POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY
Conference Proceedings
12th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

A model for prediction and evaluation of production processes based on genetic algorithm

I. Drstvensek, M. Ficko and J. Balic

Faculty of Mechanical Engineering, University of Maribor
Smetanova 17, SI-2000 Maribor, Slovenia

Paper describes means and methods for computer-based optimisation of production processes using a new approach based on technological database (TDB) with genetic algorithm incorporated into a database management system (DBMS). The TDB serves as a store of tools and machine tools from which they can be assigned to different work operations. The goal of the model is to find available resources from the TDB in order to empty the queue in shortest time with lowest costs. To this purpose the model consist the technological database that DBMS includes a genetic algorithm based optimiser. It checks the orders queue and searches for appropriate combinations of tools and machine tools from the TDB, which can be combined into needed work operations. It also performs an optimisation of time and costs according to so called static parameters of tools and machine tools.

1. INTRODUCTION

Presented model utilizes a power of relational model for database management and multicriterial genetic algorithm for optimisation of production resources. It uses an innovative idea of key information as guidance for the database development and introduces a genetic algorithm based search engine into the database management system.

2. TECHNOLOGICAL DATABASE

It is a lot more complicated to build a technological database than a business database. The basic reason lies in the fact that documentation in technological process doesn't represent the main objective of the working process and it isn't "form-like". To cover a technological process with a database we used an approach that is based on the idea of key information as guidance for the database development.

2.1. Key information

The work operation is a group of working means that bounded together enable execution of the operation. Since productivity, costs, and quality of the production process depend on the selection of the work operation, optimisation of procedures means a selection of the combination of work operations that will give the demanded result (work order) at lowest possible costs [1]. To this purpose a work operation needs to be structured in a way, which will assure the data for mentioned criteria and will be suitable for automatic handling in a database. In this manner the work operation would consist of 6 groups of data:

- Manufacturing mean (machine tool)
- Tool
- Operator
- Auxiliary mean
- Maintenance means
- Rests

Each of work operation's group of data can be composed of some attributes that describe it in form of databases tables. Such a structure enables the TDB to act as work operation's magazine, e.g., all possible work operations in a production system are stored in the magazine from which they can be assigned to different work orders. A work operation once assigned becomes unavailable to any other order until it is completed at the actual one. The described principle is the basic tool for production planning, and represents a unique way of queue scheduling [2].

2.2. The practical model

As mentioned before the work operation itself is not an entity of the TDB. It is a combination of data-groups listed above, which are the entities of the TDB. They form tables and fields of the database in which the actual data are stored.

To simplify the problem of work operation's definition the model consists only of machine tool and tool tables since the majority of optimisation can be done on these two resources. In this simplified schema a work-order is represented by a list of work operations that have to be performed over a subject of production represented by a CAD model. The scheduling stage of the production planning starts by comparing the list of work operations with the table of available work operations. After comparing, all available operations that correspond to the list of ordered operations are marked unavailable by setting the available field to the value of work order's number. The gained search field is in fact a new table containing all machine tool / tool couples marked unavailable by the actual work order.

3. OPTIMIZATION MODEL

The optimisation process starts by creating the initial generation of organisms, which then improve by reproduction, mutation and crossover from generation to generation [2]. Thus, we gradually obtain the members (organisms) of ever-higher quality that, in fact, are the solutions of the problem.

3.1. The cost functions

The cost function represents the first fitness function of our optimisation problem. It consists of three that represent the transport costs for the order, the preparation/completion costs on the individual machines and the net cost of machining.

$$\min Z=\sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}\cdot x_{ij}\cdot c_{tij}+\sum_{i=1}^{n} t_{pzi}\cdot y_i\cdot c_{si}+\sum_{i=1}^{n}\sum_{j=1}^{k} t_{tij}\cdot c_{si} \tag{1}$$

where:
n – number of machines in the production system
d_{ij} – distance between the machines i and j. It is obtained from the matrix of distances between the individual machines. That matrix is constant.
x_{ij} – indicates the presence of connection between machines i and j for the order (exists, does not exist) – the value is 0 or 1. It is obtained from the genotype of the organism.
c_{tij} – transport costs between the machine i and j per unit of length. It is obtained from the matrix of costs for interconnections between machine i and j.
t_{pzi} – preparation/completion time on machine i. It consists of the time for machine tool preparation and the time for setting the tool to the machine tool.
y_i – utilization of machine i for the order – the value is 0 or 1. It is obtained from the genotype of the organism.
k – number of operations for the order.
t_{tij} – technological time of machining for machine i and operation j. It is obtained from the NC program and depends on the used machine i and operation j.
c_{si} – price of machine hour for machine i.

The time function is the second fitness function that consists of principally the same three parts and issues from the cost functions.

$$\min Z = \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij} \cdot x_{ij} \cdot \frac{1}{v_{ij}} + \sum_{i=1}^{n} t_{pzi} \cdot y_i + \sum_{i=1}^{n}\sum_{j=1}^{k} t_{tij} \qquad (2)$$

where, v_{ij} stands for a speed of transport between machines i and j. It is obtained from the matrix of speeds of the individual transport devices.

3.2. Coding

Organism is coded as a n × m matrix; where n equals the number of work operations demanded by the work order and m equals the number of work operations data-groups + 1. The additional (+1) row represents a work operation from the work order whereas the remaining rows represent the machine tool and tool to perform the work operation, respectively. Columns of the matrix that are forming ordered triplets represent genes, which in sequence represent the organism or an individual of a population in an optimisation environment.

$\begin{bmatrix} o_1 & o_2 & o_3 & o_4 & o_5 & o_6 & o_7 & o_8 & o_9 \\ s_3 & s_1 & s_1 & s_8 & s_8 & s_4 & s_4 & s_4 & s_2 \\ t_{12} & t_{34} & t_{34} & t_7 & t_{15} & t_{48} & t_{48} & t_{19} & t_{25} \end{bmatrix}$	o_i – operation i s_i – machine tool i t_i – tool

Creation of an organism starts by filtering the database tables as described in section 2.2. In continuation the database keys from corresponding tables (o_i - operation, s_i – machine tool, and t_i – tool) are transferred into matrices as codes of organisms. Every operation requires a machine tool on which it'll be completed and a suitable tool to carry it out on this particular machine tool. The resulting organism is in fact a recipe or a scenario for work order's accomplishment.

3.3. Evolutionary and genetic operations

According to the phenotype (equals value of fitness function) a reproduction probability is given to the organisms. Such a selection method is called weighted roulette wheel selection. The overall reproduction probability in this experiment was 30%. The crossover probability used was 70%. A simple single point crossover was used. The new generation gained in this way is called a proto population, which furthermore undergoes a mutation procedure. In this procedure single genes of the population are mutated with a probability of 5%. The mutation replaces the random gene selected from the combination table.

4. CONCLUSION

Introduction of a genetic algorithm optimisation technique into the database management system of a relational database joins together two very powerful instruments. On one hand all filtering tasks are relinquished to the methods of relational algebra while on the other hand the genetic algorithm engine only deals with key values from the database's tables. Actual values are coming into account only in the evaluation stage while all genetic operations are done over the key fields of the database. It is also an advantage of this method, that after several runs of the "evolution cycle" several different solutions are obtained having a similar value of the cost functions. These solutions form alternative scenarios for occasions of unexpected events that are the only constants in turbulent production environments [4].

REFERENCES

1. G. Halevi, R. D. Weill, Principles of Process Planning, A logical Approach, Chapman & Hall, London, 1995.
2. I. Drstvensek, J.Balic, Responding ability in dynamic production circumstances, J. Mat. Proc. Techn., Vol. 133, 71-78, 2003.
3. J. Holland, Adaptation in Natural and Artificial Systems, University of Michigan Press, Ann Arbor, 1975.
4. M. Ficko, Model oblikovanja prilagodljivih obdelovalnih sistemov z genetskimi algoritmi, Fakulteta za strojništvo, Maribor, 2002.