INTELLIGENT SYSTEM FOR ASSEMBLY PROCESS PLANNING

Galina Setlak, Tomasz Kożak, Monika Piróg-Mazur, Wioletta Szajnar

Abstract: *The flexibility, customization and localization offered by computer integrated manufacturings are attractive but generate a new class of management problems. Intelligent support systems are needed for the managing: planning, implementation, configuring and operating of intelligence manufacturing systems. This paper presents a project of intelligent system for assembly process planning. The paper includes a coincidence description of the chosen aspects of implementation of this intelligent system using technologies of artificial intelligence (neural networks, fuzzy logic, expert systems, neuro-fuzzy systems).*

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

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

Introduction

Computer integrated manufacturing (CIM) provides manufacturing industry with the means to produce a variety of products efficiently. Effective planning, scheduling and control in the CIM environment depend largely on proper design of the decision support system (DSS). A manufacturing system is driven by input stimuli from the market in the form of direct product demand, market conditions and feedback on production with a variety of information perspectives. The activities of this system may be broadly classified as management (including strategic planning), design, production planning and production operation.

The planning of the modern manufacturing systems is a very complicated and responsible task. It assumed that the modern assembly systems 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, 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, 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 NP-hard problem at the centers for research and science as well as in design offices of the leading production companies in the last years.

This paper presents the application of the intelligent system Computer Aided Assembly Process Planning (CAAPP) for aiding of the module assembly technology planning, which was in [Setlak,1999] described. 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 Self Organizing Map (SOM) of Kohonen and neuro-fuzzy systems.

The approach 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 [Łunarski,1993]. In this work 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.

Concept of intelligent system for assembly process planning

The intelligent system Computer Aided Assembly Process Planning (CAAPP), which was described in [Setlak,1999], 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). 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 concept of model of the system CAAPP for aiding of assembly module planning was shown in [Setlak, 2008].

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 intelligent 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 neuro-fuzzy system for classification of assembly parts and units

The application of the clustering procedure can be classified into one of the following techniques [Jang, Sun, Mizutani, 1997]:

- hierarchical form trees in which the leaves represent particular objects, and the nodes represent their groups. The higher level concentrations include the lower level concentrations. In terms of hierarchical methods, depending on the technique of creating hierarchy classes (agglomerative methods and divisive methods);

- graph-theoretic clustering,
- fuzzy clustering,
- methods based on evolutionary methods,
- methods based on artificial neural networks.

The basic algorithms of the classification methods of machine elements are presented in [Ramachandran, 1991], [Ed. by Knosala, 2002], [Zolghadri Jahromi, Taheri, 2008].

Neural networks are widely used as classifiers; see e.g. [Jang, Sun, Mizutani, 1997], [Moon, Divers, 1998]. Classification and clustering problems has been addressed in many problems and by researchers in many disciplines like statistics, machine learning, and data bases. The basic algorithms of the classification methods are presented in [Nauck, Klawonn, Kruse, 1997], [Setlak, 2004]. In the literature various classification methods have been proposed (see e.g. [Grabmeier, Rudolph, 2002],).

In this work two approaches have been applied to clustering of parts and assembly units. As basic method it was used Self Organizing Map (SOM), which were introduced by T. Kohonen in the early ’80s. It is a class of unsupervised learning neural networks, to perform direct clustering of parts families and assembly units. This type of neural network is usually a two-dimensional lattice of neurons all of which have a reference model weight vector (is shown in Fig. 1). 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. Therefore neural networks of Kohonen are frequently used in data exploration applications as well [Kohonen, 1990], [Takagi, 2000]. 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 have been applied to classification of machine elements in group technology [Malave,1992], [Ed. by Knosala, 2002], [Setlak , 2004], [Setlak, 2008].

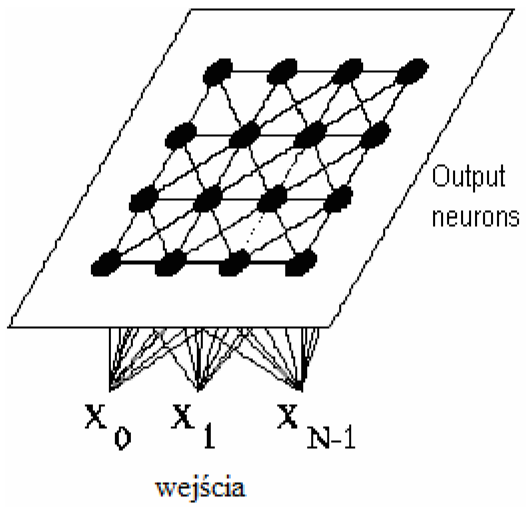

Figure 1. Self Organization Maps (Kohonen Networks)

The training of the SOM is achieved through a competitive learning process which consists of two steps that are applied iteratively.

- In the first step each input vector is compared to all the neurons’ codebook vectors. The neuron s that has its codebook vector at the shortest geometric distance to an input vector becomes the winner for that input vector.

- In the second step, each winning neuron and its surrounding neurons, i.e., neurons within a neighbourhood N_s gradually change the value of their codebook vectors in an attempt to match the input vector for which it has won.

This cycle of competition and learning processes is repeated. At each cycle the size of the neighborhood of the winning neuron is decreased. The whole process terminates when each codebook vector has reached a satisfactory approximation of their corresponding input vector.

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 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 Kohonen neural networks composed of 16 neurons.

The other approach applies fuzzy logic and neuro-fuzzy systems for classification of parts and assembly units. However, neural networks work as a "black box", which means that they produce classification results but do not explain their performance. Thus, we do not know the rules of classification. Neural network weights have no physical interpretation. Fuzzy and fuzzy-neural systems can be employed in order to solve classification problems [Rutkowska, 2002]. Some of the major woks in this area are ANFIS (Adaptive Neuro-Fuzzy Inference System, [Jang 1997]), NEFCLASS (Neuro-Fuzzy CLASSification system, [Nauck, Klawonn, Kruse, 1997]), CANFIS (Co-Active Neuro-Fuzzy Inference System), [Lin, 1996].

A neuro-fuzzy systems for classification of parts and assembly units can be presented and is shown in Fig.2.

It is connectionist multi-layer architectures of neuro-fuzzy systems. The neuro-fuzzy systems are rule-based systems that realize fuzzy IF-THEN rules, described as follows:

$$R^{(k)}: \text{IF } x_1 \text{ is } A_1^k \text{ and } x_2 \text{ is } A_2^k \text{ and. .... and } x_n \text{ is } A_n^k \text{ THEN } (y \text{ is } B_l), \qquad (1)$$

where $X=(x_1,x_2,...,x_n)^T$, x_i and $y \in Y \subset R$ for $i=1,2,...,n$ - are linguistic variables, $A_i^k \subseteq X_i \subset R$ $(i=1,2,...,n)$ are fuzzy sets characterized by membership function $\mu_{A_i^k}(x)$, B_l -for $l=1,2,...m$ – are classes, N denotes the number of rules $R^{(k)}$, for k=1,2,...,N.

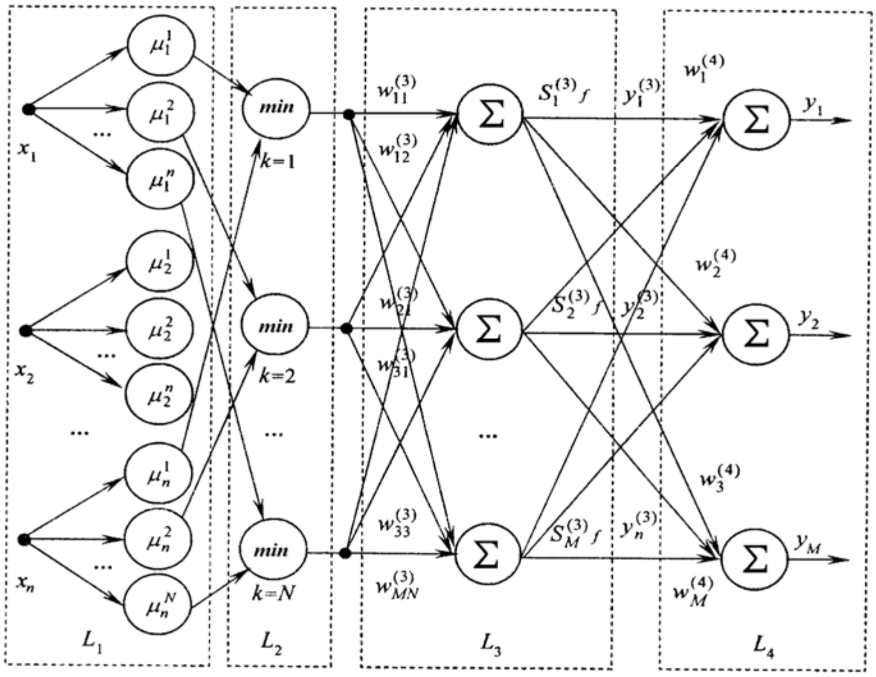

Figure 2. Fuzzy-neuro system for classification of parts and assembly units

In this fuzzy neural classifier each rule is associated with one class. The input values constitute the input vector $X^* = (x_1^*, x_2^*, ..., x_n^*)^T$. The output values represent degrees of rule activation, described as follows:

$$\tau_k = \prod_{i=1}^{n} \mu_{A_i^k}(x_i^*) \quad (2)$$

where $\mu_{A_i^k}(x_i)$ is the Gaussian membership function and

characterized by the center and width parameters, x_i^{*k} and σ_i^k :

$$\mu_{A_i^k}(x_i^*) = exp\left[-\left(\frac{x_i - x_i^{*k}}{\sigma_i^k}\right)^2\right] \quad (3)$$

The neuro-fuzzy system performs a classification task based on the values of τ_k, for k=1,2,...,N. Each input vector $X^* = (x_1^*, x_2^*, ..., x_n^*)^T$ is classified to the class B_l, for *l=1,2,...,m*, which is associated with the maximal degree of rule activation.

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

Performance of neuro-fuzzy system has been tested on the following input data. The neuro-fuzzy system has the following features:

- Each neuron represents one fuzzy IF-THEN rule.
- The number of neurons equals to the number of rules in the rule base.
- Weights of the neurons have an interpretation concerning parameters of the

membership functions of the corresponding neuro-fuzzy system.

- It is easy to modify the network architecture when a rule is added or removed (by addition or removal, respectively, the neuron that represents this rule).

Thus, in contrast to classical neural networks, the neuro-fuzzy classifier presented in this paper does not work as a "black box". This classifier is a rule-based neural network.

Neuro-fuzzy classifier can contain many neurons, so it is no problem to increase the number of rules in order to achieve better performance of the classifier.

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.

In the paper we have applied Self Organizing Map of Kohonen and basic soft techniques for classification of parts and assembly units.

The hybrid neuro-fuzzy system briefly presented in the paper was successfully applied for designing intelligent decision support system. By using several advanced technologies (combination of fuzzy logic and neural networks) it is possible to handle a broader range of information and solve more complex problems.

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 neural networks of Kohonen and neuro-fuzzy systems 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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