Annual of the University of Mining and Geology "St. Ivan Rilski"
vol.44-45, part III, Mechanization, electrification and automation in mines, Sofia, 2002, pp. 75-79

APPLICATION OF THE ARTIFICIAL INTELLIGENCE METHODS IN CAD/CAM/CIM SYSTEMS

Athanasios Papavasileiou
Technological Education Institute of West Macedonia
Greece

Emil Gegov
University of Mining and Geology "St. Ivan Rilski"
1700 Sofia, Bulgaria

Konstantinos Gavros
Technological Education Institute of West Macedonia
Greece

ABSTRACT
Recent CAD/CAM/CIM systems have reached a very high level of development and application based mainly on the development of the computer technique and the applied mathematics tendencies and information technologies. The reference review showed that the application of the scientific tendency artificial intelligence is still insufficient. In the process of work it is attempted to synchronize the potential of its wide application in the considered system class.
Key words: Projecting stage, choice of decisions, optimization in conditions of risk and indetermination.

INTRODUCTION

Design is a series of procedures, in which an analysis of designed object and conditions of environment, development of variants and choice of optimal decisions, according to the assignment of design are made. It is not needed to prove the creative character of design and necessity of extended application of artificial intelligence systems.

Intelligence is the ability of a human, in the considered case the designer, to find successful decisions in the presence of incomplete or insufficiently accurate a priori information. Artificial intelligence is a computer program, in which the intelligence of prominent specialists in certain field is synthesized and set up.

The power and potential of Artificial Intelligence (A.I.) tools for planning and controlling of manufacturing processes has been proven by many research projects and demonstrations. The most important A.I. techniques are quantitative reasoning and simulation, and the use of deep models. Typical applications are for design, manufacturing planning, machine diagnosis, machine lay-out, system configuration, task-oriented programming, man/machine communication, vision, sensor data interpretation ect. At the present time, however, it is not known how many of these systems are practicable and are being used. A conservative estimate is that the results of only 5% of all research endeavors have found their place in the factory. This may be a very discouraging reality; but there are numerous reasons for this problem, including:

- The tools for building expert systems are not sufficiently developed and are difficult to apply.
- Good expert systems usually contain several thousand rules and are huge software systems which are difficult to use on conventional computer systems.

STRUCTURE OF AN EXPERT SYSTEM

The builder of an expert system must have a model of the system for which a solution is to be sought. The model describes the properties and behavior of the system. Usually, an attempt is made to keep the model simple and to only include the important features of a process.

Numerous programs and programming packages have been developed to solve manufacturing problems. The heart of a program consists of the algorithm and data. The execution of a program is done in a concise manner laid down by the rules of the algorithm, which may include branching and looping.

The basic difference between the program and the expert system is the way knowledge is presented and processed. The expert system consists of a knowledge database containing explicit knowledge of a human expert in a specialized, domain, and a reasoning or inference engine which can access the knowledge base to derive at a decision for a described problem. The description of the problem and the context are entered by the user or by the system. An Expert system consists of the following seven components:

- *User or tutor Interface.* There are two groups of persons who must have access to the expert system. First, the tutor who set up the system and who prepares the knowledge to be entered into the database. The tutor will also maintain the expert system. Second, the user who tries to find a solution to a problem. He must be able to describe the context of his problem to the system.
- *Knowledge Acquisition Module.* This module processes the data entered by the expert and transforms it into a data presentation understood by the system.
- *Language Interface Module.* There are various ways of communicating with the system; it can be done by natural, graphical or problem oriented language. The level of abstraction of the user language will be much higher than

that of the tutor language. The language used must be understood by the interface, and a special expert system may be needed to extract from the user input the semantics which describes the problem uniquely.

- *Manufacturing Knowledge Module.* This module can be understood as a world model of the domain for which the expert system was developed. It is like a huge database which contains all factual knowledge and rules needed for the operation of the expert system.
- *Context or Workspace Module.* There are two ways of operating this module. First, the user enters into the system the description of his problem. Second, the system constructs the description itself by interrogating the user in a question and answer session. For this operation, there must be a description of the problem available to the system.
- *Interference Engine.* Essentially, this module is the knowledge processor which looks at the problem description and tries to find a solution with the help of both the factual and meta-knowledge. First, all rules of the factual knowledge are investigated by the reasoner, and, with the Help of the pattern matcher, the ones to be used are selected. Thus, a set of candidate rules are obtained. Second, one of the rules is selected and applied to the problem description by the processor.
- *Explain.* The user can communicate with the explainer to obtain a report about the operation of the expert system. He can find out how a solution was derived and which individual steps were taken. If the user desires, he can obtain intermediate data and information on how the knowledge was used.

ARTIFICIAL INTELLIGENCE APPLICATION IN MANUFACTURING

It is known that the control systems for the enterprise has to be designed in a hierarchical manner. On each level expert systems can be used to perform and to diagnose the current status of the next lower level, the planning task on that level.

- *Design*. When a product is being developed, the design process passes through the definition stage of the functions, definition stage of the physical principle, design stage of the shape, and the detailing stage. The expert system will be of help where the designer is concerned with details, such as finding available similar designs, standard components, tolerances, alternative solutions, reduce significantly trial and error searches, etc. There are three types of designs which lead to the conception of a new product. They are the new design, variant design, and modified design. It will be extremely difficult to produce a new design with the help of an expert system. There is no way of finding with this tool a solution to a problem for which no prior knowledge is stored. The variant design is based on existing functional and physical principles of a similar product. Dimensions and other physical parameters, however may be different. Here, expert systems will be of help to propose to the designer a solution based on a variant. The modified design usually has only a few alterations of an existing product. The design of the product determines, to a great extent, its manufacturing process. Expert systems can be of assistance to consult the designer about the manufacturability of the product.
- *Process planning.* When the design of the product is completed, process planning gets into action (Majumdar et al. 1989). There are two different methods used for process planning: they are the generative and variant methods. With the generative method, the part surface to be created has to be related to a manufacturing method. With variant process planning, the manufacturing process of a part variant must be known and stored in the computer as a nonparameterized variant. The designer queries a variant catalog in the computer and searches for the variant which is similar to the part to be made. This method has the disadvantage that a variant must be available for every part to be manufactured. Expert systems will mainly be of help for the first four phases of process planning:

1. *Selection of blanks or stock* (selection of material, determination of the type of blanks or stock, Calculation of the machining allowance).
2. *Selection of processes and machining sequences* (surface features, dimensions and tolerances, surface treatment and finish, piece rate, required work space for the tool, cutting direction, necessary tool changes, etc).
3. *Machine tool selection* (size of part, surface finish, machining sequences, process variants, required accuracy, piece rate, machine tools, etc).
4. *Selection of fixtures.*

- *Manufacturing Scheduling.* The information going into scheduling are the type and number of parts to be manufactured, the process plans, the bill of materials, order delivery dates, available machine tools, other resources, factory monitoring data on resource utilization, etc.

The two artificial intelligence tools most suitable for scheduling are the generate and test, and the constraint *propagation* methods.

- *Quality control.* Quality control is an important function of the manufacturing process. A quality control operation is done in several phases: First, a test plan is drafted. Second, the test system is configured and programmed for the individual products to be tested. Third, the measurements are performed and the data are recorded. Fourth, the data are evaluated and test protocols are prepared.

There are two areas where expert systems may be of considerable help to improve a quality control operation: test planning, and data evaluation and interpretation

- *Diagnosis.* Expert systems for diagnosis are the most advanced A.I. tools used in manufacturing. They play an important role in supervising complex production equipment and locating problems as soon as they arise. Presently available diagnosis systems can be defined by three categories: Statistic diagnosis systems, heuristic diagnosis systems and diagnosis models.
- *Implicit Programming of Robots and other Manufacturing Equipment*.

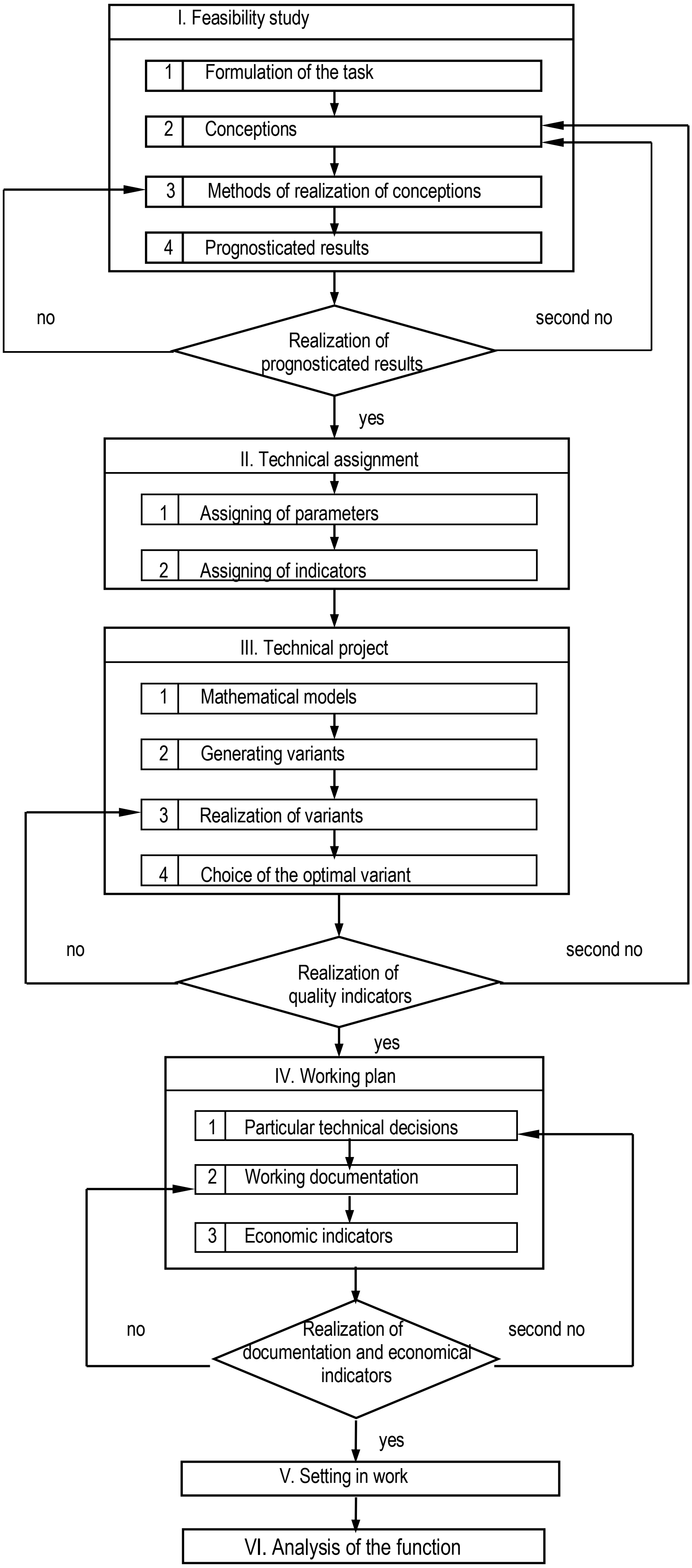
I. Feasibility study
1 Formulation of the task
2 Conceptions
3 Methods of realization of conceptions
4 Prognosticated results
no
second no
Realization of prognosticated results
yes
II. Technical assignment
1 Assigning of parameters
2 Assigning of indicators
III. Technical project
1 Mathematical models
2 Generating variants
3 Realization of variants
4 Choice of the optimal variant
no
second no
Realization of quality indicators
yes
IV. Working plan
1 Particular technical decisions
2 Working documentation
3 Economic indicators
no
second no
Realization of documentation and economical indicators
yes
V. Setting in work
VI. Analysis of the function

Figure 1.

Application of systems in the stage of feasibility study

Considering the tasks performed on that stage, development of systems is advisable the for a better-grounded choice of conceptions and principles by the realization of the projected decisions, choice of the alternative variants of the final purposes and tasks for providing the maximum values of the quality/cost criteria. A better-grounded realization of the task for the feasibility study of the developed projects has a direct dependence on the appraisal for potential application of the offered decisions in the considered stage. It is useful to develop an expert system with an extended database regarded to the projected object, the possible conceptions and the methods for their realization.

Application of systems in the stage of technical project

Here the possibilities for application are extremely extended and various. The development of a wider spectrum of variants of the design decisions with more detailed setting of the peculiarities and the parameters of ambient factors are of great significance. The most important application of the systems of artificial intelligence is in the reasoned choice of optimal variants in conditions of indetermination.

Recent computers have practically unlimited potential for formalizing of the factors (parameters) of the choice, the factors of the unspecified environment and appraisal of the optimality criteria values. It is considered here that the criteria for optimality are considerably different from criteria by the optimization in conditions of determination (determinism) and risk (stochastic conditions). In particular, the criterion for optimization under conditions of indetermination has not an only value but a multitude of values in a defined interval with a defined stage of attachment. This means that an application of a multi-digit function is reached.

Important peculiarity of the present requirements to design decisions is the presence of a multitude of criteria for optimality (task for multicriteriality of design decisions). Under conditions of indetermination (multidesignation of the particular criterion) the task for a vector optimization acquires extreme complexity not only in qualitative (semantic) sense, but also simply in quantity (combinatorial explosion). In these conditions setting the level of compromises (the level of Pareto) is practically impossible with the known conventional methods of the multi-criteria optimization theory. Assuming the possibility for applying of non-monotonous logical deductions, the application of systems of artificial intelligence is practically the only way for finding the optimal multi-criteria decisions in conditions of indetermination.

Processes in the development of design decisions

The basic conceptions of the system approach in design are:

1. Principle for coordination of the projecting works and decisions between the separate groups of designers-specialists in the relevant scientific-technical directions (technical engineers, mathematicians, mechanics, electrical engineers, etc.).

2. Principle of the iterative approach by solving problems, arisen during the realization of the projecting work. Iterative approach means that after performing of a certain number of procedures and analyses of the results, if needed, the performed procedures are repeated in order to improve and reach optimal, in the assigned purpose (assigned criteria), projecting decisions. The main requirement is the performed iterative procedures to be ensured in respect to identity the required optimal decision. It is desirable that the number of the iterative procedures is as least as possible. If a good identity is missing the iterative procedures must include some of the previous stages in order to correct already accepted decisions.

Generalized algorithm for iterative procedures in the development of design decisions

One of the many possible iterative procedures is shown through a diagram (fig.1.).

Iterative procedures are referred to every single stage of projecting, so that with an increase of the serial number of the iteration, procedures that precede the respected stage are included. For example in the stage feasibility study the non-realization of the prognosticated results leads to iteration that is addressed to procedure № 3 “Methods of realization of conceptions”, this means searching for new approaches for their realization and reaching to the desired prognosticated results. If a new non-realization of the prognosticated results, “second no”, is reached it is needed the new iteration to be addressed to the procedure № 2 “Conceptions”. This means that based on the “Formulation of the task” (procedure № 1) a new conception search must be made. In case of a new non-realization “second no” appears as a third iteration, by which new conceptions are searched for, until the formulation of the task is satisfied by the prognosticated results.

In the stage “Technical assignment” iterations are impossible, since the assigned parameters and quality indicators must be maintained.

In the stage “Technical project” the non-realization of the quality indicators leads to iteration to the same stage but by a second non-realization the next iteration requires a return to the first stage “Feasibility study”.

The iterations in stage “Working project” are performed in a similar way. A return to a previous stage is not provided, because the realization of the quality indicators in the stage “Technical project” means that new particular technical decisions inside the stage “Working project” must be searched.

CONCLUSION

Significant potentialities of the artificial intelligence methods to different stages of design are presented. These potentialities considerably increase the efficiency of the computer systems for design (CAD/CAM/CIM).

REFERENCES

Нечеткие множества в моделях управления и искусственного интеллекта. 1986. Под ред. Д. А. Поспелов, Москва, Наука.

Вощинин, А. П., Г. Р. Сотиров. 1989. Оптимизация в условиях неопределености. Изд. МЭИ - СССР и Техника - НРБ.

Computational Intelligence: Soft Computing and Fuzzy - Neuro Integration with Applications. 1998. Edited by O. Kaynak, L. Zadeh. NATO ASI Series.

First European Congress on Fuzzy and Intelligent Technologies, 1993. Aachen, Germany, September 7-10, Proceedings, Volume 1, 2, 3.

Majumdar, A; Levi, P.; Rembold, U.: 3-D Model Based Robot Vision by Matching Screne Description with the Object model from a CAD Modeler. Robotics and autonomous systems No 5, 1989.

Recommended for publication by Department of Mine Automation, Faculty of Mining Electromechanics