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Optimisation of flow of order in flexible manufacturing system by genetic algorithms

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In this paper we proposed a method of searching for optimum order flow through the flexible manufacturing system (FMS) with respect to transport times, preparation/completion times, manufacturing times and relevant costs. The paper defines two fitness functions describing the problem of optimisation of times and costs of execution of order. Then, by the genetic algorithm method such flow is found out that the value of fitness functions is as small as possible. Coding of the solutions is carried out so that the gene consists of operation and machine of which that operation is executed. First, a group of possible genes is created. Feasibility of operation on the machine is verified by searching for the operation required by the order out of the operations defined for the machine in accordance with DIN standards. In this way, only the appropriate genes and organisms and, consequently, the possibility of use of simple genetic and evolutionary operations are gained.

1. INTRODUCTION

Production management and scheduling problems in an FMS are more complicated than in job shops and transfer lines. In addition to the well known conventional methods of optimisation of the flow also the nondeterministic methods become widespread. In case of optimisation by the known conventional methods the problem on optimisation of the orderflow in FMS is a hardly controllable task. Thus, we are often compelled to optimise only one variable (manufacturing time, price etc). In addition, most methods of optimisation of the flow are based on heuristic methods of conceiving the solution and on the expert knowledge of the experts. We are frequently forced to set the limitations of the system.

The paper describes one of the approaches to searching for the optimum order flow through the FMS with respect to transport times, preparation/completion times, manufacturing times and relevant costs. The assumption is made that the preparation/completion times and the manufacturing times are known (they are obtained from CAPP modules). Genetic algorithm prove to be useful in solving of optimisation problems like this one 1.

2. OPTIMIZATION OF FLOW BY GENETIC ALGORITHMS

2.1 Fitness functions

In case of optimisation by genetic algorithms it is necessary to determine first the fitness function enabling the calculation of quality of solutions. It is also possible to use several fitness functions at a time. When searching for solutions of the problem presented across several factors by which the final solution - of existing at all – is conditioned. During the stage of planning it is possible to work out several alternative working procedures, which we optimise with regard to:

- most favourable version with respect to time or,
- economically most favourable version.

We selected two fitness functions: the function of the variable manufacturing costs and the function of the time spent. Taking the current requirements into account, the user selects between these two functions, since in the production systems different situations occur. Sometimes the costs are of key importance and sometimes the spent time.

The cost function consists of three parts. It comprises the transport costs for the order, the preparation/completion costs on the individual machines and the net cost of machining. In this way, the majority of the variable costs for execution of the order are covered. Also the time function consists of three parts and issues from the cost functions.

2.2 Coding

The sequence of the flow is determined in accordance with the breakdown of the work progress into the individual operations and on the basis of determination of the machines on which the individual operations will be performed. The organisms must carry the information as to which operations have to be performed for the order to be fulfilled and on which machines the said operations must be carried out. One gene comprises one operation and the machine on which the operation is performed (Figure 1). The method of standard operations according to the DIN standard is used for verifying the feasibility of the group of operations on a machine.

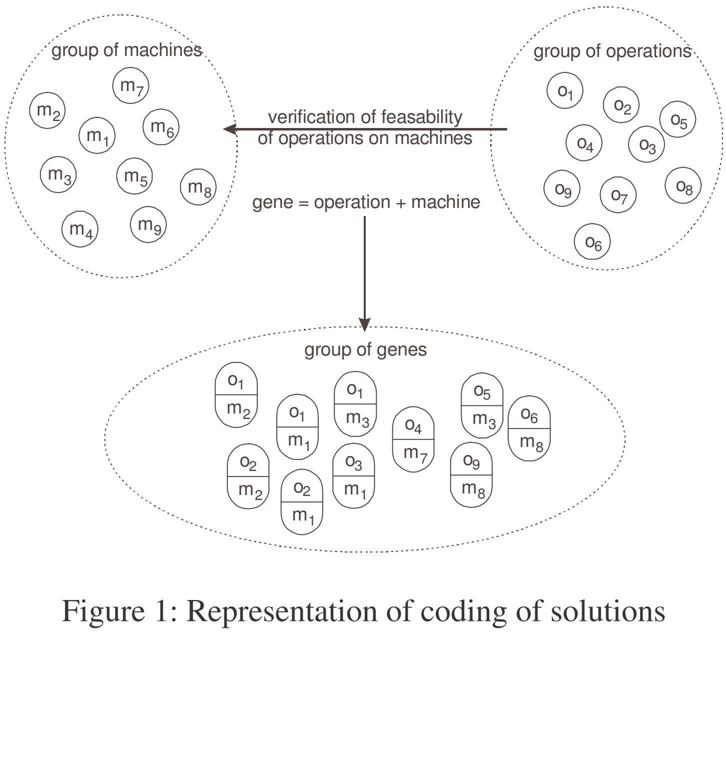

Figure 1: Representation of coding of solutions

The organism is:

$$\begin{bmatrix} o_1 & o_2 & o_3 & o_4 & o_5 & o_6 & o_7 & o_8 & o_9 \\ s_1 & s_3 & s_8 & s_8 & s_2 & s_4 & s_4 & s_4 & s_1 \end{bmatrix}$$

During planning of technology the technological process is determined, the work operations required by the shape and geometry of the product are determined. The operations are mainly defined by describing (to be face milled, to be milled up to depth etc.). Such type of describing however makes difficult the processing by known programme tools on computers. From the known standards it is possible to conclude that the area of describing the work operations has been studied very precisely (table 1).Such manner of designating the work operations makes describing of operations considerably easier. For some known machine tool it is possible to determine the standard operations which can be effected on a machine tool. In parallel it is also necessary to prepare the conditions for execution of certain order on several units of the FMS 2.

Table 1
Example of standard operations

Survey of possibilities of execution of standard operations on a multiple – operation drilling and milling machine (example)		
Ser.No.	Code of operation according to DIN 8589	Description of operation for easier understanding
1	3.2.2.1.	Group of operations of face sinking
2.	3.2.2.2.	Group of drilling operations
3.	3.2.2.3.	Group of thread-cutting operations (is hole drilled)
4.	. . . . .	. . . . . .
6.	3.2.3.2.	Milling of round shapes

When an order has already been introduced into production, it is often necessary to search for an alternative machine tool for certain operation or group of operations. Automated searching for an alternative machine tool during performing of the production management is certainly the user's wish. We can come quickly to the conclusion that complete automation is not possible since it is almost impossible to describe workpiece by a suitable method 3.

2.3 Feasibility of orders with respect to tools and working devices

Output data from such selection are:

- order selected,
- machine tool on which the selected order is feasibility,
- working devices which must be provided on the machine tool for selected order,
- tools which must be a available on the machine tool for selected order,
- start time of equipped the machine 4.

2.4 Evolutionary and genetic operations

We see that the number of correct genes is limited. Each operation can be performed only by a limited number of machines. Therefore, first all possible genes are generated and thus a group of genes is created. Out of the group we then select the individual genes and assemble them together in correct organisms. The appropriate organisms are those that represent such sequence of the flow which results in the fulfilled order. The group of genes is used also in the operation of mutation. Due to the manners itself of coding and generation of the initial operation we can use the most simple single point or multiple-point crossover. Like crossover also the mutation is very simple with this type of coding. The sole condition to be considered in mutation is that the genes in the organism are to be replaced by the genes containing identical operation. The replacement gene is selected from the group of genes.

2.5 Evaluation

Each organism is evaluated by two cost functions. The cost function, which is more important for the user at a given moment, is of greater weight. In case several solutions equally good with respect to the first cost function are obtained, out of these solutions we pick that solution which best solves the other cost function.

With respect to the organism the matrices [X] and [Y] containing the values x_{ij} and y_i are generated. The matrices of technological times [t_t] and preparation/completion times [t_{pz}], made by CAPP modules, are also generated with respect to the organism. On the basis of those matrices depending on the organism itself and on other matrices, which are constant for the existing production, the values of cost functions are calculated.

3. CONCLUSION

Contrary to other methods of optimisation of flow in the FMS the genetic algorithms have some incontestable advantages. By contrast with most other methods with genetic algorithms we make solutions according to the random principle by genetic and evolutionary operations and we do not use any rules when conceiving the solution. The sole limitation is that the solution made must be feasible. The quality of solutions made is evaluated by the two fitness functions. When solving by that method it is not necessary that the optimum solution will be obtained but it will be surely one of the better. It is also an advantage of this method, that after several runs of the genetic algorithm we can obtain several different solutions having a similar value of the cost functions.

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