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KNOWLEDGE-BASED SYSTEMS TO SUPPORT PRODUCTION PLANNING

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Original scientific paper
Proposed concept of proactive manufacturing planning uses sets of knowledge to create plan. These sets of knowledge are gained from transformation of historical data of selected indicators. This concept uses the analysis of occurred events, which is done by applying data mining methods to known historical data. Results of analysis are then recorded into knowledge-based system for further use. Application of data mining techniques helps to find hidden relationships with high influence on final decision of planner. This concept aims to navigate planner during creation of real plans resulting from real situations. Unknown situations are modelled using simulation module.

Keywords: *data mining, decision trees, knowledge-based systems, proactive planning, production planning*

Sustavi temeljeni na znanju kao podrška planiranju proizvodnje

Izvorni znanstveni članak
Predloženi koncept proaktivnog proizvodnog planiranja koristi skupove znanja za stvaranje plana. Ti se skupovi znanja dobivaju transformacijom povijesnih podataka izabranih pokazatelja. Taj se koncept koristi analizom događaja koji su se dogodili, a provodi se primjenom postupaka rudarenja podataka na poznate povijesne podatke. Rezultati analize se zatim spremaju u sustave temeljene na znanju za daljnju uporabu. Primjena metoda pretraživanja podataka pomaže u pronalaženju skrivenih odnosa s jakim utjecajem na konačnu odluku onoga koji planira. Svrha je tog koncepta da vodi planera tijekom stvaranja realnih planova koji proizlaze iz realnih situacija. Nepoznate situacije se modeliraju primjenom modula simulacije.

Ključne riječi: *planiranje proizvodnje, proaktivno planiranje, rudarenje (pretraživanje) podataka, stabla odluke, sustavi temeljeni na znanju*

1 Introduction
1.1 Proactive approach in knowledge-based systems

Series of processes after receiving an order up to its realization are interdependent. They communicate important information with each other and process it with appropriate algorithms. Information flow is defined by the structure of these processes and by the sequence of their execution. Starting of individual processes is managed by predefined rules.

Depending on characteristic of proactive approach, some changes of processes may start before the system begins to respond to individual occurring events. In a real world, correctness of using of selected planning actions, methods and techniques of planning depends on reality, by reviewing if changes in processes were started correctly and if required goal was reached at the end.

Proactive approach controls given situation by active influence on given process before unwanted situation occurs. Opposite approach is characteristic by reacting on situation after it happens.

Based on aforementioned characteristics we can conclude that proactive approach in knowledge based systems for manufacturing planning assumes that manufacturing planning system will play an active role in fulfilling objectives based on requirements defined by company management. For example manager of production, trade, technical or economic manager tries to keep processes falling under his competence within the predefined values for the selected indicators. Management tasks are built for the purpose of achieving the planned values of indicators that reflect the goals of the company and are often tied to the motivational system. For example sales manager is interested in the volume of sales of products, purchasing manager tries to minimize the costs associated with buying and holding stocks of materials in warehouses. The production manager is obliged to observe the values of indicators reflecting the highest efficiency and lowest operating cost of production. Values of these indicators are monitored and adapted to the current required goals of the company.

Selection of an appropriate indicator and adjustment of its scale is an important act in control of monitored process. This also applies to the planning process, where there is a very important interconnection between all relevant indicators at different levels of the plan creation. Individual assessment of processes can cause that the effort to increase the level of one indicator on the one hand, may have a negative impact on the overall level of efficiency on the other.

The proposed knowledge-based system needs to take into account current and expected development of the business environment and its surroundings. The result of this analysis and the subsequent transformation of indicators would then decide on the manufacturing company's ability to deliver the product in required quality, cost and time based on proactively created plan. Based on the status of development of indicators monitored at given time, the company could then assess its ability to produce and deliver the product within the required time frame.

1.2 Knowledge-based proactive planning concept design

The proposed concept of proactive planning consists of planning modules of standard company information system, a system for transformation and analysis of selected indicators, the expert system for the design of a proactive manufacturing plan, and simulation module for modelling previously unknown situations, Fig. 1.

Design of final proactive plan is possible to be set by expert system, whose knowledge base acquires knowledge gained by data mining (DM) from the data warehouse (DW), to which access is controlled via interference mechanism (IM).

The simulation module enables to simulate the resulting variants for newly created problems [11].

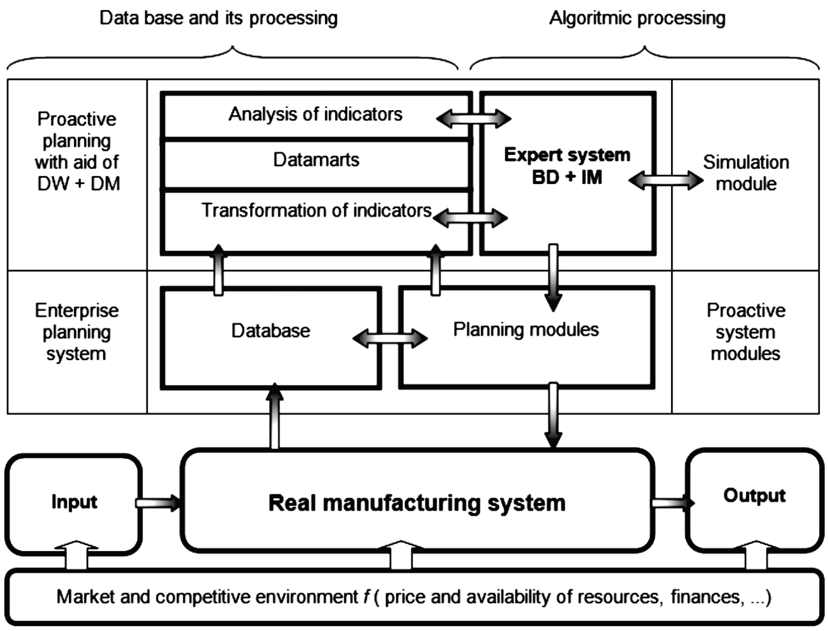

Figure 1 Proactive manufacturing planning concept design – modules

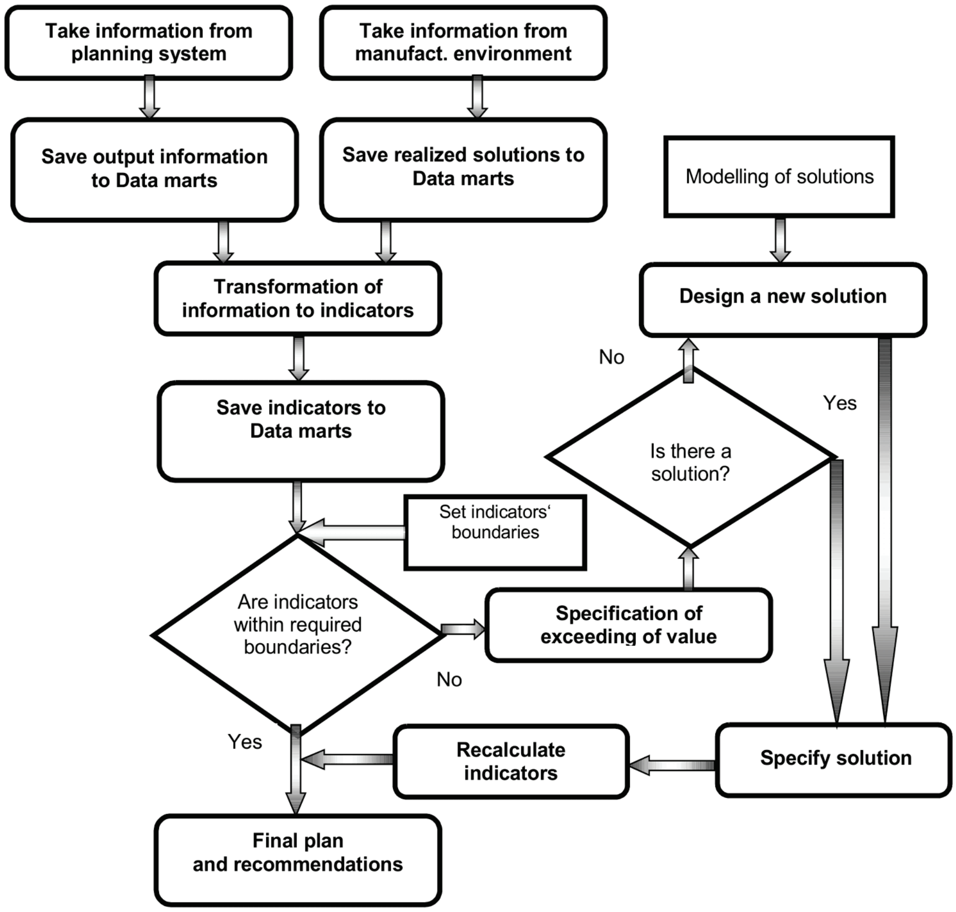

Figure 2 Algorithm of the concept

The proposed concept allows historical information obtained from the realized production orders, from their proposed plans and the actual behaviour to be utilized for repeated use in the design of the production plan. This production plan can be called "proactive" because it will be constructed with the knowledge of expected known and unknown events. This interconnection of information technologies enables to detect problems early and to avoid them. The proposed concept is based on planning modules, and the concept also allows acquiring these data from the existing ERP systems.

The resulting data of realized business cases, purchases and realized production, but also the resulting economic evaluation of the performance of manufacturing company are transformed into indicators at the end of the business case. The concept captures the change of indicators and their development also after changes in the input parameters. The dynamics of the system is captured and indicators can assist in the design of a new production plan.

Algorithm of the concept describes the transformation of the data to indicators that reflect the state of the manufacturing system at a given time in Fig. 2.

The result of individual steps is evaluation of implementation of the proposed plan using the required economic indicators as well as customer requirements, which clearly determine the suitability or unsuitability of the decision made. In the case of using modelling tools, the concept enables to define the upper and lower boundaries of individual indicators, or the definition of "warning" about potential failure caused by the decision.

Hierarchy of indicators is designed in the way that it could describe as accurately as possible what is happening in the company and what is the development of customer requirements, in order to satisfy him in terms of time, volume and quality.

Finding a suitable setting of indicators and searching for known and less known causes and relations to successfully plan production in this concept ensures the top module, which will search and recommend the best plan variants based on historic and present values of indicators.

The best variant is characterized by required values of selected parameters, which will be adjusted by production planner, market analyst and chief economist.

On exceeding of the boundary set for selected indicators, the system would respond by querying the data warehouse using data mining techniques to help find a solution based on our knowledge of the processes we have so far. After implementation of the selected solution, the system as an expert would make a conclusion making an entry into the system. The content of the entry would be a result that brought the decision.

The concept of proactive production planning with support of data technologies requires a high-quality database platform with an integration of techniques for data mining. Nowadays, with support of fast data technologies, processing of these data should no longer be a problem. Great emphasis should be put on the design and type of information, their location and how to work with them to make gradual information processing leading to usable knowledge that would be used by expert system for further work in order to design a more suitable plan.

This structure of concept ensures that comprehensive information on the status and development of indicators for a selected business case are available at given time and that it is possible to determine which parameters and their development and indicators caused the adverse conditions. Or in other case, which warnings were issued with enclosed record of action taken or not taken by responsible manager.

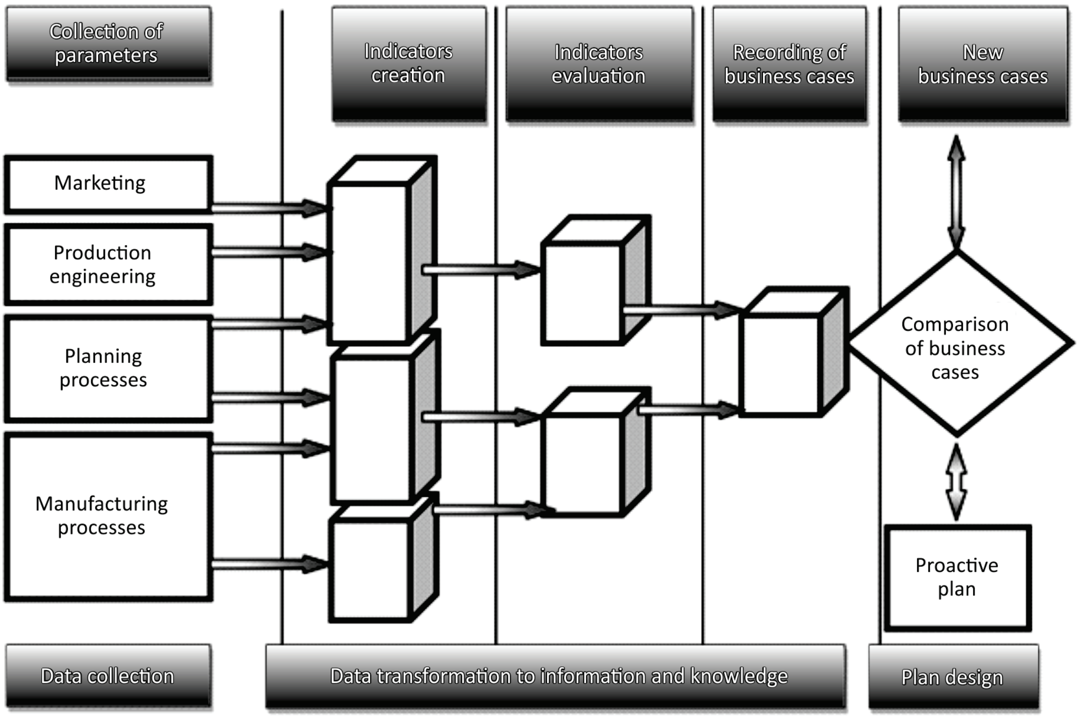

Figure 3 System of transformation of indicators

2 System of indicators

Companies create a number of indicators for monitoring the performance of individual processes. The existing system of indicators and their influencing parameters is necessary to be arranged to a suitable structure for the purpose of further use.

Selected indicators from system of indicators are for example [2, 5, 7, 8, 9]. The present concept considers a group of selected indicators, which will be constantly updated through data warehouse. Emerging situations will be analysed by data mining methods such as decision tree learning.

The resulting knowledge of the behaviour of the indicators in a given situation will be entered into a knowledge based system for further use.

Production engineering indicators:

- Number of documents processed per employee.
- The processing time for a single document.
- The number of defective/returned documents.

- Number of unrealized orders.

Planning indicators:

- Production capacity utilization.
- Downtime of machinery.
- Product range composition.
- Number of overdue tasks.
- Size of the work in progress.
- Average time to complete order.
- The average delay time.
- The average number of requests per workplace.

Manufacturing indicators:

- The average number of items produced per department, per order.
- The degree of standardization, mechanization and automation.
- The average number of items planned per worker.
- Average time to process orders.
- Cost of production order.
- The cost of downtime.
- Cost of maintenance.

3 Knowledge-based systems and their benefits for manufacturing planning and control

Planning and control of manufacturing process is a complex task, because it is influenced by many factors which have impact on time and quality of delivery of required product. Employees at manufacturing control level are responsible for fulfilment of defined performance indicators. Every day they are forced to solve problems related to insufficient quality or performance at workplace. Employees or information systems monitor and record information about process states, which is later additionally discussed with manufacturing operators. Usual feature of manufacturing is variability in performance and quality. Same order assigned to different manufacturing teams produces different values of performance and quality. This fact creates a question if there is a variant of manufacturing plan, in which planner/supervisor assigns manufacturing task to workplaces and operators so that he can reach the highest possible effectivity of production process. We tried to find the answer by experiment in a manufacturing company, where the final product, with 70 possible variants, is manufactured by pressing. This company owns three machine presses and operates two shifts. Final production can be characterized by occurrence of 15 types of defects, which together create defected items of approximately 15 % of all items produced. Aim of the experiment was to find out if poor production quality of selected range of products is caused by particular press, and to what extent is this poor quality dependent on particular operator. By applying data mining methods to 20 most defective variants, we concluded that defectiveness of particular variant is very likely to be dependent on selection of particular press, as shown in Fig. 5. These dependencies can also be seen from visualization of relation between defectiveness, particular variant and selected press, as can be seen in Fig. 4. By using data mining methods, specific support system can be created, which could help planner in decision making processes.

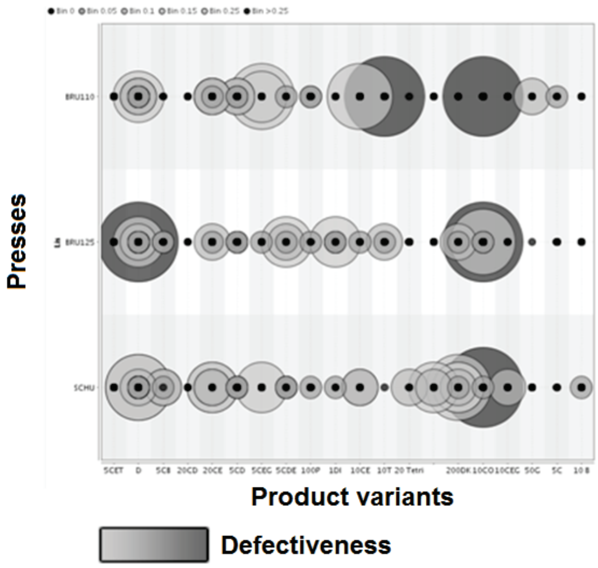

Figure 4 Relation between defectiveness, variant and press

Similar situation can be observed when we visualize defectiveness in relation of operators to particular presses as shown in Fig. 5. Three different operators perform differently while producing the same products on the same machines, which can also be knowledge used either for investigating possible reasons for differences in defectiveness of items among operators, or to simply accept this distribution and use it for prioritization of operators based on their ability to produce the lowest amount of defective items.

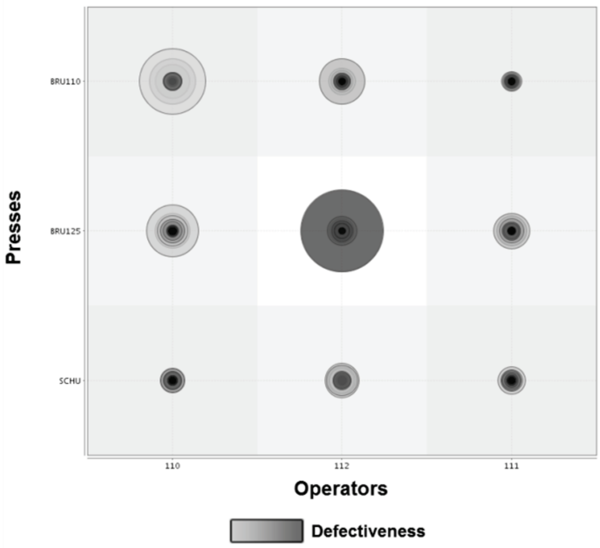

Figure 5 Relationship between defectiveness, operator and press

Result of data mining process, which can partially be seen in Fig. 6, is a model that can be used for creating the most efficient plan based on given circumstances, which then increases probability of lower defectiveness in future. This model was created by inputting historical manufacturing data into decision tree learning algorithm.

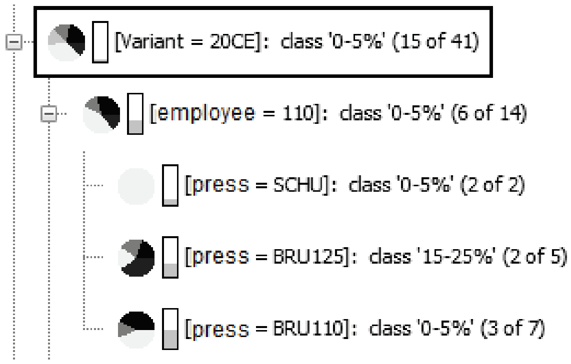

Figure 6 Proposed model for assigning production tasks

If a planner considered these sets of knowledge during creation of production plan, company could significantly lower its amount of defective products. For instance, during production of variant 20CE by assigning employee 110 to press SCHU the probability of occurrence of defects lowers to 5 %. Planner would then prioritize assigning employee 110 to presses SCHU, BRU125 and BRU110 respectively.

4 Conclusion

This knowledge-based proactive concept demonstrates a relatively easy way to acquire knowledge from existing monitored company data and applies data mining techniques to their transformed version. Absence of need to model complex functions over time makes it a very flexible solution for further data mining. Using decision tree classifier is just one of the options. Production data could, after relevant transformation and consideration of model accuracy parameters, be also fed into other more complex types of data mining algorithms such as artificial neural networks or genetic algorithms.

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