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Optimising the layout of multi-row flexible manufacturing system by genetic algorithms*

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The paper presents a model of designing of the flexible manufacturing system (FMS) by genetic algorithms. In the model, the automated guided vehicles (AGVs) for transport between components of the flexible manufacturing system were used. Quality of the design of transport between the individual parts of the system is the key factor of successfulness of the system. The paper discusses the arrangement of devices in the flexible manufacturing system in multiple rows. In this connection, the most favourable number of rows and the sequence of devices in the individual row is established by means of genetic algorithms.

1. INTRODUCTION

The optimum arrangement of devices and machines in the flexible manufacturing system is one of the basic requirements in designing of the flexible manufacturing system, since good solutions in the design of such a system are a basis for its efficient operation and for low operating costs. It was estimated that 20% to 50% of the manufacturing costs are due to handling of work pieces; by a good arrangement of devices it is possible to reduce the manufacturing costs for 10% to 30% 1. Therefore, already in an early stage of designing of the system it is necessary to have an idea of the layout of the devices.

In the flexible manufacturing system, designed anew, the devices must be arranged in the best possible way. Usually the selected target function are the minimum total costs of handling of work pieces. In general, those costs are the sum of the transport costs (these are proportional to the intensity of the flow and distances) and other costs.

The problem of arranging of devices is one of so called NP problems. The problem is theoretically solvable also by testing all possibilities (i.e. random searching) but practical experience shows that in such manner of solving the capabilities of either the human or the computer are fast exceeded. For these reasons we proceed to design the flexible manufacturing system by genetic algorithms. In this way we designed the flexible manufacturing system whose devices are arranged in one or multiple rows.

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2. PROBLEM OF ARRANGING IN ROWS

The manner of arranging of working devices largely depends on the type of production 2. The machines fed by AGVs are usually placed in one or multiple rows. Also the machines fed by the crane robot are placed in such way. An example of such placing is shown in Figure 1.

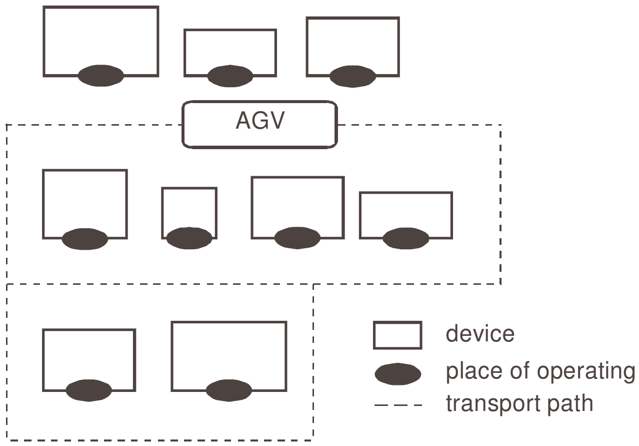

Figure 1. Placing of machines fed by AGVs in multiple rows

The AGVs are very flexible and increasingly present in modern factories, particularly in the flexible manufacturing systems. In case of bad layout of machines more AGVs are required but they are insufficient utilized. Also the software for the control of transport is very complicated and difficultly reaches the optimum states. Therefore, it is of key importance how the devices should be arranged in order to assure optimum execution of transport of materials and workpieces. In principle, the devices fed by AGVs, are arranged into different layout in one or multiple rows. Often the size and the form of the space available are limited, but even when there are no space limitations we need to know into how many rows the devices should be arranged.

3. MODEL OF ARRANGEMENT IN ROWS

Prior to solving the problem we set ourselves the limitations that will be taken into account. These limitations are:

- all machines are of rectangular shapes,
- the machine is operated in the center of that space,
- all machines in the row look into the same direction as shown in Figure 1.

When searching for the solution by genetic algorithms it is necessary to determine the target function which, in our case, is the sum of variable costs in a time period. For such manners of solving of the problem it is necessary to know the matrix of the transport quantities between the individual devices N in a time period 3. Also the variable transport costs, depending on the transport means used, must be known.

3.1 Fitness function

In order to find by means of these data the optimum layout of the devices N, we must find the optimum of the following target function:

$$f = \sum_{i=1}^{N} \sum_{j=1}^{N} f_{ij} \cdot c_{ij} \cdot L_{ij}, \tag{1}$$

where f_{ij} is the frequency of transport between the devices i and j, c_{ij} are the variable transport costs for the quantity unit and L_{ij} is the distance between the devices i and j 3. The number of all devices is equal to N. The costs of transport between two devices can be determined if their mutual distance L_{ij} is known. During execution of the genetic algorithm, the values f_{ij} and c_{ij} do not change, the value L_{ij} changes with respect to the mutual position of devices and with respect to position in the arrangement. In order to determine L_{ij} we need also the dimensions of the devices, the minimum available distances between the devices, the widths of the transport paths and coordinate of the points of operating.

3.2 Coding of organism

Each organism represents one of the possible solutions of the problem of arranging. The sequence of working devices in the organism is equal to the genotype of the organism. If we have, for example, six working devices arranged in arrow, the genotype of the organism (the sequence) can be equal to:

$$[s_4, s_1, s_6, s_3, s_2, s_5, a],$$

where the gene s_i represents the device i and his position in the organism represents the position in the arrangement. However, such gene would represent the arrangement in one row only. For that reason we add into the organism the gene a representing the greatest possible length of the row. The parameter a can be determined in advance ant it represents the width of the space available. Selection of the parameter a can also be left to the genetic algorithm. In this case, in order to avoid formation of illegal organisms we limit the selection of the parameter a to a interval reaching from the length of the longest device to the sum of the lengths of all devices with appurtenant intermediate spaces (layout in one row only).

On the basis of the parameter a the arrangement into rows is determined. So many devices are arranged into the row, that the length of the row does not exceed the parameter a. When the length of the row is equal to the length a, the next device is placed into a new row. The procedure repeats, until all devices have been arranged into rows. Such manner of coding guarantees that all organisms are correct even after completion of genetic operations 4.

3.3 Genetic operations

Many genetic operators exist for such type of coding. The most suitable crossover is the partial mapped crossover 4 and the most suitable mutation is inverse and reciprocal mutation. The above coding of the organisms and selected genetic operations ensure correctness of all offspring.

3.4 Genetic algorithm

Solving by means of the genetic algorithm takes place in the following way. First the matrix of the frequencies of the transport, the matrix of the transport costs, the matrix of the least allowable distances, the matrix of the machine dimensions, the width of transport paths and the greatest length of the row (a) are determined. For the evaluation of the individual organisms and selection, first the arrangement into rows is determined. On this basis of the layout, the coordinates of the points of operating are determined. When calculating coordinates also the dimensions of the devices, the minimum allowable distances between the mutual devices and the widths of the transport paths are considered. Thus the matrix of coordinates of operating is obtained:

$$\begin{bmatrix} x_4 & x_1 & x_6 & x_3 & x_2 & x_5 \\ y_4 & y_1 & y_6 & y_3 & y_2 & y_5 \end{bmatrix}$$

On the basis of coordinates the lengths of transport paths between the individual machines l_{ij}, can be determined. If several paths between machines i and j are possible the shortest one is selected. Then, by means of evolutionary and genetic operations we gradually arrive at better arrangement.

4. CONCLUSIONS

By means of the presented algorithm we can find the optimum layout of the devices in the flexible manufacturing system. The model searches for the optimum layout in rows and finds itself the optimum numbers of rows. The solution can be either the layout in one row or the layout in many rows. The model does not limit itself to one solution only, but it can propose us several equally good solutions which can differ very much.

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