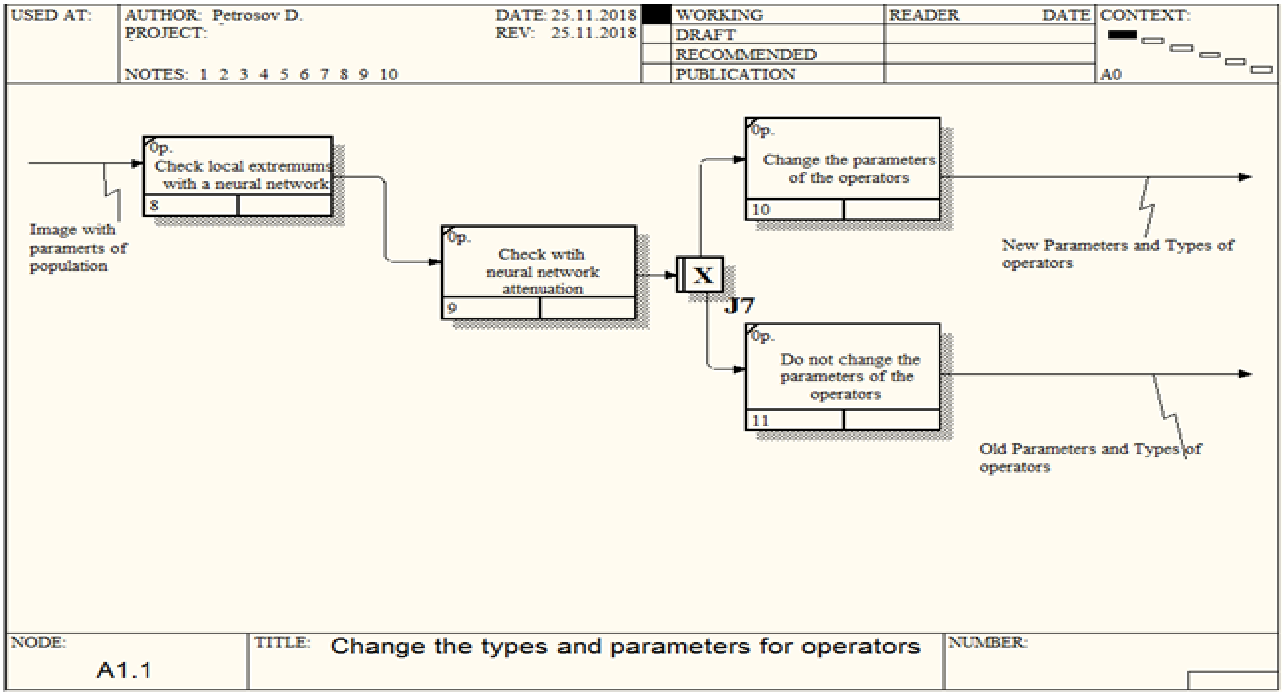

Figure 6 – The decomposition of the process "Change operator types and parameters"

Thus, on the basis of the prepared image, using the neural network and under the rules of change concerning genetic algorithm operator functioning parameters, it will be decided to change the parameters or (if no fading trends or local extremes are detected and the convergence rate is satisfactory) to leave the parameters unchanged.

4. DISCUSSION

As can be seen from the abovementioned models, there is the possibility of a controlled genetic algorithm development. At that, the control can be carried out directly in the process of finding solutions not only during the solution of structural-parametric synthesis problem, but also during the solution of other classes of problems. To this end, it is advisable to study various states of the genetic algorithm using simulation tools and a number of computational experiments. Based on the data obtained, an alphabet should be created from the obtained images and change rules should be prepared for the parameters of the evolutionary procedure. On the basis of the obtained data, it is required to develop a neural network of RAAM class, which should be trained the genetic algorithm management during the search process. It is advisable to describe all the models with a single mathematical apparatus; for this purpose, the use of Petri net theory is recommended, which has a large variety of permissions [5] that facilitate the description of the neural network approach, genetic algorithms and element base. Since all the presented tools have the property of parallelism, it is possible to use GPGPU technology (General-purpose computing for graphics processing units) [6, 7], which in its turn will improve the performance of intelligent decision making support systems.

5. CONCLUSION

The main result of this work is to create the models of a controlled genetic algorithm using IDEF0 and IDEF3 methodologies. They considered the main processes that occur during the solution of this class of problems. Control is achieved by changing the parameters of functioning or by changing the types of genetic algorithm operators through the increase or the decrease of their destructive capacity. The paper presents the examples of images on the basis of which an artificial neural network may decide to change the parameters of the evolutionary procedure operation or non-interference. It is proposed to create a controlled genetic algorithm aimed to solve not only the problems of synthesis of large discrete systems with a given behavior, but also in various subject areas. During the use of a single mathematical apparatus of Petri net theory, it is possible to create the models that will have the property of parallelism, which will make it possible to use parallel programming technologies.

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