APPLICATION OF ARTIFICIAL INTELLIGENCE TOOLS ON MANUFACTURING

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ABSTRACT

Manufacturing systems in industries has dramatically changed as a result of advanced manufacturing technologies employed in today's factory. Factories are now trying to attend and maintain a world-class status through automation that is possible by sophisticated computer programs. The development of CAD/CAM system is evolving towards the phase of intelligent manufacturing system. A tremendous amount of manufacturing knowledge is needed in an intelligent manufacturing system. Artificial intelligence techniques are designed for capturing, representing, organizing, and utilizing knowledge by computers, and hence play an important role in intelligent manufacturing. Artificial intelligence has provided several techniques with applications in manufacturing like; expert systems, artificial neural networks, genetic algorithms and fuzzy logic. The potential power of AI is very great and it is believed that with the exploitation of AI methods, it will only possible to build well conceived and intelligent computer integrated manufacturing systems. In this paper the meaning of artificial intelligence and some of the most effective artificial intelligence tools are introduced. The applications of artificial intelligence tools in design and manufacturing are also discussed with some examples.

***Keywords**: CAD/CAM, Expert System, Genetic Algorithm, Fuzzy Logic, Neural Network.*

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1. INTRODUCTION

Artificial Intelligence (AI) emerged as a computer science discipline in the mid- 1950s. AI is concerned with systems that exhibit the characteristics usually associated with intelligence in human behaviaur, such as learning, reasoning, problem solving, understanding language, and so on. The main goal of AI is to simulate human behaviour on the computer.

The applications of AI in manufacturing, in particular, play a leading role in the technology development of intelligent manufacturing systems. The system belonging to this phase may be characterized by their ability to solve problems without either a detailed, explicit algorithm available for each solution procedure, or all the facts, mathematical relationship and models available in perfect arrangement and complete form for a deterministic and unique answer to be found. The manufacturing applications of AI span a wide spectrum including manufacturing system design, process planning, and process monitoring control, product quality control, and equipment fault diagnosis. The aim of this paper is to present the state of the art and highlight the recent advances on the AI applications in manufacturing.

2. EXPERT SYSTEMS

An Expert Systems (ESs) also called a knowledge-based system is an intelligent computer program that uses knowledge and reasoning techniques to solve problems that are difficult enough requiring significant human expertise for their solution [1]. An expert system may emulate the external behaviour of an expert, or it may attempt to closely model the internal mental processes of the expert as well. Ess has the ability to justify or explain the rationale behind a specific problem solution. ESs are particularly useful for problems based on a limited knowledge domain. Like conventional programs, ESs usually performs relatively well-defined tasks. Unlike conventional programs, expert systems can explain their actions, justify their conclusions, and provide end users with details of the knowledge they contain. An Ess system generally consists of the components as shown in the figure 1.

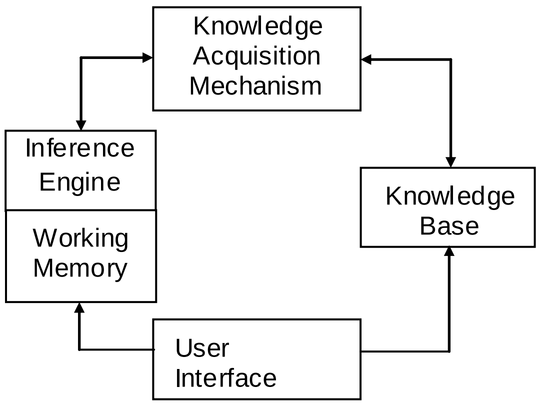

Figure 1: Structure of an Expert System

The user interface is designed to provide a convenient means of two-way communication between the user and the inference engine. An end user who tries to find a solution to a problem can describe the context of his problem to the system by means of the user interface. The knowledge base is a file that contains the facts and heuristic that makes up an expert's knowledge. A knowledge base is different from a typical data file or database. In a database, knowledge about the problem domain may be implicitly represented by the structure of the database. The actual contents of a database are the facts, data or information rather than knowledge. On the other hand, in the ESs, knowledge about the problem is explicitly represented in the knowledge base. A knowledge acquisition mechanism is used to acquire human expertise and transform into the knowledge base. This module processes the data entered by the expert and transforms it into a data presentation understood by the system. The inference engine is the knowledge processor that looks at the problem description and tries to find a solution with the help of factual and meta-knowledge. It can be considered as a program that applies domain knowledge to known facts to draw conclusions. The explainer is used to find out how a solution was obtained from an expert system and which individual steps were taken. The user can communicate with the explainer to obtain a report about the operation of the expert system.

ESs offers an environment for incorporating the capabilities of humans and the power of computers. Some of the advantages of ESs are summarised as follows:

- ESs can accommodate new expertise whenever new knowledge is identified
- ESs are able to explain their recommendations
- ESs can apply heuristics to reduce the complexity of search
- Ess reduce the company's reliance on human experts by capturing expert knowledge and store the knowledge in computers

Some of their disadvantages are listed below:

- Debugging and maintenance of a large (or complex) ES is very difficult
- The human expert must be available in order to build an ES
- The human expert must be able to articulate the rules that define the solution and not lapse into vagueness or incoherence
- The development of an ES can be a lengthy-process depending on the size of the problem domain
- An ESs performance drops off sharply if the problem deviates even slightly from the expected problem domain
- In a large and complex ES, the execution time of the system can also be a problem

There are numerous ESs being developed for almost any manufacturing activity [2]. ES is widely used in design, process planning, scheduling, material handling, quality control, machine diagnosis, machine layout and other operations.

3. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Network (ANN) technology imitates the brain's own problem solving process. Neural networks are systems composed of many simple processing elements operating in parallel and whose functions are determined primarily by the pattern of connectivity.

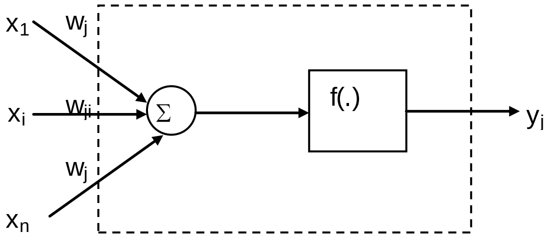

Figure 2: Model of a Neuron

Figure 2 illustrates a typical model of a neuron. Output signal y_j is a function f of the sum of weighted input signals x_i. The activation function f can be a linear, simple threshold, sigmoidal, hyperbolic tangent or radial basis function. Instead of being deterministic, f can be a probabilistic function, in which case y_j will be a binary quantity, for example, +1 or –1. The net input to such a stochastic neuron; that is, the sum of weighted input signals x_i, will then give the probability of y_j being +1 or -1

A neural network may be considered as a black box that can accept a series of input data and produce from these one or more outputs [3]. A neural network takes an input numeric pattern and produces an output numeric pattern. A typical ANN structure is illustrated in Figure 3.

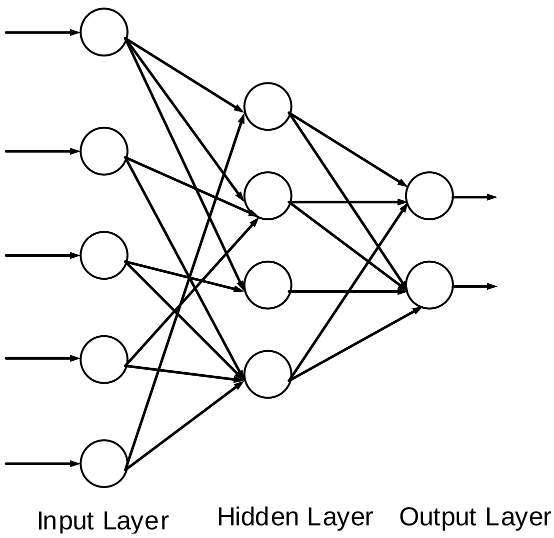

Figure 3: A Typical ANN Structure

As depicted in Figure 3, the basic components of an ANN are neurones. A group of neurones is called a slab. Neurones are also grouped into layers by their connection to the outside world. If a neurone receives data from outside world, it is considered to be in the input layer. If a neurone contains network's predictions or classifications, it is in the output layer. Neurones between the input and output layers are in the hidden layer(s). A layer may contain one ore more slabs of neurones.

Most of the ANN models can be trained adaptively. Adaptive neural networks can be trained using two types of training procedures, supervised training and unsupervised training. In supervised learning, the training process involves providing the network with known sets of input and the corresponding outputs. A network is said to have learned if it can produce the desired outputs when a sequence of inputs are provided. In unsupervised learning, the learning process is based on clustering. Unsupervised networks can classify a set of training patterns into a specified number of categories without being shown in advance how to categorise.

A potential important advantage of neural networks is their high degree of error resistivity. The advantages of ANNs over conventional computing are listed below:

- ANNs have the ability to generalise. From past experience, they can give a solution to a new problem.
- ANNs do not need an expert to represent knowledge and does not require much programming knowledge
- ANNs have a simpler structure, since only the input and the output of the system are simulated
- ANNs have a good ability to tolerate faults and missing data, making it useful where all the rules and data are not known
- ANNs are self-organising and can learn. These characteristics make it suitable for those tasks that were originally done by humans
- The massive number of processing elements (neurones) makes neuro-computing faster than conventional computing
- When fully developed, neural hardware is expected to be 20 to 50 times smaller in size than conventional computers

However some of the scientific economic expectations on ANNs are unreasonable. This is because ANNs have the following drawbacks:

- The configuration of an ANN is usually time consuming, as one needs to use a trial-and-error method to find the proper neural network architecture for a given problem

- The knowledge representation of an ANN is imprecise and not easily understood
- ANNs cannot explain its results explicitly, which implies that the user interface of a neural network may not be as friendly or productive as that of an expert system
- The current learning algorithms for ANNs are not efficient enough and cannot guarantee network convergence
- How to derive some type of optimal training set for a neural network application still remains a question

The application area of neural networks in CAD/CAM is quite broad. It covers nearly all of the fields spreading from the design phase through simulation, control, monitoring and quality assurance to the maintenance.

4. FUZZY LOGIC

Fuzzy Logic (FL) is another tool of AI that is gaining popularity in recent years. It is based on the observation that people make decisions based on imprecise and non-numerical information; fuzzy models or sets are mathematical means of representing vagueness and imprecise information, hence the term fuzzy. These models have the capability of recognising, representing, manipulating, interpreting, and utilising data and information that are vague and lack certainty. Linguistic examples are: a few, almost all, more or less, very important, good, poor, appropriate, acceptable, etc. [4]. Anything that was built using conventional techniques can be built with the FL. However, in a number of cases, conventional solutions are simpler, faster, and more efficient. The key to successful use of FL is clever combination with conventional techniques [5].

Fuzzy logic has been mainly suggested to handle fuzzy concepts, inexact information, and approximate reasoning in expert systems. In FL, the knowledge representation is explicit, the verification is easy and optimisation of the system performance is possible. On the other hand, FL has no training ability. Everything should be defined explicitly to the system. Trainability is the most important function of ANNs. Therefore, if the explicit knowledge representation capability of fuzzy logic is combined with the learning power of ANNs, a more powerful technology can be obtained. Such systems are called NeuroFuzzy Systems.

Matsuhista has built a fuzzy washing machine that combines smart sensors with fuzzy logic. The sensors detect the colour and kind of clothes present and the quantity of grit, and a fuzzy microprocessor selects the most appropriate combination from 600 available combinations of water temperature, detergent amount and, wash and spin cycle times. Zhang and Huang have recently developed a fuzzy approach for process plan selection [6]. In their approach, each process plan is evaluated and its contribution to shop floor performance is calculated using the fuzzy set theory.

5. GENETIC ALGORITHMS

Genetic Algorithms (GAs) are robust search algorithms based on the mechanics of natural selection and genetics. They are used to abstract and explain the adaptive processes of natural systems to design artificial systems software that retains the important mechanisms of natural systems. GAs work with a coding of the parameter set and search from a rich population of strings. They use only an objective function (fitness) information, not derivatives or any other auxiliary knowledge. GAs use probabilistic transition rules, not deterministic rules. The flowchart of simple GA is given in figure 4. There are basically four genetic operators: selection, crossover, mutation, and inversion [7]. There are also other types of operators that yield good results like partially matched crossover (PMX). The choice of operators depends on the problem and representation scheme employed. For instance, operators designed for binary strings cannot be directly used on strings coded with integers or real numbers.

The aim of selection procedure is to reproduce more of individuals whose fitness values are higher than those whose fitness values are low. The selection procedure has a significant influence on driving the search toward a promising area and finding good solution in a short time. However, the diversity of the population must be maintained to avoid premature convergence and to reach the global optimal solution.

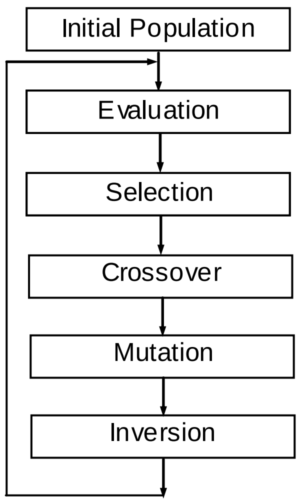

Figure 4: Flowchart of a basic GA

An example of one point crossover, mutation, and inversion is shown in figure 5. Important control parameters of a simple GA include the population size, crossover rate, mutation rate, and inversion rate. Several researchers have studied the effect of these parameters on the performance of a GA [8-9].

Parent 1 : 1 0 0 | 0 1 0 0 1 1 1 1 0

Parent 2 : 0 0 1 | 0 1 1 0 0 0 1 1 0

New string 1 : 1 0 0 | 0 1 1 0 0 0 1 1 0

New string 2 : 0 0 1 | 0 1 0 0 1 1 1 1 0

(a) Crossover

Old string : 1 1 0 0 |0| 1 0 1 1 1 0 1

New string : 1 1 0 0 |1| 1 0 1 1 1 0 1

(b) Mutation

Old string : 1 0 | 1 1 0 0| 1 1 1 0 1

New string : 1 0 | 0 0 1 1| 1 1 1 0 1

(c) Inversion

Figure 5: Crossover, mutation, and inversion of binary string segment

A large population size means the simultaneous handling of many solutions and increases the computation time per iteration; however, the probability of convergence to a global optimal solution is higher than with a small population size. The crossover rate determines the frequency of the crossover operation. A low crossover frequency decreases the speed of convergence to such areas. If the frequency is too high, it can lead to saturation around one solution. The mutation operation is controlled by the mutation rate. A high mutation rate introduces high diversity in the population and might cause instability. On the other hand, it is usually very difficult for GA to find a global optimal solution with too low mutation rate.

GAs has found application applications in engineering problems involving complex combinatorial or multiparameter optimisation. GA is widely used for scheduling the operations of a job shop, for designing the knowledge base of fuzzy logic controllers and many other problems.

6. CURRENT STATUS OF AI TECHNOLOGY AND ITS FUTURE

There have been numerous applications of AI for CAD/CAM for almost all design and manufacturing activities; from feature recognition to optimisation. ES is widely used in design, process planning, scheduling, material handling, quality control, machine diagnosis, machine layout and other operations. ANNs can be used for; quality control, pattern recognition, resource allocation, optimisation, scheduling, maintenance and repairing, process control and planning, database management, simulation, and robotics control. FL has been preferred for those problems in which there are conflicting process parameters, while GAs have been generally used for the optimisation issues such as optimisation of cutting parameters and operation sequences.

The impact of Artificial Intelligence (AI) tools (like Expert Systems, Neural Networks, Genetic Algorithms, and Fuzzy Logic) on the planning of manufacturing processes has been proven by recent research projects and actual implementations. There are numerous packages being developed for almost any manufacturing activity. A conservative estimate is that only 5% of all research endeavours have found their place in the factory. This may be a very discouraging reality; but there are following reasons for this problem:

- The tools for building intelligent systems are not sufficiently developed and are difficult to apply.
- The methods for acquiring knowledge from experts to develop expert systems are not very well understood.
- There are too few qualified people available who really know how to apply AI tools.

Using or developing right tools, methods and environments can solve these problems. However, the potential and power of AI is very great and it is believed that with the exploitation of AI methods it will only be possible to build well conceived and intelligent CAD/CAM systems in which many routine jobs (which may become very repetitive and boring, after the skill has been acquired) are taken out of the experienced manager so that his creativity can be devoted to solving more complex problems in factory [10].

The development of powerful, intelligent, optimised and flexible CAD/CAPP/CAM systems in IMS concept will only be possible with the extensive and true use of Artificial Intelligence. AI tools like ESs, ANNs, GAs, FL, SA offer promising solutions in the areas of product definition, layout design, process planning, optimisation and so on. The next generation of intelligent manufacturing systems will hopefully integrate the computational paradigms of expert or knowledge based systems and artificial neural networks, as well as other promising methodologies like fuzzy logic and genetic algorithms. Different techniques related to AI must be used in amalgamation to eliminate and to take the disadvantages and advantages of individual methodologies, respectively. Thus, it will be possible to realise the goals of lMS.

7. CONCLUSION

Over the past 40 years, AI has produced a number of powerful tools. This paper has reviewed four of those tools, namely, expert system, artificial neural networks, fuzzy logic, and genetic algorithms. Applications of the tool in CAD/CAM have become more widespread due to the power and affordability of present-day computers. It is anticipated that many new applications will emerge and that, for demanding tasks, greater use will be made of hybrid tools combining the strengths of two or more of the tools. Other developments in AI that will have an impact in engineering include data mining, or the extraction of information and knowledge from large databases, and multi-agent systems, or distributed self-organising systems employing entities that function autonomously in an unpredictable environment concurrently with other entities and processes. The appropriate use of these new AI tools and the tools presented in this paper will contribute to the creation of more competitive engineering systems.

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