Intelligent Manufacturing Systems

DESIGN CONCEPT OF INTELLIGENT MANAGEMENT SYSTEMS

Galina Setlak, Sławomir Pieczonka

Abstract: *In this paper a concept of designing and building intelligent decision support systems in production management is introduced. The new approach to the design of intelligent management systems is proposed based on integration of artificial intelligence technologies (fuzzy logic, artificial neural networks, expert systems and genetic algorithms) with exact methods and models of decisions search and simulation techniques. The proposed approach allows for creating intelligent decision support systems of complex, unstructured management problems in fuzzy conditions. The systems learn based on accumulated data and adapt to changes in operation conditions.*

Keywords: *artificial neural networks, fuzzy inference systems, classification, decision support system, intelligent manufacturing systems*

ACM Classification Keywords: *I. Computing Methodologies, I.2 Artificial Intelligence, J. Computer Applications J.6 Computer-Aided Engineering*

Introduction

Globalization of the world economy and growth of competition on the market impose increasingly greater demands on modern entrepreneurs. Currently, management and control of production enterprises is impossible without an application of appropriate tools supporting decision making at each stage of a company's functioning from designing through to product exploitation. CIM (Computer Integrated Manufacturing) Systems are an example of such available tools that enable composite automatization of technological and organizational preparation for manufacture, current supervision, technological process control, organization and management. The development of CIM Systems has, in recent years, been directed at applying the methods of artificial intelligence to support decision processes and production control as well as monitoring, simulation and technological process diagnosis. IM (Intelligent Manufacturing) [Chlebus, 2000], [Zuomin Dong, 1994], [Ladet, Vernadat, 1995] is the most recent idea in the development of automatization and computer integration of production systems. According to the definition given in [Chlebus, 2000], Intelligent Manufacturing is:

> "a set of methods, procedures and Cax tools (eg. CAD, CAP, CAM) equipped with artificial intelligence tools and supporting designing, planning and manufacturing."

The following, among others, are the basic constituent elements of Intelligent Manufacturing Systems mentioned in publications:

- intelligent machines and tools, i.e. numerically controlled machines and robots,
- intelligent manufacturing systems, and
- intelligent management systems.

The concept of intelligent manufacturing combines the ability of decision-making support systems in generative systems to obtain knowledge, to learn and to adapt to a changing environment and to the actual arrangement of system components. The nature of intelligent manufacturing is system's possibility to learn and its self-development as well as the possibility to generate information necessary to control the integrated production system.

The aim of the work is to present a conception of designing and creating one of the components of Intelligent Management Systems as Intelligent Decision Support Systems alongside with the basic methods and tools of artificial intelligence which are necessary to support decision making in these systems.

Basic Assumptions Behind the Conception of Designing Intelligent Management System

Intelligent Management System of a production enterprise denotes an information system which provides necessary information, enables its analysis and use of analytical and simulation - based decision making models in order to assist decision making at each stage of decision process, as well as it is capable of learning and adapting to the dynamically changing environment and the current arrangement of system components. In other words, it is a decision supporting system based on the applied methods and tools of artificial intelligence able to solve complex decision problems, semistructurised or non-structurised, requiring the processing of incomplete, unreliable, contradictory, or difficult to formalize knowledge.

The demands towards Intelligent Management Systems in a production enterprise are as follows:

- A possibility of collecting and processing different types of information from all sources, both internal and external, in order to acquire and model knowledge necessary to make decisions at all levels of decision process in an enterprise. At the same time a possibility of modeling knowledge and processes, based on human thinking, is required.
- In a decision process, at decision selecting, the decision maker's subjective evaluation based on his experience and intuition should be taken into account in IMS.
- There should be a possibility of preliminary information handling and analysis with analytical methods as well as modern artificial intelligence technologies.
- A possibility of detecting emergency and critical situations and of prompt reaction to them. There must be a possibility of situational data analysis in real time, necessary in an emergency inside the production system or in its surroundings.
- A possibility to allow for complexity and comprehensiveness of decision-making issues in strategic management support.
- Taking into account the lack of stability and change dynamics, both in the surroundings and inside the enterprise, the IMSs under design should have the capability for learning from experience and adapting the experience to intensive alteration of working conditions.

In the conditions of modern economy, information and data bases which were fundamental for integration processes of design, planning and production control within CIM, are not sufficient; what is essential is a broadly understood knowledge of all these processes. Data and information collection, modeling and processing, currently evolve into a process of knowledge gaining, modeling and processing. The concept of knowledge is not clearly defined in the literature. Knowledge does not only encompass very extensive and dispersed resources of different types of information, but also, and above all, it is a complex structure of links between pieces of information and it involves information that is difficult to formalize. Experience, qualifications, human intuition, and models of different processes (including discreet, dynamic and stochastic processes) are all knowledge. Therefore, the basic demand that an intelligent management support system should meet is the necessity for collecting and processing all types of knowledge from all sources, external and internal, in order to gain and model the knowledge necessary to make optimum decisions.

Considering the above, what should be the base in methodology of intelligent systems design is an approach that would address knowledge management issues and would combine the existing manufacture engineering systems and subsystems with artificial intelligence technologies in order to create integrated environment for comprehensive decision-making solutions.

Class ERP (Enterprise Resource Planning) information systems created in the late 1990s work in all enterprise management areas: storage, production, finances (including management accounting), distribution, transport and servicing. Additionally, they enable firms to cooperate with clients and partners effectively and in a modern way. Currently, integrated systems assisting class ERP economic activity are commonly introduced, chiefly in large production enterprises. In recent years, more and more integrated software packages (from e.g. Cognos, Connect Distribution, Comarch, Microsoft, Oracle, Sybase, and SAP) have been appearing, both in the world and on the home market, including packages that apply Business Intelligence technologies. Systems based on Business Intelligence technologies are used to collect information, mainly in data warehouses, and to analyze the data to support decision making in business processes. BI technologies enable users to conduct a detailed data analysis with the aid of different types of analytical tools (e.g. OLAP or data mining). The effective use of Business Intelligence tools is very much dependent on data warehouses creation, which makes it possible to unify and relate the data collected in various information systems of an enterprise.

It needs to be emphasized here that both class ERP systems and systems with Business Intelligence technologies, despite many advantages, do not solve all the problems related to knowledge processing and modeling such as, for instance, those pertaining to linguistic data or the natural language.

The analysis of the existing methods and approaches to the creation of enterprise management support systems indicate that data warehouses currently constitute the basis for modern information systems and guarantee effective use of the information included. Thus, implemented ERP systems and systems with Business Intelligence technologies can be utilized as sources of knowledge while creating intelligent management system of an enterprise.

IMS Design Approach

The suggested frame of IMS design uses the basic rule of object methods in which modeling of information and processes is concurrent. It is also assumed that the design process is based on a single conceptual category of ‘an object’. The frame works on some assumptions made in the methodology of design and implementation of open systems for computer integrated enterprises CIMOSA (Open Systems Architecture for CIM). CIMOSA was developed by AMICE (European Computer Integrated Manufacturing Architecture) Syndicate within European Union ESPRIT research projects in the years 1986-1996 [CIMOSA Association, 1996], [Ladet, Vernadat, 1995]. CIMOSA introduced an integrated enterprise modeling methodology based on processes.

In CIMOSA architecture an enterprise is defined as a set of domains consisting of a set of organizational processes realizing elementary objectives of the enterprise activity. In the approach presented an assumption was made that the domain may be defined for one or several spheres of the enterprise activity, implementing one or several management functions, while the enterprise organizational processes are linked to the market surroundings.

Based on the problem analysis conducted and the existing methods, and taking into account the afore listed demands from IMS, the following basic rules for designing intelligent systems for decision-support in management can be formulated:

1) Intelligent Management Systems should be created as open architecture systems of modular structure that would allow for their evolution, thus extending a range of possibilities in both the design process and the functioning.

   The rule will also secure, in IMS, the use of different methods of modeling and processing of knowledge gained from different sources as well as updating the knowledge in real time. The open modular architecture enables IMS to quickly adapt to the changing environment and according to the condition of the enterprise components.

The Intelligent Management system can be described as a distributed system in the following way:

$$IMS = <M, R(M), F(M), F(IMS)>,$$

where

M={Mi} – set of formal or logic-linguistic models performing specific intelligent functions;

R(M) – choice function of required models (set of models) in a given current situation;

F(M)={F(Mi)} – set of model modification functions;

F(IMS) – modification function of IMS and its basic structural elements M, R(M), F(M).

2) The designed IMSs should be made into adaptable systems and capable of learning from experience. A designed IMS should be able to aid the organization of a production process at any given time. The reconstruction of knowledge models and decision processes should be conducted immediately every time the need for process reorganization arises due to changes in the system. Learning systems design will ensure effective system functioning in real complex conditions.

3) An IMS of distributed architecture should be developed to be equipped with possibility of parallel information processing in order to increase its efficiency in collecting and exchanging a large amount of information, its analysis as well as in making group decisions. It is essential to utilize contemporary information technologies including local and global computer networks.

4) Widespread application of multimedia technology, computer graphics and hypertext in information presentation.

Conceptual Model of Intelligent Management System

In the presented approach to IMS design it is recommended that IMS's should be created as open architecture and modular structure systems, enabling the application of several methods of knowledge presentation and the integration of different knowledge processing schemes in the inference process, as well as the application of several learning methods. In intelligent manufacturing systems, the following selected contemporary methods and techniques of knowledge and decision process modeling should be integrated:

- Artificial neural networks – the most fascinating tool of artificial intelligence, capable of modeling extremely complex functions and, to some extent, copying the learning activity in the human brain.
- Fuzzy logic – technologies and methods of natural language formalization, linguistic and quality knowledge processing and fuzzification.
- Genetic algorithms and methods of evolutionary modeling – learning algorithms based on theoretical achievements of the theory of evolution, enriching the artificial intelligence techniques above.

The combination of these tools, in which knowledge is represented symbolically, with the traditional expert system will make it possible to create complex programmatic tools for solving difficult decision-making problems at each stage of enterprise functioning.

The conceptual structure of Intelligent Management System is illustrated in fig. 1.

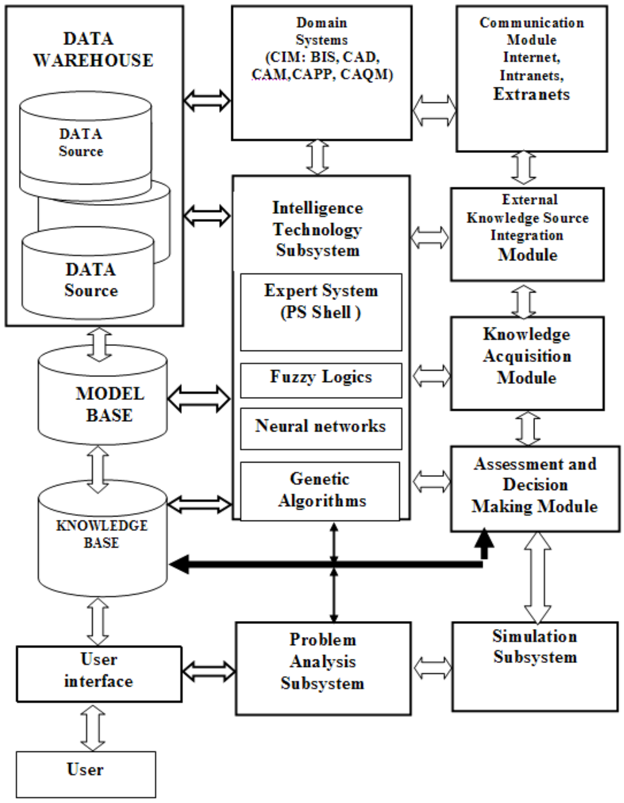

Figure 1. A conceptual structure of Intelligent Management System

The structure of IMS consists of the following subsystems and modules:

1) Modules which are very common in Intelligent Systems architecture
   - Databases and knowledge base
   - Inference Engine
   - Knowledge Acquisition Module
   - Explanation Engine
   - User Interface (graphical or command line; preferably with natural language understanding functionality)
2) The subsystems of Intelligent Technologies
   - Expert subsystem (eg. Expert System Shell)
   - Fuzzy Logic Subsystem
   - Neural Networks Subsystem (eg. NeuroSolutions or Statistica Neural Networks)
   - Genetic Algorithms Module (eg. Genetic Library)
   - AI Technologies Integration module
3) Domain-oriented Information Systems
   - Management Information System (MIS)

- Computer Aided Design System (CAD)
- Computer Aided Process Planning System (CAPP)
- Computer Aided Quality Management System (CAQM)
- Management Support System (MSS)

4) Problem Analysis Module
   - Problem Simulation Module
   - Monitoring Module
5) Decision selection and assessment subsystem. It includes practically verified analytical procedures as well as problem solving probabilistic methods that turned out to be very effective in several real applications.
6) Communication subsystem. It is based on computer networks technologies and Internet infrastructure that enable to acquire information from external sources.

Expert systems enabling decision support in product design and production process, planning and production control as well as management have been widely used for several years in integrated production systems CIM [Kacprzyk, 2001], [Ladet, Vernadat (ed.), 1995]. The classic expert systems are based on symbolic representation and knowledge processing. The symbolic processing of knowledge is a characteristic feature of most expert systems that are known [Kisielnicki, Sroka,1999]. In such expert systems, the following kinds of knowledge base can be indicated: database, rule base, text base, model base, and common sense knowledge base. The symbolic representation of knowledge had prevailed in research until very promising results were achieved in a research on artificial neural networks by Rumelhart and McMlelland (published 1986). What can be observed since that time is an intensive development of the application of these most fascinating artificial intelligence tools to solve very difficult problems in different areas, including monitoring, controlling and supervision of technological processes for manufacturing. Artificial neural networks are modern computational systems parallel processing data and, above all, having the capability of adaptation and learning and a high defect and fault tolerance.

Knowledge processing in neural networks is conducted dynamically [Mulawka, 1996]. This basic quality of neural networks has been widely used by researchers for over twenty years to create so called hybrid expert systems. In the research here presented, neural networks are used to classify and cluster data for marketing analysis [Setlak 2004], [Setlak, 2001] as well as to classify constructional and technological modules; they are, then, the basic tool for data exploration, such as data mining, etc.

Hybrid expert systems were created as a result of integrating traditional expert systems, artificial neural networks, genetic algorithms and fuzzy systems in different configurations [Rutkowska, Piliński, Rutkowski, 1997]. In such systems, thanks to neural networks, the process of knowledge gaining, which is, admittedly, the most difficult stage of creating an expert system, is largely facilitated (instead of loading rules, the neural network is trained based on a representative pattern). Fuzzy systems are built using the fuzzy set theory and fuzzy logic [Kacprzyk, 2001], [Zielińskiego, 2000], in which dependencies are expressed as fuzzy rules of the 'IF/THEN' type and which include linguistic and qualitative variables. The possibility of processing, by fuzzy systems, qualitative knowledge representing information which cannot be precisely described using traditional methods of mathematics or binary logic, enables users to use these tools in intelligent decision support systems. As any artificial intelligence method, fuzzy logic is an attempt to describe reality in a way akin to human reasoning. In fuzzy systems knowledge is stored in structures of symbolic character. Fuzzy reasoning can be easily implemented as a neuron-like numerical procedure, which made it possible to develop many effective methods of teaching fuzzy systems.

Consequently, the theories of fuzzy sets and that of fuzzy logic has become an indispensable tool in designing hybrid intelligent systems, including those supporting management.

The term of evolutionary algorithms refers to computational systems of problem solving, which work based on the rules observable in natural evolution of living organisms [Rutkowska, Piliński, Rutkowski, 1997]. To evolutionary algorithms also belong such methods as genetic algorithms, evolutionary programming and evolutionary strategies. However, due to the limited scope of this paper, the differences between them were not addressed here.

The idea of genetic algorithms is based on processes observable in nature, such as natural selection, evolution of species, mechanisms of reproduction and heredity. Simplicity and versatility are two important positive features of evolutionary algorithms. In IMSs, genetic algorithms are successfully used, especially in solving optimization tasks based on one or many criteria. Apart from that, genetic algorithms are used to find the most effective neural network structure or neural-fuzzy system and as procedures teaching neuron-like structure. As a result of the research, genetic algorithms were recognized as very effective tools for solving complex practical optimization tasks including NP-hard problems such as scheduling manufacturing tasks.

In intelligent systems supporting management of integrated enterprises, simulation modeling methods must be used to solve various problems, both at the stage of designing and that of production system functioning. Petri Net model is currently the universal tool for modeling production processes.

Conclusions

In the work, a certain conception of designing intelligent systems for enterprise management was presented. Based on the conception, a methodology of creating the IMS is being developed based on the integration of artificial intelligence technologies with exact methods, well-known in the decision making theory, as well as with simulation modeling methods. The approach proposed will open up a possibility to build an IMS of open structure, combining existing information systems with the information sub-systems in production engineering using artificial intelligence technologies in order to create an integrated environment for comprehensive solving of decision-making problems in the system of intelligent manufacturing.

Intelligent manufacturing is the most promising and future-oriented of production system developments aiming at further automatization, optimization and integration of manufacturing processes. Intelligent processing of data from different sources will enable the integration of the data as well as strategic analyses and correct decision making. Flexible analysis, diagnosis and reporting scenarios will make it possible to create a basis for evaluation of the current situation and to facilitate and accelerate decision processes at each stage of the enterprise functioning. Fully integrated intelligent manufacturing systems will, in the near future, enable enterprises to function effectively and reliably on the global market, complying with its rising requirements.

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Authors' Information

Galina Setlak, *D.Sc, Ph.D., Eng., Associate Professor, Rzeszow University of Technology, Department of Computer Science , W. Pola 2 Rzeszow 35-959, Poland, and The State Professional High School, Czarnieckiego 16, 37-500 Jarosław, Poland, e-mail: gsetlak@prz.edu.pl*

Sławomir Pieczonka *- PhD Student, M.A. The State Professional High School, Czarnieckiego 16, 37-500 Jarosław, Poland: e-mail: slawomir.pieczonka@pwszjar.edu.pl*