ON THE POSSIBILITY OF GENETIC ALGORITHMS IMPLEMENTATION IN THE EXPLOITATION DOMAIN

Michał Pająk

Radom University of Technology, Faculty of Mechanical Engineering
Department of Thermal Technology, 26-600 Radom, ul. Krasickiego 54, Poland
tel. (48) 48 361 71 49, e-mail: michalpajak@tkdami.net

Maciej Woropay

University of Technology and Agriculture in Bydgoszcz, Faculty of Mechanical Engineering
Department of Exploitation, 85-796 Bydgoszcz, ul. Kaliskiego 7, Poland
tel. +48 52 340 84 95, e-mail: kem@atr.bydgoscz.pl

Abstract

The optimization issues are very often met in the area of industrial exploitation systems management. The solution space of the optimization process expands because of the production systems complexity. Frequently, there is no possibility to find the accurate solution of the problem. Sometimes, in case of real industrial systems it is not necessary to find the optimal solution. Very often the suboptimal one is sufficient. In the paper the genetic algorithms are proposed as a tool for optimization process of the exploitation issues. Thanks to it, the computerised expert systems could be created. The implementation of the systems in the area of exploitation management could increase the quality of the process. Optimization characteristic of exploitation processes, the possibility of optimisation implementation, genetic algorithms characteristic, service graph critical path searching, optimisation of power units maintenance scheduling process are presented in the paper. Within the framework of work a real industrial issue of the service processes optimisation the genetic algorithms have been proposed.

Keywords: *genetic algorithms, exploitation, exploitation systems, optimization, artificial intelligence*

1. Optimization characteristic of exploitation processes

Currently the development of industry and hi-tech technology effects the complexity increase of industrial exploitation systems. The systems consist of bigger and bigger number of components. This causes the complication of exploitation processes. The correct course of the processes depends on the exploitation control. The decision processes of this domain could be assisted by the computerised expert systems implementation.

According to the theory in the group of exploitation processes it could be distinguished the perusing and using processes, service processes and auxiliary ones [1]. The using and the service processes are the most important of them [2]. In real industrial systems the using processes are assisted by computerised systems very often but the service ones are not. The computerisation and automation of service processes face a lot of difficulties [3]. One of them is the complexity of service systems.

The complexity of the systems effects the huge solution space for decision-making problems of this domain. The solution space consists of correct and incorrect solutions but all of them should be considered. Frequently the mathematical model of considered problems is so complicated that it is impossible to find the solution in the analytic way.

Unfortunately, the number of solutions is so big that it is also impossible to check all of them on the current level of information technology. Because of that it is necessary to implement the optimisation process.

The basic element of optimisation process is the quality function. In case of service process optimisation issues the quality function very often is defined by the list of criteria. These criteria model the shape of the solution space. The optimisation criteria result from the conditions of service process, so the criteria changes in the time. Because of that the shape of solution space also changes in the time.

From the optimisation point of view the service process are characterised by huge, unknown solution space changeable in the time. Beside the above features the solutions of the service management optimisation problems should be find in the limited period of time. The limits of the expert system response time is determined by the maximum delay of decision making process or the timeliness of optimisation criteria.

It could be also noticed that in real industrial issues the more important is to find optimal or suboptimal solution in defined period of time than finding the accurate solution after defined period of time.

2. The possibility of optimisation implementation

The optimisation issues in the domain of service processes are described by digital (often integer) values. Such issues are very difficult to optimise from computation point of view [4]. The reason of that is the lack of such analytical features as differentiability or linearity. Often the multimodal and big size of solution space could be met. All of that and the limitation of the response time effects the useless of implementation such algorithms as B&B (Branch-and-Bound), dynamic programming or linear and non-linear programming in these cases. Therefore the good solution in this kind of optimisation problems is the implementation the approximate methods. The methods enable to find the approximate solution and the quality of solution increases with the calculation time.

The approximate methods could be divided into two groups. Construction and correction ones. The construction methods are fast and could be easy implemented but generated solutions are not very accurate. The correction methods are slower and they need the starting point, which is corrected during algorithm operation, but they get the solution of very good quality. Thanks to correction method implementation it is possible to create the compromise between response time and solution quality in flexible way. This kind of optimisation method is currently strongly developed so there is a lot of promising algorithms enable to get high quality solutions. Unfortunately, these new method are not stable yet so they should be examined to implement them into practice.

In case of real industrial issue the implemented optimisation method should be stable and well examined so in the paper the genetic algorithms are proposed.

3. Genetic algorithms characteristic

The genetic algorithms are the tools for solution space exploration. They are based on the biological populations processes [5]. The basic idea of genetic algorithms is to present in the coded form the considered problem solutions. The solutions are modelled in form of chromosomes population which evolve in the time in the competition process. The quality of each chromosome could be calculated using fitness function of the algorithm. The value of the fitness function determines which chromosomes take part in the competition process called selection. New chromosomes are created using crossing and mutation operators. The genetic algorithms are implemented in case of optimisation and search problems. During search process the algorithm collects the information about initially unknown solution space and uses it to bias the search direction into more promising subspaces. It means that the genetic algorithms are the adaptive optimisation method. Thanks to it the algorithms could be implemented with good result to exploration of big, complicated and unknown solutions spaces where the conventional method are insufficient [6]. The genetic algorithms can be implemented in different domain of industry and science. The main reasons of that are the short time of solution finding and reliability in case of complex problems. The genetic algorithms can be easy joined with existing models so they can be used to build hybrid technologies. Although the genetic algorithms not guarantee the global optimum location, they usually find good enough approximation of correct solution very fast. Recently a lot of genetic algorithms implementations could be observed. They are implemented in industry domain, optimisation, robotic, pattern recognition, learning, neural networks, fuzzy systems, artificial life etc.

4. Service graph critical path searching

On the basis of detailed ranges of service operations the time of overhaul is determined. Defined service time is the input information for maintenance activity schedule creation process. The complexity of the process increases with the size of exploitation system because it is necessary to take into consideration all the dependencies between service operations. The interactions between service works can be found in different fields especially in the area of working surface, human resource and operation time of machines. The next condition is a strict correlation between service operations and delivery of goods and spare parts. In the activity graph the activities, which should be done sequentially, are marked. After that the service activity graph is created. On the base of created graph analysis the critical path is determined. The critical path is the longest set of edges that connect the start and the end node of the graph [7]. The activities, which are the elements of critical path, are called the critical activities. The time of whole overhaul results from critical operations time.

To implement the genetic optimisation of the considered issue the initial population of the chromosomes is created. Each chromosome is build from genes representing the presence of each operation in critical path. So that, the problem is optimised using binary coded genetic algorithms. The length of each chromosome of initial population is equal to the amount of the activities in the service activities graph. The fitness function is a sum of the weights of service activities graph edges represented by genes with value 1 in considered chromosome (1):

$$Q = \alpha \cdot \sum_{i=1}^{n} G_i \cdot W_i \ , \tag{1}$$

where: Q - fitness function,
n - amount of service activities graph edges ,
G_i - the value of i index gene of the chromosome,
W_i - the weight of the i index graph edge,
α - correctness factor of the considered chromosome {0,1}.

The algorithm tries to maximize the value of fitness function. In this case it is possible to implement two point crossing operator and the operator of non-uniform mutation.

5. Optimisation of power units maintenance scheduling process

The schedule of power units overhauls is created with one-day precision. The length of the repair is determined as integer digit. So, the schedule is represented by integer coded chromosomes. Thanks to it the analysis of the chromosomes could be performed on the genotype and phenotype level at once.

The time of one step of genetic algorithm is determined by the length of chromosomes. Therefore it is necessary to prepare the shortest form of coded solution. To do it the chromosomes consist of the numbers of the start days of overhauls. The length of overhauls is defined by the experts of the power unit's maintenance management. Nowadays the power unit's maintenance activities are executed according to strategy of planned repairs. Each power unit is serviced once a year. Therefore the length of the chromosome equals to the amount of power units installed in the power plant. Each gene of the chromosome presents the number of the first day of the overhaul in the year

(2). The range of correctness for the values of the genes is limited by value zero and the length of maintenance campaign reduced by the length of the adequate overhaul (3). The formula placed below describe the chromosome and the rage of correctness of the chromosome genes:

$$C_n = \{ c_1^n, c_2^n, \ldots, c_{b_n}^n \}, \tag{2}$$

$$c_i^n \in < 0, d_n - rd_n > . \tag{3}$$

where: C_n - chromosome,
b_n - amount of power units,
d_n - length of the maintenance campaign,
rd_n - length of the overhaul,
n - index of the solution.

After carried out experiments the *BLX-α* and *FCB* crossing operators are proposed in the considered issue as efficient solutions. As a mutation operator the non- uniform mutation operator is suggested.

6. Conclusions

During the studies carried out in the field of the maintenance activity optimisation the following conclusions were formulated:

- currently the development of the industry and hi-tech technology effects the complexity increase of industrial exploitation systems,
- frequently the mathematical model of service problems is so complicated that it is impossible to find the solution in the analytic way,
- from the optimisation point of view the service process are characterised by huge, unknown solution space changeable in the time,
- the optimisation issues in the domain of service processes are described by digital (often integer) values,
- in case of real industrial issue of the service processes optimisation the genetic algorithms are proposed,
- the genetic optimisation of the critic path search tries to maximize the value of fitness function for binary coded chromosomes using two point crossing operator and non-uniform mutation operator,
- the genetic optimisation of the power unit maintenance schedule tries to minimize the value of fitness function for integer coded chromosomes using *BLX-α* crossing operator and non-uniform mutation operator.

References

[1] Woropay, M., *Podstawy racjonalnej eksploatacji maszyn,* Wydawnictwo Instytutu Technologii Eksploatacji, Bydgoszcz - Radom , 1996.

[2] Hebda, M., Mazur, T., *Podstawy eksploatacji pojazdów samochodowych,* Warszawa, WKŁ 1980.

[3] Pająk, M., *Optymalizacja harmonogramów remontów bloków energetycznych,* PhD dissertation, Politechnika Radomska, Radom, 2004.

[4] Smutnicki, C., *Algorytmy szeregowania,* Warszawa, EXIT 2002.

[5] Herrera, F, Lozano, M, Verdegay, J. L., *Tackling Real-Coded Genetic Algorithms: Operators and Tools for Behavioral Analysis,* Department of Computer Science and Artificial Intelligence University of Grenada 1992.

[6] Kalotka, J., Pająk, M., *Biblioteka narzędziowa do tworzenia oprogramowania* HERKA, W., Sewastianow, P., *Szeregowanie zadań na jednej maszynie (aspekt wąskiego gardła) w warunkach niepewności rozmyto-interwałowej*, Częstochowa 20.XI.2003.