Evolutionary Approaches to Cut Wooden Sheets in the Furniture Production

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Abstract: - **The application of evolutionary algorithms to cut wooden sheets in the furniture production is presented. A combined EA is used as a probabilistic approach in the search of quasi-optimal solutions. The performed research show that the usage of these algorithms significantly reduces the unutilized material, the cutting time is decreased and also that there is a significant economic effect.**

Keywords – **evolutionary approaches, evolutionary algorithms, optimization, random search, selection, crossover, mutation.**

I. INTRODUCTION

Evolutionary algorithms (EA) are a method for search based on the selection of the best species in the population in analogy to the theory of evolution of Ch. Darwin.

Their origin is based on the model of biological evolution and the methods of random search. From the bibliographical sources [2], [3] it is evident that the random search appeared as a realization of the simplest evolutionary model when the random mutations are modelled during random phases of searching the optimal solution and the selection is modelled as "removal" of the unfeasible versions.

The main goal of EA-s is twofold:

- abstract and formal explanation of the adaptation processes in evolutionary systems;
- modelling natural evolutionary processes for efficient solution of determined class of optimization and other problems.

During the last years a new paradigm is applied to solve optimization problems EA-based and modifications of EA. EA realize searching a balance between efficiency and quality of solutions at the expense of selecting the strongest alternative solution [2], [3].

The continuously growing number of publications and also of the practical implementations during the last years is a stable proof of the growing expansion of the scientific and application research in the domain of EA.

In order to give a general fancy for the type of applications, they could be classified in four main directions [2]: science, [4] engineering [5] industry [1], [7] and various other directions (miscellaneous applications) [2], [8].

We propose in the rest of the paper the usage of the EA for effective cutting wooden sheets in the furniture production.

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II. THE PROPOSED APPROACHES

An often met problem in practice is the one for rational cutting out of used materials with of process for materials and the power supply minimal residuals (waste). The unceasing growth require minimization of expenses for the production of any product.

Criteria for effectiveness are represented by the coefficient of usage C_u. There have been offered sets of mathematical methods to solve similar problems, but they are oriented to solving statistical problems when the original information is a priori completely known and it does not change during the production process.

We shall examine the solution of a problem for cutting the wooden sheets. The dimensions of the wooden sheets are with different parameters depending on the specific case.

Different initial blocks for cutting are used depending on the dimensions, gauges and makes. So the portfolio of the orders is divided in groups depending on the specified peculiarities of the initial blocks.

If we ignore the organizational specifics of this production the problem for cutting may be formulated in the following way: choose the number of products from the portfolio of the orders and according to the dimension and the type of the initial block perform rational cutting with minimal losses of the original material. These losses must be minimal, so we must maximize C_u according to the formula

$$C_u = \frac{\sum_{r=1}^{n} S_r}{S_{eb}} \qquad (1)$$

where the numerator is the sum of the surfaces for the orders from the portfolio of the orders and S_{eb} is the surface of the original block. The maximal meaning of C_u is $C_u = 1$ but it is very hard to achieve this value in reality. If we know the obtained value of C_u and if we compare it with $C_u = 1$ then we make draw conclusion(s) for the quality of the performed cutting. The solution of such class of problems in our case is based on imitative modeling and an evolutionary algorithm for optimization.

The imitative model describes the operation of the system realizing rational positioning (arrangement of the orders). The original information about the model is the portfolio of the received orders which consists of a definite set of orders with given dimensions (length and wideness) and also the number in the portfolio. As a result from the operation the model must position the orders along the surface of the original block and

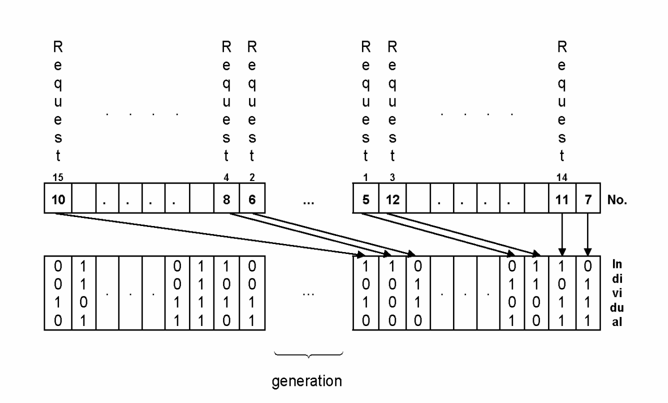

Fig. 1

after the end of the operation it must issue the rational value for C_u which must be near to the optimal one and equal to it. The Evolutionary Algorithm (EA) is used to solve the problem for C_u optimization. The basis of the imitative model is the algorithm realizing positioning of the orders. It describes the operation of the system, i.e. it checks the possibility to position the successive order and it performs the operation. Its original data include the values of the order numbers that are issued by the algorithm for optimization, i. e. EA [1]. Each order has its identification number which describes it precisely. The process of positioning the orders along the surface of the original block requires that the order number must be determined; it is taken from the portfolio of the orders and the sequence to position them along the surface of the original block must be found. Every order in the portfolio of the orders has a serial number related to it which varies between zero and the number of the orders in the order portfolio.

After any initialization the system automatically determines the length and the string of the chromosome. The number of genes in every individual is equal to the number of orders in the table of back orders. The binary encoding of the order numbers necessary for the EA operation is shown at Fig. 1 Let the number of the obtained orders is 15. Therefore the individual is a binary string-chromosome with a length of 60 bits. The genes in this string are 4 bits long each of them. These genes by themselves are the encoded values of the sequential order numbers. Every gene has a length of 4 bits which follows from the condition for encoding the maximal order number. In this case 4 bits allow the binary encoding of 15. The number of genes equals to the number of orders, i.e. it is equal to 15. So we obtain a solution for every individual where every single gene determines the successive number for the respective order.

III. Evolutionary Algorithm to Solve the Problem

The solution of the above stated problem is based on a evolutionary algorithm (EA). The solution of the already postulated problem is via a new EA which is created on the basis of a combination of elements from several algorithms of Gen [5], Falkenauer [4] and Goldberg [6] as a probabilistic approach to quasi-optimal solutions, using certain parts of the algorithms, above mentioned and we have also added some supplementary elements, that allow larger choice of the criteria and better selection after the population accomplished, which leads to decrease in number of the necessary computations.

The optimizable EA quantity is the goal function that is intended for the individuals. Hence the goal function must increase with the growth of the criterion value; the role of the latter is performed by C_u. The function is chosen based on the experiments done with the model to ensure the correct development of the population. The main EA parameters are selected after the preliminary experiments with the model; the cited below meanings are accepted:

- number of individuals in the population – 50;
- crossover probability – 0,65;
- mutation probability – 0,35.

The operation of the imitative model follows the algorithm for disposing the requests along the surface of the original block. The input data for its operation is the set of sequential block numbers determined by the EA.

The generalized block scheme including also the EA is given in Fig. 2.

Briefly the idea of operation is formulated below:

1. Past the startup initialization are loaded the portfolios with the possible requests which can be principally realized and which can be continuously updated.
2. Dimensions of the original blocks of standard wooden sheets are determined. They can be of various sizes, thickness and quality.
3. Input of the current order requests.
4. Decoding of bits. The string-chromosome is decoded, i.e. the serial numbers are determined.
5. Choice of the serial number. Sequential numbers are counted and the serial number is determined.
6. Validity test is performed for a request with such number. If there is no such number then go to step 5.
7. In the opposite case the algorithm chooses the request with this number.
8. The request is disposed if possible can it settled.
9. Go to step 5 if no.
10. Settled request
11. If the request is final then a validity test is performed for the number of the individual.
12. Choose a final request (10, or 30, or 60).
13. If no go to step 5.
14. Testing of a individual population (50).
15. If 50 go to step 21.
16. If no choose a variant
17. Variant 1-GF_1: The next consecutive steps concern the choice of the goal function and the respective genetic procedures such as sorting, crossover and mutation.
18. Variant 2 – GF_2 – below the procedures are described.
19. Select and save the best solution.
20. Next individual and go to 4.
21. Finally the best solution from all generations is passed to the cutting machine which realizes the cutting-out of the original standard block.

The end condition is determined from the inequality:

$$\frac{GF_{max} - GF_{mid}}{GF_{max}} > 0,85 \qquad (2)$$

where GF_{max} and GF_{mid} are respectively the maximal and middle meanings in the current population.

Variant 2: The shown above system solves the problem as a simplified version. Real production orders can be usual and urgent, normal and with priorities. Based on these factors we present an heuristic approach with a goal function which is a sum of three monoms, namely

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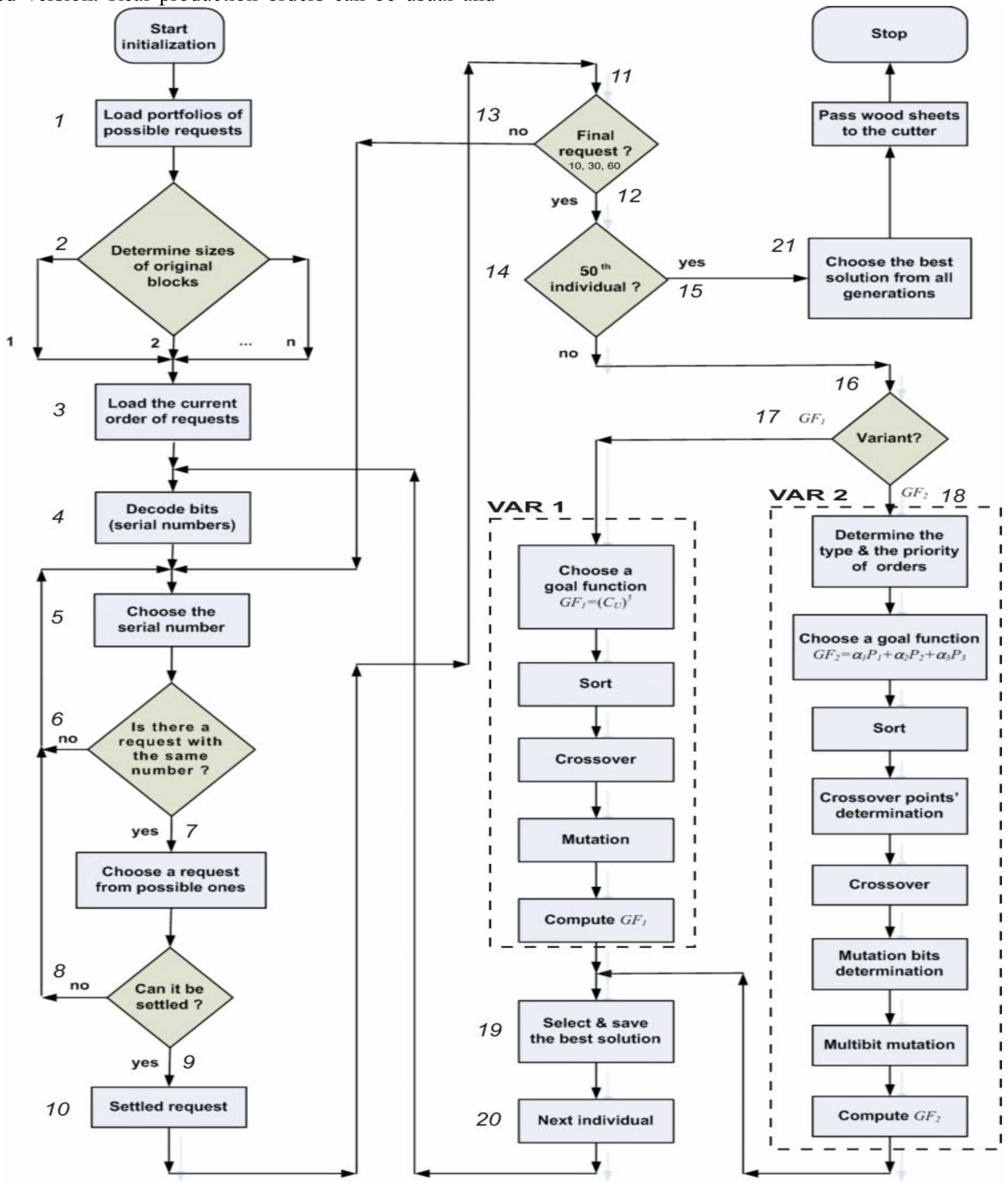

Fig. 2

$$GF_2 = \alpha_1 P_1 + \alpha_2 P_2 + \alpha_3 P_3 \qquad (3)$$

where P_1 is a parameter for the order urgency, P_2 is the order priority, P_3 is a parameter defining C_U; α_i are weight coefficients with $i = 1, 2, 3$.

P_1 is determined during the portfolio setup process. The ordered suites of furniture are divided into blocks which can be usual and urgent. The system model includes an urgency parameter for every block. It is a Boolean variable with possible values 0 and 1. P_1 is determined in the following way. Initially it is set to 0. Afterwards for every block from the order the value of the parameter for the order urgency is added to the value of P_1. In this way P_1 is equal to the number of urgent blocks in a given order.

P_2 is calculated analogously to P_1 but the block priority (0 or 1) is used instead. The difference from P_1 is in the following fact. If the percentage exceeds 60% then the priority of the rest is set to 1.

P_3 represents C_U. It is calculated according to the description above.

The weight coefficients α_i define the significance of each parameter in the formula for *GF*. Their values are determined depending on the concrete situation. In the context of the presented cases they have the following values: $\alpha_1 = 8$, $\alpha_2 = 1$, $\alpha_3 = 4$.

For the solution of this problem there were proposed heuristics leading to the modification of the EA (variant 2). The modification of the optimized algorithm is realized by changes in the operators for crossover and for mutation. The crossover mechanism includes a crossover between an individual of the predecessors with a breakpoint in some item (this breakpoint is randomly chosen) followed by an exchange between the ends of the chromosome strings of the individuals to obtain two individuals of the offsprings. The mutation mechanism is a single-bit mutation where for an arbitrarily chosen individual randomly is determined some gene and byte in the string chromosome followed by an inversion of the given byte. The research of the algorithm's performance for big orders' portfolios demonstrated that such schemes influence insignificantly the development of the population which in its turn causes bad results. It was proposed that the solution should include the mechanism of multi-point crossover and also of the multi-byte mutation.

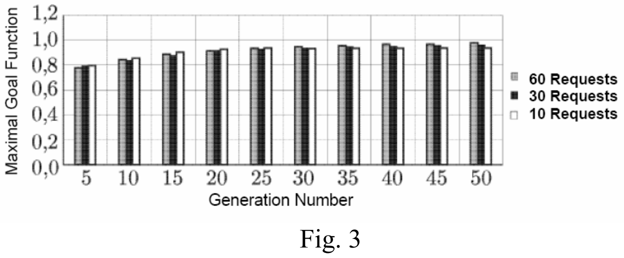

Fig. 3

The realization of the multi-point crossover and also of the multi-byte mutation goes through the definition of the breakpoints and also of the mutation points. The option accepted these two parameters to be equal so they are calculated via one and the same formula.

$$C = \frac{N}{D} \qquad (4)$$

where *N* is the number of the requests that do not participate in the orders' portfolio; *D* is some parameter (divisor).

It is evident from the expression that for the breakpoints and also for the mutation points the meaning of the divisor must be defined. The research induced the value of this parameter to be equal to $D = 10$.

Fig. 3 presents the results from the system research (variant 2). They respond to various requests in the orders' portfolio, namely, 10, 30 and 60 requests.

IV. Conclusions

The estimation criterion for the obtained results is C_u. The operation of EA is based on a priori selected portfolios with requests giving high values for C_u. With so selected parameters the EA finds solutions in 80-90% of the cases when the average waste is between 10 and 15% depending on the size of the original block.

The implementation of the new system for cutting applying the GA led to increased possibilities for cutting new original blocks and C_u was considerably improved; the wooden sheet waste which varied between 25 and 35% dropped down to 10-15%.

In the process of the future developments there could be developed and specified the evolutionary variants of the algorithms, taking in, to consideration the given features of the practical application and thus develop new approaches, which optimize the cutting out of different types of materials and receive considerable effect and saving. They are very appropriate for optimal cutting out of textiles, marble and other blocks, glass, metal (sheets) materials, cardboards etc.

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