Genetic algorithms of physical modelling with postcrossover survival

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Abstract. This paper describes the peculiarities of the system synthesis algorithms realization. The system synthesis algorithms are divided into some categories. They are divided according to the synthesized system as algorithms of the mathematical models synthesis and algorithms of physical models synthesis. Mathematical modelling is a setting process of the corresponding mathematical object (a mathematical model) to the real object. In physical modelling a real investigated system is replaced by another fitting physical model reproducing properties of the model that keeps its physical nature. Applying randomness and probabilistic processes the algorithms can be divided into stochastic and deterministic algorithms. A deterministic algorithm is an algorithm with the strictly defined rules. The deterministic algorithms involve all the determined rules. Stochastic algorithms have some uncertainty and use random values at some stage of its functioning. The choice of the algorithm depends on the problem’s requirements.

1. Introduction

Nowadays algorithms of the system synthesis structures are one of the leading directions of the scientific development. They are of high importance for solving scientific and practical problems as their quality and efficiency depends on the quality of the synthesized system with their application. The synthesized algorithms are classified according to certain parameters. In general, they can be divided into two important categories, deterministic and stochastic algorithms. A deterministic algorithm is an algorithm whose rules are strictly defined. These algorithms do not involve any handlers of random event [1, 2].

The stochastic algorithms or probabilistic algorithms have some uncertainty and use random values to save the operating time by replacing the absolute reliability of the results by the reliably with the certain probability.

Traditionally the deterministic algorithms are more widely used since the probabilistic algorithms are labour-intensive, and they have a lot of iterative calculations [3, 4]. But over time, the development of computational tools and probabilistic algorithms will allow to realize the benefits by increasing the...
speed of calculation. Also the algorithms can be divided according to the realization type of the applied models.

2. Modelling of synthesized systems

Modelling is the substitution of one object, called a system by another object, called a model and conducting experiments with a model (or models), investigation of the model properties based on the results of experiments in order to obtain the information about the system [5, 6]. Modelling allows exploring such systems. The direct experiment with these systems is:

a) difficult to perform;
b) unprofitable;
c) generally impossible.

The object of investigation in the theory of modelling is a system. A system is a set of interrelated elements combined into one unit in order to achieve a certain goal determined by the destination of the system. This element is a minimal indivisible object considered as a whole. If the system is a set of interrelated elements then a complex is a set of interrelated systems [7, 8].

An element, system, complex are relative terms since any element being divided, being considered is not an indivisible object. It becomes a system, and vice versa any complex becomes a system if its constituent elements are regarded as system. It is possible to apply mathematical models of systems and their components. This approach is effective when the characteristics of simulated elements are known in advance.

The application of physical modelling in stochastic algorithms has its advantages. The application can help to obtain new systems with unexpected results.

To investigate the characteristics of the process functioning of any system S with the help of mathematical methods, including the machine methods, the formalization of the process, is to be carried out, i.e. a mathematical model is to be designed.

The mathematical modelling refers to the process of establishing the compliance with this real object of any mathematical object called a mathematical model and the investigation of this model. It allows receiving characteristics of this real object. The type of the mathematical model depends both on the nature of the real object and tasks that we have in object investigation and the required reliability and accuracy of this problem solving. Any mathematical model, as any other model, describes a real object with a certain degree of approximation to the reality.

If we deal with the physical (full-scale) modelling, the investigated system is replaced by its corresponding material system that reproduces properties of the studied system saving its physical nature. Due to the fact that the nature of the physical and original models is the same, it is possible to ensure the similarity of the processes occurring there without full information about their mathematical descriptions. This is an advantage of the physical model in comparison to the mathematical one. The advantage of the physical modelling is an increasing number of factors that we have in physical experiments.

In science, every experiment produced to identify these or those laws of the phenomenon under study or to check the results taking into account the accuracy and applicability of the found theoretical method is modelling. That means that an object of the experiment is a specific model which has the necessary physical properties, and in the course of the experiment the basic requirements for physical modelling must be carried out. In technique the physical modelling is used in the designing and construction of various objects to determine various properties (characteristics) on the appropriate models of the whole object and its separate parts. The physical modelling is used not only due to the economic reasons, but also because field tests are very difficult or impossible to realize when it is too large (small) in comparison to the full-scale of the object or due to the values of the other parameters (pressure, temperature, process flow rate, and so on).

The new system can be synthesized by building the physical model without information about all the parameters and laws they are supported [9-11].
The models construction of any physical system “black boxes” can be used as elements they are constructed from. The structure of these “black boxes” is unknown and therefore it cannot be modelled mathematically. The specific choice of the algorithm is determined by the specific problem.

All the stochastic algorithms can be divided into separate classes with their own advantages and disadvantages. One can distinguish genetic algorithms as such class of algorithms; they can apply principles similar to the principles of evolution of living organisms.

3. Genetic algorithms, its benefits and possible disadvantages

Genetic algorithms are among the most important mathematical methods of analysis and synthesis of systems. Their role in the modern methods of development is very high.

A genetic algorithm is a heuristic search algorithm used for solving optimization and simulation by random selection, combination and variation of desired parameters using mechanisms similar to the natural selection.

An algorithm starts with a random set of initial solutions called a population. Each element of the population is called a chromosome and represents a solution to the problem in the first approximation. A chromosome is a string of some symbols; they are not obligatory to be binary.

The initial population is developed by a random generation. Its chromosomes are evaluated using “fitness functions” whereby each genotype is associated with a certain value (“fitness”) which determines how well a described phenotype solves the problem.

Chromosome evolves over multiple iteration called generations. In each iteration a chromosome is evaluated using some measure of conformity, fitness function. To develop the following generation, new chromosomes called offspring are formed either by a crossover of two chromosomes, parents, or by accidental changes (mutations) of one chromosome. A new population is formed by (a) the selection of conformity according to the function of some parents and offspring, and (b) the deletion of remaining in order to maintain a constant population size. From the resulting set of solutions (“generation”), taking into account the values of “fitness”, the solutions are selected. Usually the best individuals are more likely to be selected. The “genetic operators” (in most cases “crossover” and “mutation”) are applied and in the result we have new solutions. This set of actions is repeated iteratively, so an “evolutionary process” is modelled and it repeated several life cycles (generations) until stopping criterion of the algorithm will be completed. Chromosomes with a greater adherence function are more likely to be selected (to survive). After several iterations the algorithm converges to the best chromosome which is either an optimal or near-optimal solution [12-15]. In general, a genetic algorithm includes the following steps: generation; checking of survival; crossing / mutation; selection.

But the practical application of genetic algorithms is facing a number of problems.

One of these problems is the problem of post checking. In a typical genetic algorithm checking the survival function is performed before the crossing. “Species” first “survive”, and only then they cross and produce “offspring”. But in this way the selection could occur only in systems due to the feature for which fitness function could be detected at any time.

4. Post crossover survival

The variety of problems supposed to be solved applying genetic algorithms is very wide. In the application of this method we can face the problem when the fitness function (a criterion maximized by this method) can be verified crossing and what is more after its checking, the chromosomes lose their ability to cross.

More often this problem occurs when applying a genetic algorithm, a stochastic test system is performed and when such an algorithm performs a physically existing system and the result of the fitness function test is determination if the system would continue to exist after testing.

One of the most obvious solutions of this problem may be the choice of different fitness function tests, implementation of the different function that analyses the “chromosome”.
Besides the application of such methods it is possible to fulfil the direct modification of the algorithm. Instead of checking a fitness function after each generation of the new generation, we can apply a delay of one generation.

Genetic algorithm is as follows. The starting is the same. At first step some initial set of chromosomes (some initial population) is generated. Then, a crossover operator is applied to this population without taking fitness into account. A new generation is initialized, but an old generation is kept and it is analysed about a fitness function applied to. Accordingly, an old generation loses its capacity to cross. But those chromosomes lose their fitness function value and this value is transferred at each chromosome, an offspring of the old generation. The offspring of the chromosomes of the old generation is eliminated.

In general, the algorithm is as follows:
- Preparation of N-generation;
- Crossing / mutation and getting non-selected generation N + 1;
- Checking the chromosomes survival of generation N;
- Searching the appropriate offspring among chromosomes of the generation N + 1;
- Selection and development of the generation N + 1.

5. Conclusion
Thus introducing this modification, we are able to apply genetic algorithms to solve problems where fitness checks and finding of the target fitness function leads to the destruction of the chromosome or impossibility of its crossing. As an example of such problems one can consider physical modelling where a test object is irrevocably destroyed or loses the ability to crossover.

This algorithm may be effective, for example, in case of the development a highly reliable system with a valid subsequent test. The quality evaluation of such a system can be destructive test of its physical model which will be determined by the maximal load.

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