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Design Methods that Work

IMPLEMENTATION OF MATRIX METHOD AND EVOLUTION ALGORITHM FOR REORGANIZATION OF DESIGN PROCESSES.

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Abstract: *In this article a matrix method is implemented for design processes planning. Optimization of that kind of processes requires minimization of iteration loops and parallelization of design operations. For that purpose an evolutionary algorithm was proposed and a new computer program has been set up. An application of the tool to an industrial real life design problem is demonstrated.*

1. INTRODUCTION

Each realization process should be planned for the shortest execution time and minimal cost without decreasing the quality of the product. It can be achieved by proper process decomposition and by optimal coordination of the tasks.
Engineering design processes often include a number of feedbacks. During planning, the feedbacks should be minimized to achieve optimal realization time. Traditional network-based planning methods, like PERT, CMP, MPM, etc, and popular Gantt's charts are not suitable for dealing with the iteration processes. On the contrary, a matrix form implemented in this paper - known as the design structure matrix – is a very efficient tool for analysis and reorganization of processes in which feedbacks are present [1,2,3]. It is particularly suitable for complex processes with a great number of partial tasks, which causes extreme difficulty with solving those types of optimization problems.
For solving of this kind of optimization processes first an algorithm and then a computer program were developed by the authors. The design structure matrix method is the base of this program. A particular feature of the program is implementation of a special evolutionary algorithm that enables the user to easily receive the optimized structure of the matrix [4].
As an example of application a real life problem from a manufacturing company is presented. The example demonstrates how the evolutionary algorithm managed to find significant decrease of the process time and cost.

2. IMPLEMENTATION OF THE METHOD – CASE STUDY

Our method is based on the process decomposition and then on its representation in the matrix showing dependencies among the partial tasks. The example of that matrix is shown in figure 1.
Partial tasks are indexed in the matrix main diagonal. Lines above the diagonal connect tasks, which can be executed subsequently, i.e. they show feed-forward or progressive connections, whereas the lines below the diagonal indicate feedback connections.
Each instance of the matrix can be related to a definite process structure. Changing positions of the tasks in rows and columns of the matrix, yet keeping the connections between them, one changes the order of realization of the tasks. Thus matrix representation is a very useful tool for minimization of duration and cost of the process [5]. In simple problems a good solution can be found by trial-and-error approach supported by the user knowledge and skill in manipulation the matrix. However, in complex processes with large number of tasks, analyzing all combinations without using a suit-

able computer aid is a very complicated and time consuming procedure. For that reason, following J. L. Roger's suggestion [2], a special evolutionary algorithm and computer program have been created.

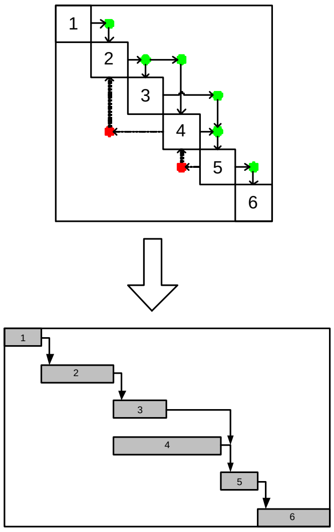

Fig.1. *Matrix and Gantt Chart*

The following case is taken from the industry and is based on real data. The problem consisted in fast executing of complex design calculations. The whole process was disassembled into 16 partial tasks, for which connections were identified, and times and costs of execution were estimated. The original structure of the realization process (as it had been planned in the company), put in its matrix form, was the input for the computer program.

The dialog window shown in fig. 2 presents all partial tasks with their times and costs. Overall time of the original process that takes also into account possible concurrency of some tasks is 160 units, in which 84 units are attributed to 6 feedbacks. The realization cost of the all tasks, allowing for iterations, was equivalent to 650 cost units. In this original process structure the feedbacks caused 332 cost units, which means ca 51% of the overall design cost.

In fig. 3 the Gantt's bar chart of the process is shown, as received from the MSProject computer program.

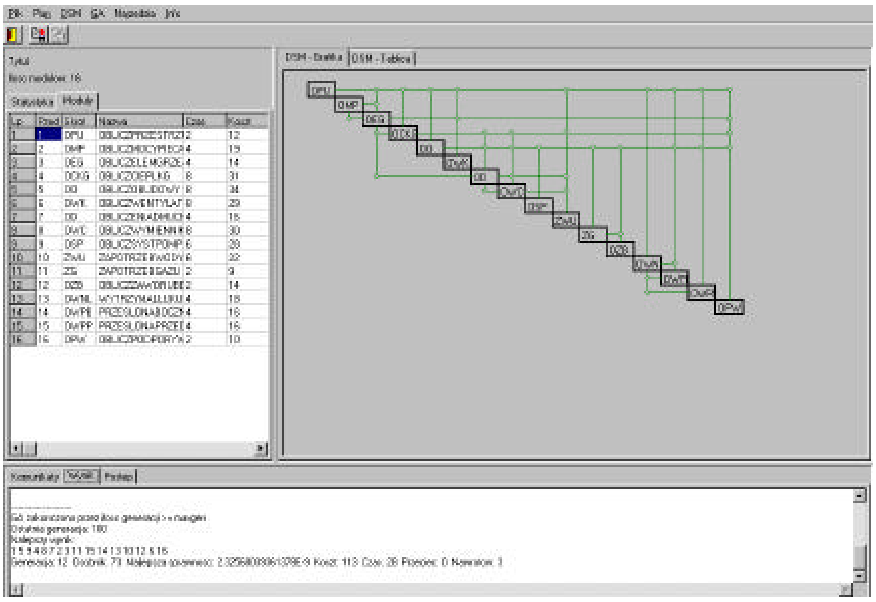

Fig .2 Dialog window

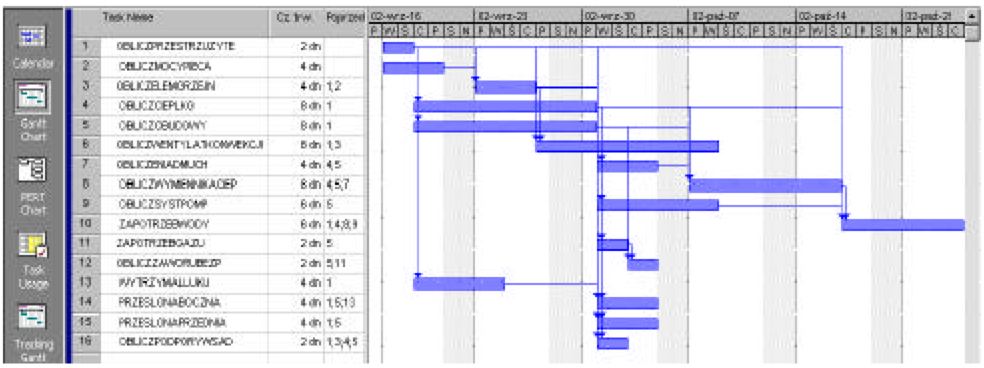

Fig.3 Gantt's schedule

For finding the best sequence of the partial tasks the process was subjected to optimization for shortest realization time and least cost. As a result of the evolutionary algorithm implementation a new process matrix was generated by the computer program (fig. 4). The order of partial tasks execution was changed. However, the connections between the tasks remained maintained.

The number of process feedbacks was reduced from 6 to 3, which shortened the realization time from 160 units to 104 units. Overall cost of the process amounted to 431units.
In fig. 5 a new Gantt's chart of the process realization is shown.

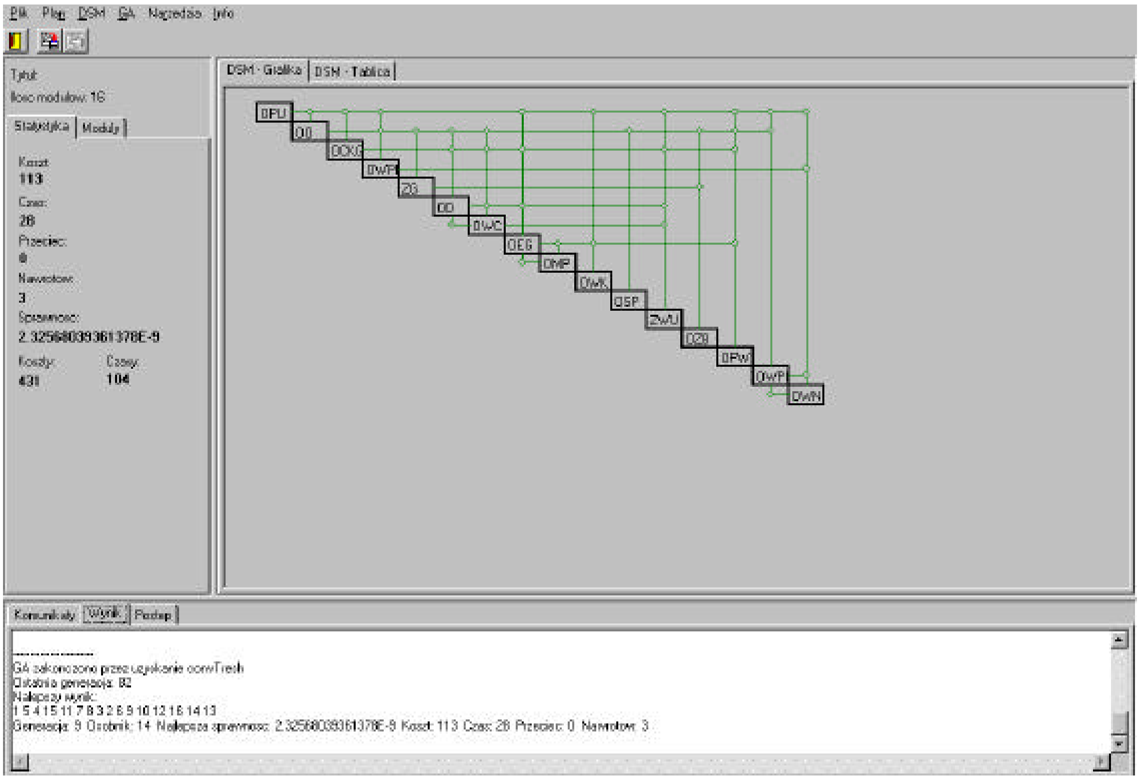

Fig.4 New process matrix realization

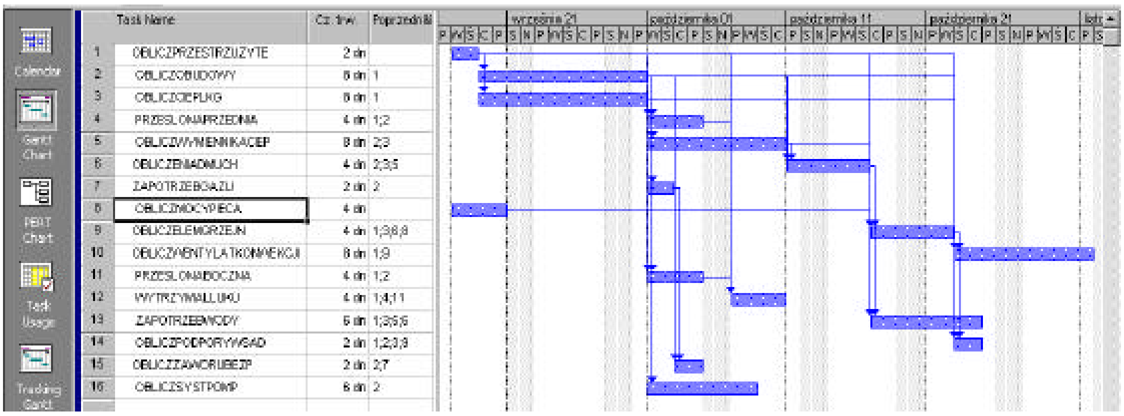

Fig.5 New Gantt Chart

3. SUMMARY AND CONCLUSION

A real life design calculation process, taken from a manufacturing company, was used for the test case presented in this paper. Original plan of the process realization included 6 feedbacks. As it had been evaluated, it would need 160 time units to be completed. After the optimization procedure, which involved mapping the process in the design structure matrix form and the evolutionary algorithm implementation, the overall process duration time was reduced to 104 time units with only 3 feedbacks (tab.1). Thus, a possibility of shortening the process realization time by 35% has been proved. Simultaneously, the overall process cost was reduced to 431 cost units.

Table 1. *Duration and cost of the design process before and after optimization*

	Design process original	Design process optimized	Savings
Time of feed-back loops realization	84 units	28 units	66%
Overall process time	160 units	104 units	35%
Cost of feedback loops realization	104 units	113 units	66%
Overall process cost	650 units	431 units	34%

Figures in Table 1 do not take into account the possible simultaneity of carrying out of some tasks. Simultaneous realization can make the whole process shorten, however it does not directly influence the cost.

It should be noticed that implementation of the result in the company appeared not so easy because it would depend on several constraints that were not taken into the account. These were, among others: the company organizational structure, its human resources, dependency on suppliers, available equipment, etc.

Notwithstanding the noticeable discrepancy between industrial reality and the idealized design process model, the method presented in this paper has proved numerous advantages over network planning methods. A number of engineering design organization problems has already been solved for industry by means of the design structure matrix.

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