INTELLIGENT SYSTEM FOR COMPUTER AIDED ASSEMBLY PROCESS PLANNING

Galina Setlak

Abstract: This paper presents the concepts of the intelligent system for aiding of the module assembly technology. The first part of this paper presents a project of intelligent support system for computer aided assembly process planning. The second part includes a coincidence description of the chosen aspects of implementation of this intelligent system using technologies of artificial intelligence (artificial neural networks, fuzzy logic, expert systems and genetic algorithms).

Keywords: Artificial intelligence, flexible assembly systems, neural networks, fuzzy logic, fuzzy neural networks, group technology formatting rules.

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

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Introduction

The planning of the modern flexible manufacturing systems including the Flexible Assembly Systems (FAS) is a very complicated and responsible task. It assumed that the FAS are universal enough to be able to connect a high production capacity with the small quantities of production lots and short cycle time. It should ensure a production under the conditions of dynamical and sudden changes of the product range, the planed fixed dates for order realization and also the possibility of fast introducing of product design change into production [Boothroyd, Knight W., 1994]. According to the opinions of many assembling specialists the module assembly engineering is the fundamental and most promising direction of the development of the modern assembly technology [Grabmeier J., A. Rudolph, 2002], [Szabajkowicz, 1998]. The module technology is based on rules of the group production technology, which dominated in last dozen or so years, it improves and develops it [Szabajkowicz, 1998]. In addition, the module assembly technology enables a production adjusting according to market requirements, an easy adjusting oft the assembly system to every change of the product design, adding new engineering assembly modules. The planning of the flexible assembly modules in accordance with the modular engineering is the all-important problem at the centers for research and science as well as in design offices of the leading production companies in the last years.

This work presents the concepts of the intelligent system Computer Aided Assembly Process Planning (CAAPP) [Setlak,1999] for aiding of the module assembly technology planning. The CAAPP was developed in order to aid the decision making in the designing and functioning of the flexible assembly systems. In order to fulfill the identification and clustering tasks for product, parts and assembly unit groups, additional program modules are used, which include neural networks (Kohonen and Fuzzy Kohonen clustering network). In this paper, we handle decision making as a classification problem where an input pattern is classified as one of given classes. In this paper, neural networks are used as classification systems, which eventually could be implemented as a part of decision making systems. The second part includes a coincidence description of the chosen aspects of implementation of this intelligent system using technologies of artificial intelligence (artificial neural networks, fuzzy logic, expert systems and genetic algorithms).

The approach a problem of the modules assembly technologies

The module assembling engineering consists in presenting of the production process as a set of technological modules. The technological module is considered as a structurally closed part of the processing, which conforms to the functionality, integrity and universality requirements. The module assembly means, that the assembly system has a modular structure and each module realizes a defined function or a limited function range, which are part of a general assembly process. According to the definition [Szabajkowicz, 1998] a technological assembly model composes "an integral set of the main and auxiliary activities of assembling, which are realized in a defined sequence at one station and uses a defined tool set for connecting of surfaces, parts, subassemblies, assemblies". The connection of the elementary technological modules lies in a proper development and selection of technological modules. Each of them realizes a proper design module of construction.

During the planning of the flexible assembly systems with the modular assembly engineering the following stages can be selected:

- Analysis of the construction of the assembled product and the assembling technologies.
- Identification and classification of objects into groups and subgroups of the processed parts and (technological similar) assembly sets. The working out of a typical flow chart (based on common assembly sequences, similar to the manipulation activities, duration, etc.).
- Separation of autonomic, integrated assembly activities from the flow charts, then assembling the separated assembly units into groups depending on equipment with instrumentation to carry out these operations.
- Planning of structures and functions of the constructional modules.
- Preliminary planning of elementary technological modules.
- Assembling of the elementary modules and selection of proper, possible variants of the technological and constructional modules.
- Optimization of the technological module structure and the structure of the constructional module realized.
- Clustering of the elementary technological assembly modules.
- Final planning of the technological assembly modules, the modular technological complexes and of the corresponding constructional modules.

The analyses of the construction of the assembled product concerns first off all the analysis of a producibility for the product construction, which is in the present generally made using the DFA methodology (Design For Assembly). The analysis of the producibility for a construction must be carried out in order to simplify the product constructions, reducing the part forms and subassemblies number. The questions concerning the producibility of product constructions assembled automatically were investigated among other in [Boothroyd, Knight W., 1994], [Łunarski J.,1993]. In these works the fundamental quality and quantity characteristics for producibility of product constructions for automatically assembling are presented (these are such features, as: interchangeability, regulation possibility, easy controlling and tool accessibility etc.). Planning products for assembly using the modular technology the constructional product modularization principle is to be kept. That means that by planning of units, subassemblies and parts following steps must be taken:

- Identification, separation of parts and basic surfaces;
- Use of typical assembly diagrams and methods;
- Aspiration to adjust a new product to such a construction, that the existing constructional modules and technological modules can be used.

By working out the expert system for modular assembly aiding system planning the necessity of integration of the constructional planning process with the processing planning was taken into consideration in order to utilize better the existing production equipment and eventually expansion or modernizing of it.

Conception structure of expert system for aiding of planning of the flexible assembly modules

The intelligent system Computer Aided Assembly Process Planning (CAAPP) outlined in this paper uses PC-Shell 4.0. – domain independent expert system shell, having strong hybrid properties. The PC-Shell has been implemented in Artificial Intelligence Laboratory (AITECH, Katowice) [Michalik, 1996]. The PC-Shell 4.0 system integrates the expert systems shell using blackboard architecture elements and the simulator of the neural network. It assures the knowledge representation as declarative expressed rules, facts and distributing knowledge in the neural network. The expert knowledge can contain in some knowledge sources. A conception model of the expert system for aiding of the flexible assembly module planning is shown in the Figure 1.

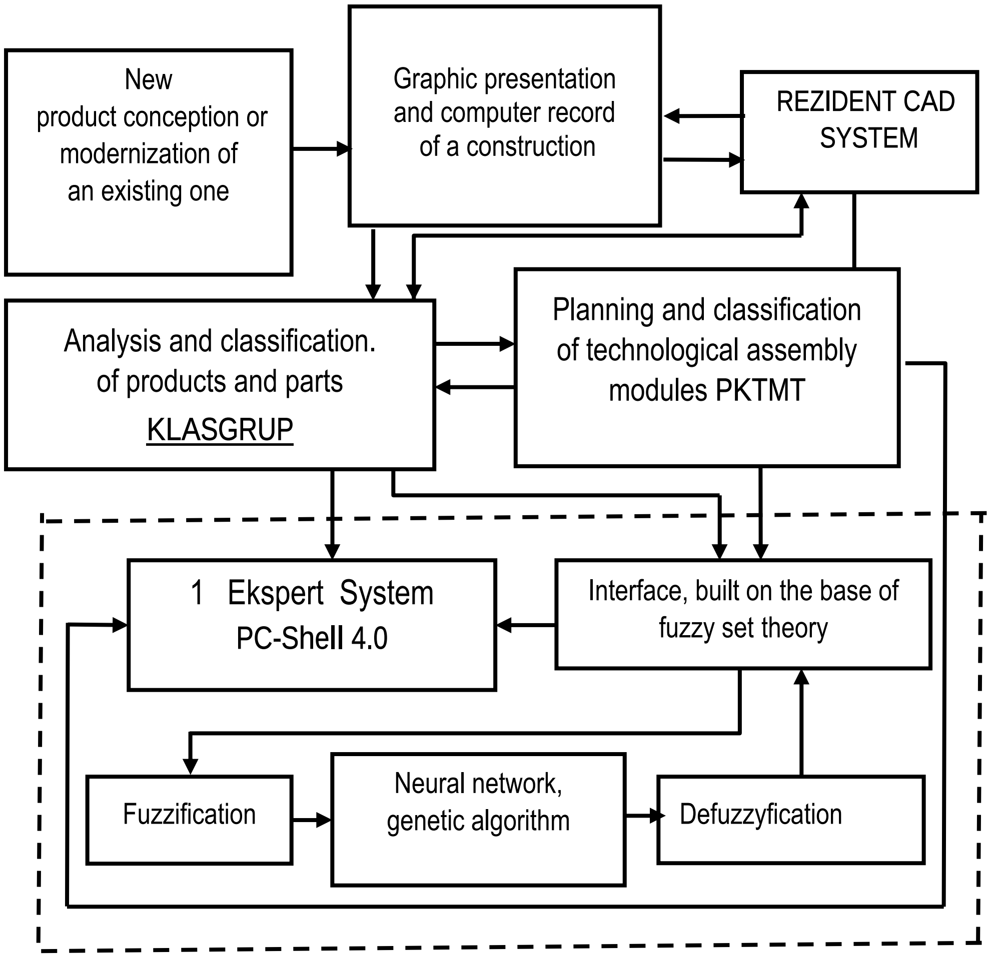

Fig.1. Conception model of a hybrid expert system.

Hybrid expert systems PC-Shell 4.0, as others classical expert systems, are built upon fundamental components: ♦ a knowledge base, ♦ an inference engine (interpreting knowledge stored in the knowledge base and making deductions), ♦ knowledge engineering system, ♦ automatic knowledge acquisition, ♦ explanation subsystem, ♦ user interface – one for accessing the knowledge base through the knowledge acquisition module, and another one for system users accessing the system in the consultation mode or in the explanation (tutor) mode and additional component part – the neural network.

The PC-Shell 4.0 system integrates the expert systems shell using blackboard architecture elements and the simulator of the neural network. It assures the knowledge representation as declarative expressed rules, facts and distributing knowledge in the neural network. The expert knowledge can contain in some knowledge sources. This system enables procedural knowledge representation too. The PC-Shell 4.0 system makes possible an integration of the declarative knowledge representation with procedural knowledge representation language, which enables programming of the system activity. The knowledge representation language SPHINX is a mean for building intelligent applications. It is the way of integration of particular artificial intelligence systems. The program in the PC-Shell system consists of instruction set included in the control block. The subset of language instruction enables the integration of neural network and the expert system.

The realization of application in the PC-Shell system is following:

- Creating by the NEURONIX subsystem one or some neural application.
- Elaborating knowledge base in form of knowledge sources.
- Integration of the elaborated knowledge sources on the level of knowledge representation language.

In this context the cooperation between systems usually follows by data interchange. Each of the subsystems realizes specifying purposes. It works by autonomous way and transmits results of its activity to the other system. Especially spectacular and also practically useful are results of expert system and neural network integration. We can describe following examples of their cooperation [Michalik, 1996]:

- the neural network realizes numeric data processing for the expert system ;
- expert system controls the learning process of neural network;
- the neural network is made for building knowledge base of the expert system;
- the expert system transforms the output neural network data in order to show other suitable for people interpretation.

A hybrid intelligent system has four major parts: PC-Shell 4.0 and Fuzzy Neural system (Neural networks, the Fuzzifier, the inference engine, the rule base, and the defuzzifier.

For aiding of the planning of the modular assembly technologies and to solve the problems of identification and classification of products groups, parts and units, the program modules have been developed, which complete the expert system CAAPP. These are the program module KLASGRUP and the module PKTMT. The program module KLASGRUP includes all procedures, which are necessary to carry out the constructional analysis of the planned or modernized product, and procedures to clustering the processed parts and (technological similar) assembly units of the mounted parts in order to separate and work out the constructional modules. The module PKTMT contains procedures for classification and grouping of the technological assembly modules. The details of the working out and structure of the expert system CAAPP, which technologically aids the assembly production preparation, are shown in the work [Setlak,1999].

To realize and test the program modules form aiding of the planning of the flexible assembly systems using the modular assembly engineering the knowledge base must be completed with following data:

- typical constructions;
- constructional features of the product parts;
- typical assembling flow charts and assembly methods;
- machinery data, technical equipment of the production system data;
- production costs for representatives of products from technologically similar groups.

In form of algorithms the constructional product analysis methods and assembly technology are formalized. The expert system CAAPP has been expanded by two additional modules; in addition a user interface has been introduced, which enables a presentation of a quality, verbal information in form of referring to adequate primary fuzzy sets. It enables a use of fuzzy inference engine in the program modules KLASGRUP and PKTMT the neural networks are used to classify the assembly parts and group the products.

Application of neural networks and hybrid intelligent systems for classification of assembly parts families

In the literature various classification methods have been proposed (see e.g. [Grabmeier J., A. Rudolph, 2002],). Some of them are based on neural networks, fuzzy systems and genetic algorithms (see e.g. [Zolghadri Jahromi, M. Taheri, 2008]). Neural networks are widely used as classifiers [Malave,1992], [Zurada,1992]. Classification and clustering problems has been addressed in many problems and by researchers in many disciplines like statistics, machine learning, data bases. The basic algorithms of the classification methods of machine elements are presented in [Ed. by R. Knosala, 2002], [Ramachandran S., 1991], [Zolghadri Jahromi, M. Taheri, 2008]. The application of the clustering procedure can be classified into one of the following techniques [Grabmeier J., A. Rudolph, 2002]:

- graph -theoretic clustering,
- partitional in which a set is divided into *m* subsets, where *m* is the input parameter. These algorithms minimize the criterion function (*K*-means and *K*-medias);
- hierarchical form trees in which the leaves represent particular objects, and the nodes represent their groups. In terms of hierarchical methods, depending on the technique of creating hierarchy classes (agglomerative methods and divisive methods).
- fuzzy clustering,
- methods based on evolutionary methods,
- methods based on artificial neural networks.

In this work two approaches have been applied to clustering of parts and assembly units. The Kohonen self organizing map and fuzzy Kohonen neural network we have used in this work.

As basic method it was used Self Organizing Map (SOM), a class of unsupervised learning neural networks, to perform direct clustering of parts families and assembly units. SOM is an unsupervised neural network proposed by Kohonen [37] which consists of only two layers of neurons. Kohonen neural networks are unsupervised schemes which find the “best” set of weights for hard clusters in an iterative, sequential manner. This type of neural network is usually a two-dimensional lattice of neurons all of which have a reference model weight vector. SOM are very well suited to organize and visualize complex data in a two dimensional display, and by the same effect, to create abstractions or clusters of that data. The SOM can learn to recognize clusters of data, and can also relate similar classes to each other. SOM networks can also be used for classification when output classes are immediately available - the advantage in this case is their ability to highlight similarities between classes. SOM of Kohonen has been applied to classification of machine elements in group technology [Ed. by R. Knosala, 2002], [Setlak, 2003].

The other approach applies fuzzy logic and fuzzy neural systems for classification problems. Fuzzy and fuzzy neural systems can be employed in order to solve classification problems [Lin, 1996], [Nauck D.. R. Kruse, 1995].

In this work an application of the fuzzy version of the Kohonen self-organizing map network has been considered.

The fuzzy Kohonen clustering network integrates the concept of fuzzy c-means clustering technique into the learning rate and updating strategies of the Kohonen network [James C., Bezdek I., 1994]. It can be viewed as a Kohonen self-organizing type of fuzzy c-means, where the ”size” of the update neighborhood and learning rate in the competitive layer are automatically determined from training data. The cluster membership values of the input patterns are computed as a function of the distance between that pattern and the different cluster centers. These membership functions are used to determine the learning rates for the network weights updating.

The fuzzy Kohonen clustering network uses fuzzy membership values as learning rates, automatically extracted during learning from the training data. Also the adjustment of the update neighborhood is embedded in the learning procedure. Moreover, an increased number of fuzzy Kohonen network output nodes produce a better generalization performance of the modular classification system. The fuzzy Kohonen clustering network is shown in Figure 2. Combination of fuzzy c-mean and the Kohonen self-organizing feature maps was first considered by [Bezdek I., 1994] to make the Kohonen algorithm an optimization procedure. The algorithm combines the fuzzy membership values of the fuzzy c-mean for the learning and neighborhood size parameters and the update rules of the Kohonen feature maps.

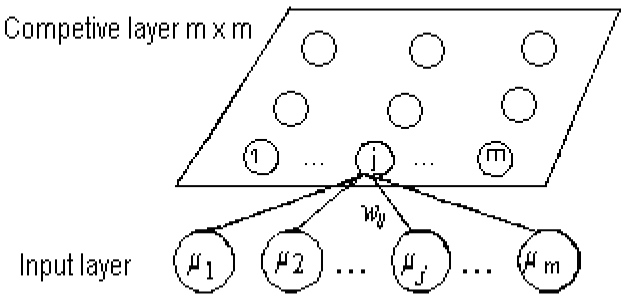

Figure 2. The structure of the fuzzy Kohonen clustering network

The update rule for the fuzzy Kohonen algorithm can be given as [Bezdek I., 1994]:

$$w_{i,t} = w_{i,t-1} + a_{ik,t}(x_k - w_{i,t-1}, \quad i = ,12,...,c; k = 1,2,...,m \tag{1}$$

where $W_{i,t}$ is the centroid of the i^{th} cluster at iteration t , x_k is the k^{th} data point (or compound feature set) and α_{ik} is the only parameter of the algorithm and according to Huntsberger

$$a_{ik,t} = \left(U_{ik,t}\right)^{m(t)}, \tag{2}$$

where m(t) is an exponent like the fuzzification index in fuzzy c-mean and $U_{ik,t}$ is the membership value of the compound x_k to be part of cluster i. Both of these constant varies with each iteration t and given as:

$$U_{ik} = \frac{1}{\sum_{j=1}^{c} (D_{ik} / D_{jk})^{2/(n-1)}}, \quad 1 \le k \le n, \quad 1 \le i \le c \tag{3}$$

$$D_{ik} = (x_k - w_i)^T (x_k - w_i) \tag{4}$$

$$m(t) = m0 - \Delta m * t \tag{5}$$

$$\Delta m = (m0 - m_j)/max\ iter \tag{6}$$

where D_{ik} is the distance and m0 is some constant greater than the final value (m_f) of the fuzzification parameter m. The final value m_f should not be less than 1.1, in order to avoid the divide by zero error in equation 3.

In the examples below the presented algorithm have been used the method of geometrical description of the units of machine engines described in [Knosala,2002].

Geometrical features of structural elements were presented in the form of the matrix of properties. This method consists in exploiting geometrical primitive conditions which basic geometric features of similar are describing. Next made coding of geometrical features which consists in using wood is B-Rep method in order to receive the structure of the model in the three-dimensional space (3D). As a result of the division of the model of the element in three dimensions with the determined resolution to layers a matrix image of the element is received. The method of geometrical description of the units of machine is shown in figure 3.

The format of input data is being presented as follows:

<x> <y> <z>

<nr element> <nr layer > < the number of layers>

<x_{11}> <x_{12}> … <x_{1n}>

….

<x_{n1}> <x_{n2}> … <x_{nn}>

Where three first values means the resolution of the division of the 3D element into classes.

Grouped elements were written in the digital form at the 16x16x16 division in harmony with the accepted accuracy of the description of elements. The training data set includes 16x16X16 data items. The Fuzzy Kohonen neural networks composed of 16 neurons.

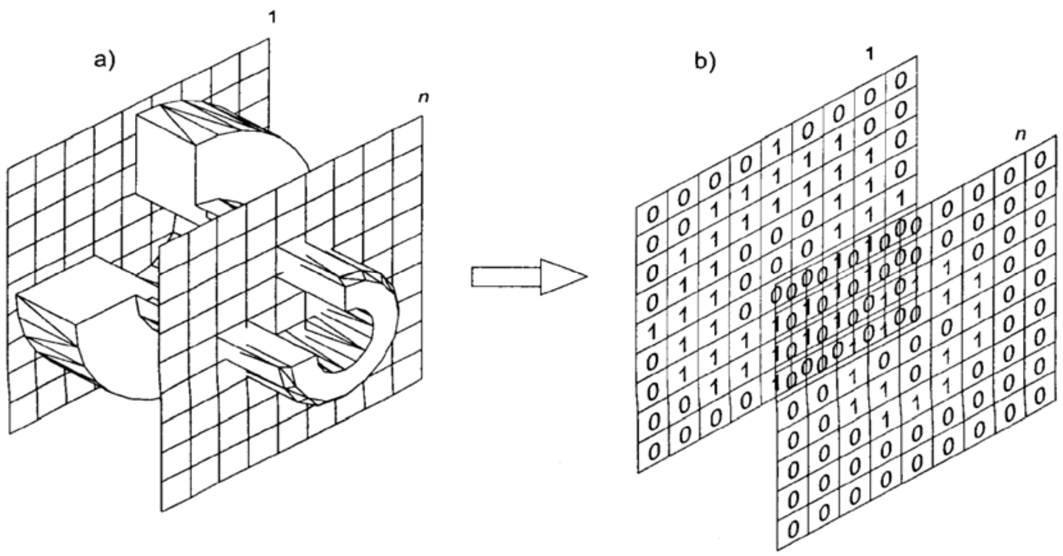

Figure 3. The method of geometrical description of the units of machine

Conclusions

The approach to the aiding of production systems planning based on the modular technology, proposed in this work, is a very promising direction for research on the field of the new production technologies. In the present the base problem at a practical realization of the presented expert system is lack of an access to data and work immensity, necessary to the pre-processing of the input data and to enter them into the knowledge base.

The way of integration of the neural network and the classical expert system presented in this paper is an interesting solution on the level knowledge representation language. Preliminary tests indicate that the approach employed in the PC-Shell system is capable of supporting problem formulation in ill-structured problem domains.

Future research in this work will be using the description of properties received as output date in program to the design CATIA. The research conducted proves that fuzzy Kohonen Neural Networks are a very effective and useful instrument of classification of the elementary assembly modules and can be employed in order to solve direct clustering of parts families.

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