ملخص

نظرا للتقدم السريع في مجال الكمبيوتر والذكاء الصناعي وأساليب المفاضلة والرسم الثلاثي الأبعاد باستخدام الكمبيوتر مثل ال solidworks والتطور السريع والذاكرة العالية لقواعد البيانات كل ذلك أدى إلى التطور السريع للاستخدام الأمثل للكمبيوتر في مجال الهندسة الصناعية بهدف إنتاج المشغولات بدقة عالية و الحصول على أعلى معدل إنتاج بأقل تكلفة ممكنة ومن ثم الحصول على أعلى ربح ممكن من العملية الإنتاجية. الهدف الرئيسي من هذه الرسالة هو استخدام الذكاء الصناعي في تطوير نظام تكامل بين التصميم باستخدام الكمبيوتر والتصنيع بمساعدة الحاسب الآلي حيث يعتبر ذلك ضرورة في قطاع الصناعة لكثرة المعلومات المتاحة في هذا المجال.

إن الهدف من البحث هو اقتراح نظام التوليد الأوتوماتيكي للتعرف علي كيانات الرسم ومعالمها التي تتم على المنتج والخاص بأجهزة الكمبيوتر الشخصية وذلك باستخدام نظم الخبرة .هذا النظام يحتوي على قاعدة بيانات خاصة بعمليات التشغيل ومجموعة من المشغولات الأسطوانية السابق إنتاجها وتقسيمها إلى مجموعة من المعالم لكل معلم منها طريقة الإنتاج المناسبة وان هذه البيانات تم استخلاصها من خبراء في مجال التشغيل ومن الكتب الخاصة بهذا المجال وتم وضع هذه البيانات في صورة قواعد بحيث يسهل على النظام استخدامها واستنتاج الحلول بطرق منطقية منها بالإضافة إلى ذلك يحتوي هذا النظام على قاعدة بيانات خاصة بعدد القطع المختلفة والمستخدمة في هذه العمليات وظروف القطع المختلفة. ويعتمد هذا النظام على رسم المشغولات الأسطوانية في المحاور الثلاث صلبة .ويقوم النظام بإنشاء البرامج الخاصة بماكينات التحكم الرقمي واختيار العدة القاطعة وظروف القطع المناسبة لكل عملية. باستخدام النظام الجديد لا يتطلب عمالة ذات خبرة عالية من الخبرة والتدريب مما يوفر من أجر العمل ويتم القضاء علي الجهد والزمن والتكاليف وفي حالة منتج جديد مطلوب اتخاذ قرار لإنتاجه يسهل من حساب تكلفته وتحديد مسار إنتاجه والوقت اللازم لذلك .

❖ الفصل الأول:

ويقدم نبذة تاريخية عن التقدم الذي حدث في التوليد الأوتوماتيكي لكيانات الرسم الثلاثي الأبعاد التي تتم على المشغولات الأسطوانية وأنواعه المختلفة سواء كان استخلاص الكيانات من لاشيء أو بالاعتماد على التعديل في كيانات موجودة بالفعل ويتناول أيضا عرض بعض تطبيقات ماكينات التحكم الرقمي وبرامجه.

❖ الفصل الثاني:

يشرح الذكاء الصناعي وتطبيقاته في التصميم والتصنيع ومفهوم نظم الخبرة حيث تحول خبرة الإنسان إلى قواعد يتفهمها ومعالج بيانات ينظر في المشكلة ويحاول إيجاد حل لها بمساعدة قاعدة البيانات أو المنطق الغير واضح حيث يتم اتخاذ القرار بالاعتماد على بيانات غير دقيقة وغير خطية أو الخلايا العصبية حيث يتلخص في محاولة فهم وظائف مخ الإنسان أو البناء الوراثي وتتلخص في فرض حل عشوائي من مجموعة الحلول المتاحة عن تحويل الرسم الهندسي إلي صور أخرى من خلال معبر يحمل مجموعة الصفات الوراثية لكل شكل أو الاستنتاج بناءا على الحالة ومكوناتها وأنواعها المختلفة وتتميز هذه الطريقة بأنها تتميز بخليط من المميزات لكل كيانات ومعالم الأجزاء الاسطوانية بالاعتماد على مقارنة الحلول السابقة أو التوليد من لا شيء وتتكون من حقائق وقواعد وتعتمد على قواعد البيانات وفي حالة منتج جديد يراد إنتاجه يحول إلى ملف نصي ويقسم إلى مجموعة من الكيانات ويتم مقارنتها بالكيانات الموجودة في قاعدة البيانات فان كانت موجودة أخذها وان لم تكن موجودة يولدها بناءا على قاعدة البيانات و القواعد الموجودة.

❖ الفصل الثالث:

يتم في هذا الفصل شرح كيفية الرسم الصلب الثلاثي الأبعاد وأنواعه وميزة كل نوع وتناول أنواع الرسم بهيئاته المختلفة وتناول بالتفصيل ال STEP حيث تتكون من ثلاث طبقات رئيسية هي طبقة

التطبيق والطبقة المنطقية و الطبقة الفيزيائية وهذه الطبقات الثلاث مدون بها كل شيء عن الرسم سواء كان أبعاد الشعلة وتفاوتاتها وتضاريس السطح والشكل الهندسي.

❖ **الفصل الرابع:**

يتناول هذا الفصل المعايير المختلفة التي تؤخذ في الاعتبار عند المقارنة بين هذه الكيانات الاسطوانية للمعالم التي يمكن وضعها للأجزاء الاسطوانية والعمليات الصناعية التي تتم عليها وكيفية اختيار كل عملية وظروف القطع الملائمة وعدد القطع المطلوبة وكيفية تتابع هذه العمليات ووضعها في برنامج يسهل تناول واستخدامه.

❖ **الفصل الخامس:**

يحتوي هذا الباب على ملخص الرسالة وكذلك أهم التوصيات المقترحة للدراسات المستقبلية .

ثم أخيرا المراجع والملاحق.

تم بحمد الله

ABSTRACT

The link between CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) is still not as integrated as desired. Although in most CAD systems, data can be processed within the CIM (Computer Integrated Manufacturing System) environment by integrated software components to produce information like manufacturing data, assembly data, etc., there are a significant number of cases where an external CAD resource needs to be processed for further integration with CAM. In this context, the research aims at developing an approach to integrate CAD and CAM, specifically for the rotary parts by any CAD environment. The proposed system is developed in three phases. The first phase involves, a CAD model from a three-dimensional solid CAD environment in STEP format. The second phase is about a system for data extraction which is used to extract the useful geometrical data from the component through the STEP file. The last phase includes the Feature Recognition system that is developed to organize the data extracted from the STEP file, which contains geometrical, topological, surface roughness and all details obtained from design features, using a pattern recognition technique. Furthermore, Feature Mapping is performed to map the design features into the corresponding predefined manufacturing features from database followed by the generation of an optimized G code ready for manufacturing.

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مؤلفين آخرين:	Mostafa, Mohammed Abd Algawad(super)
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NOMENCLATURE

2-D	Two Dimensional Product
3-D	Three Dimensional Product
AI	Artificial Intelligent
B-Rep	Boundary Representation
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CBR	Case Based Reasoning
CIM	Computer Integrated Manufacturing System
CNC	Computer Numerical Control Machine
DXF	Data Exchange Format
FR	Feature Recognition
ES	Expert System
G code	CNC code
GT	Group Technology
IGES	Initial Graphics Exchange Specifications
IMS	Integrated Manufacturing Systems
NC	Numerical Control Machine
NG	Numerical Control Machine
PDES	Product Data Exchange Specifications
STEP	Standard for the Exchange of Product Data Format

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جامعة أم القرى
كلية الهندسة و العمارة الاسلامية
قسم الهندسة الميكانيكية

تكامل التعرف علي الملامح الهندسية و الطوبوغرافية المميزة لمنطقة محددة من الشكل و توليد شفرة التحكم الرقمي باستخدام الحاسب الآلي للأشكال الدائرية في بيئة نموذجية للتصنيع باستخدام الحاسب الآلي

مشروع تخرج كجزء تكميلي للحصول علي درجة الماجستير في الهندسة الميكانيكية

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الدكتـــور / محمد عبدالجواد مصطفى

صيف 2014

Umm Al-Qura University
College of Engineering & Islamic Architecture
Mechanical Engineering Department

Integration of feature recognition and CNC code generation for rotary parts in a typical CIM environment

A Graduation Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

Submitted by:

Abdul Kareem Baker Al-Sayegh

Supervised by:

Dr: Mohammed Abdel Gawad Mostafa

Summer 2014

ملخص

نظرا للتقدم السريع في مجال الكمبيوتر والذكاء الصناعي وأساليب المفاضلة والرسم الثلاثي الأبعاد باستخدام الكمبيوتر مثل ال solidworks والتطور السريع والذاكرة العالية لقواعد البيانات كل ذلك أدى إلى التطور السريع للاستخدام الأمثل للكمبيوتر في مجال الهندسة الصناعية بهدف إنتاج المشغولات بدقة عالية و الحصول على أعلى معدل إنتاج بأقل تكلفة ممكنة ومن ثم الحصول على أعلى ربح ممكن من العملية الإنتاجية. الهدف الرئيسي من هذه الرسالة هو استخدام الذكاء الصناعي في تطوير نظام تكامل بين التصميم باستخدام الكمبيوتر والتصنيع بمساعدة الحاسب الآلي حيث يعتبر ذلك ضرورة في قطاع الصناعة لكثرة المعلومات المتاحة في هذا المجال.

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The link between CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) is still not as integrated as desired. Although in most CAD systems, data can be processed within the CIM (Computer Integrated Manufacturing System) environment by integrated software components to produce information like manufacturing data, assembly data, etc., there are a significant number of cases where an external CAD resource needs to be processed for further integration with CAM. In this context, the research aims at developing an approach to integrate CAD and CAM, specifically for the rotary parts by any CAD environment. The proposed system is developed in three phases. The first phase involves, a CAD model from a three-dimensional solid CAD environment in STEP format. The second phase is about a system for data extraction which is used to extract the useful geometrical data from the component through the STEP file. The last phase includes the Feature Recognition system that is developed to organize the data extracted from the STEP file, which contains geometrical, topological, surface roughness and all details obtained from design features, using a pattern recognition technique. Furthermore, Feature Mapping is performed to map the design features into the corresponding predefined manufacturing features from database followed by the generation of an optimized G code ready for manufacturing.

References

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I would like to express my sincere gratitude to my advisor who guided me through this work, Dr. Mohammed Abdel Gawad Mostafa, for the continuous support and guidance through my master degree study.

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CHAPTER ONE

GENERAL BACKGROUND AND LITERATURE REVIEW

1.1 Introduction

Manufacturing feature recognition (FR) is the process of recognizing manufacturing features from a computer-aided design (CAD) model. It is the main high technology aimed at integration of design, computer aided process planning and manufacturing activities in computer integrated manufacturing systems. A feature is a generic shape that is useful in some computer-aided application, such as geometry construction, process planning, and design for manufacturing [1]. Manufacturing features differ from design features, even within manufacturing requirements, there is no feature component that covers all the manufacturing processes. For example, machining features differ from molding features and other manufacturing domain features. This is due to different requirements of manufacturing processes. Consider a computer-numerical-control (CNC) turning and milling feature set. The set is not only dependent on the specification of the machine tool, but also on the type and shape of the cutting tools and the machine controller. It makes the size of the set larger, and requires unlimited number of tools. Feature recognition seems impossible to develop a system appliable in manufacturing. This requires pre-processing of input parts by graphic software in order to separate out features that cannot be completely processed automatically. A process planner can then handle the separated parts individually. It is also in line with the concepts of concurrent engineering and design for manufacture where manufacturing planning is simultaneously carried out to ensure manufacturability of a part on available manufacturing facilities [41].

Feature recognition system is capable of handling any part that can be machined on a three axes CNC turning or milling machine while using a set of standard cutting tools. This system can recognize features which can be machined with the available machining resources [31].

1.2 Review of Literature

1.2.1 General

Automatic manufacturing feature recognition and feature model conversion have been active research areas for more than two decades. Feature recognition methods have been developed, such as graph-based, rule-based, volume decomposition, neural network-based and hint-based methods.

Multi research papers have been published on various techniques and a few elementary commercial feature recognition software have been reported one of the important techniques is the STEP developer which was developed by NASA organization. The complete generation of feature recognition is not yet developed. Among the various techniques, the hint-based technique has caught the major attention of researchers because of its capability to recognize features in real industrial parts having complex features. When features interact, some information is needed to recognize these features by program. Other techniques such as graph-based and rule-based techniques fail to recognize the interacting features. The graph-based method is basically a technique for graph representing a feature in the part graph. Due to feature interaction, some edges and nodes may be lost and graph matching may fail like surface roughness and topology parameters [7].

In manufacturing, there is a rapid motion towards improvements in computer-aided design (CAD) and computer-aided manufacturing (CAM). This development has been treated in separate activities. Many designers use CAD with a little misunderstanding of CAM. This sometimes results in a design which can not be on machined or the use of expensive tools and difficult operations. This creates higher costs in production and noncompetitive products in marketing. In rapid motion, design must be modified several times, resulting in increased machining lead times and costs. Therefore, great savings in machining times and costs can be achieved if designers can obtain the best machining parameters to produce the products while designing. This can only be achieved through the use of fully integrated CAD/CAM systems.

The need to integrate CAD and CAM has long been recognized and many systems have been developed. The development of graphics software and different formats makes easy methods to integrate CAD, CAM and CAPP components [1]. In a different study, a rule-based system was developed, for transferring engineering graphics into computer aided manufacturing (G code) program for two dimensional products [2]. Another development in integrated CAD/CAM systems for design and manufacturing of turned components studied two-dimensional shaped components and neglected the specification of the part quality [3]. In the USA, the Air Force began testing an air defense system known as Semi-Automatic Ground Environment to graphically depict data received on radar systems [5]. They made the first computer program to manage the data. In 1960, computer scientists at MIT produced another project called Sketchpad, an application that is now considered to be the first design program made for industrial specifications. After that, General Motors made a similar program for car industry.

Rapid motion in development leads the world towards the integration of CAD and CAM systems. However, all integration between CAD and CAM is not verified until now. This technique of integration between CAD and CAM has been relatively slow in comparison with the developments made in each of these technologies. The cause of the little motion towards development of integration depends on database formats and the lack of common graphics formats. Now, many researchers have been contributing their part towards the integration of CAD/CAM/CAPP systems.

Automotive companies worked on a development to adopt the technology and used it first in car body design, and rapidly applied it in other industry sectors [8]. At present time solid modeling software became available. It allowed users to take geometric shapes such as extrude, fillet, boxes and cones; and mixed those using Boolean operations.

1.2.2 Computer Aided Designs (CAD)

CAD is used by architects, engineers, drafters, artists, and others to create precision drawings or technical illustrations. CAD software can be used to create two-dimensional (2-D) drawings or three-dimensional (3-D) models. CAD is used for creation, modification, analysis and optimization of designs [3]. The computer programs which are used by engineers in design can be classified as CAD softwares. In other words, CAD tools which are used in the geometric computer program for drawing parts, to customized application programs, such as those for analysis and optimization [4]. Another study [5] made a survey in CAD applications. The study discussed useful computer applications in terms of drafting, design, documentation and implementation.

1.2.3 Feature Recognition

Feature recognition defines domain independent form features as a set of faces specification and its topological and geometric characteristics. It creates a form feature as addition or subtraction of solid feature from based solid. The definition of feature is the "type" based on the local topology of participating base-solid faces and "shape" based on shape of the feature-solid. Feature recognition is the main stone in the integration of computer aided design and computer aided manufacturing [6].

Another research worked on group technology codes [7] for rotational parts from a solid geometry model. The generated GT code is made up of three kinds of code systems; unique geometry code, macro geometry code and semantic code. The method for identifying features [8], uses a graph called the Attributes Adjacency which uses a database that depends on faces and edges (convex or concave). This method requires the adoption of a heuristic method to limit the search.

Series of papers presented the Edge Boundary Classification (EBC) approach [9], considering the use of information of solid models which define solid state and neglect the sides of a boundary entities. This search enables recognition of the features in parts which are produced on two-dimensional numerical control machines; like pockets, slots, fillets and step shafts and also for turning features, both in prismatic and rotational parts. One of the earliest works in feature recognition proposed a technique known as expressions for extracting features from the boundary representation of two-dimensional or three-dimensional shaped parts [10].

Definitions of the part geometry are based on a combination between an automatic identification of two-dimensional shaped and a feature-based shaped geometries. One author established the minimum number of gripping based on the shape of the part, the raw material type and the geometrical tolerances to determine the machining operations [11]. Another author studied the manufacturing feature recognition of a rotational component using DXF files [12], where he used a C++

program to obtain the information from the DXF file. The authors could extract the information from the profiles which are drawn with Polyline only and classify the features in form of horizontal, vertical, inclined and curved entities. The structure and operation of a prototype feature recognition system 'IPFR' can describe the feature recognizer by accepting entity descriptions from CAD systems in the form of DXF files through a DXF translator [13].

Another research studied part feature recognition algorithm for rotational parts [14]. His system serves as the intelligent part feature recognition system which extracts part definition data from CAD systems using " IGES standard data format and the program is written by PROLOG language. Another study presented a survey paper on feature recognition techniques which is used in computer aided process planning (CAPP) [15], it discussed various methods used in feature recognition like cell division, cavity volume, convex hull, and other methods.

Furthermore, others introduced of a computer-integrated system to design feature recognition in order to achieve computer aided process planning [16]. They used two modules; first, STEP feature recognition module to extract a solid design model, which is converted to a group technology code that can be used as input data to recognize feature patterns. Second, Rule-based process planning module to map the features to the appropriate operations.

Others proposed a feature extraction technique, for rotational parts, based on STEP file of geometric data of basic meaningfull features from CAD files [17]. Researchers of [18] studied the feature extraction from standard DXF file for the prismatic parts, their work focused on a code classification algorithm for the parts to read DXF code and extract features for the selection of machining parameter in milling machines.

Authors of [19] studied the automatic extraction of geometric and non-geometric part from CAD tools. They used a heuristic search to interpret characteristic attributes of dimension sets which contain linear, diametrical, radial and angular dimensions. They used Natural Language Processing techniques to define the features.

The wire frame part was obtained as a model system from AutoCAD as a DXF file which was used for prismatic parts [20]. Containing a hole, step, slot and protrusions with orthogonal boundary faces. The graphs are translated in strings and then the strings are matched with the patterns in a knowledge base.

Another paper focused on Edge Boundary Classification (EBC) [21] using solid models that identify the solid and void sides of a boundary entity for pattern recognition. The logic approach is introduced on B-rep solid modelers [22]. It contains a set of production rules; defining form feature.

The geometry-decomposition approach [23], for feature recognition, was viewed as volumes to be removed by machining operations. It defined the concept of cavity features, as primitives, are the material to be removed or machined.

Application to holes in prismatic parts proposed a shape feature recognition frame work [24]. It discussed a system consisting of a feature definition part and a feature matching part. Another study presented a hint-based method for recognition of machined features [25], the study was the basic of generation notes and depended on rule-base techniques and it was applied to 2.5 D swept features only.

The development of an object-oriented feature-based design system for integration between CAD and CAPP systems [26], used Advanced Modeling Extension of AutoCAD. The design information of a prismatic part was converted into the process plan with the knowledge depending on rule-based feature mapping system .

The prototype of Feature Based Automated Process Planning system was proposed to recognize the features from the metal removal point of view rather than from the design part point of view [27]. The extraction of cylindrical-based features was discussed from a neutral data format [28], namely STEP (Standard for the Exchange of Product Model Data) file produced by any CAD system like solidworks, and developed a rule-based algorithm for the extraction of the cylindrical features.

Feature extraction system was developed to take STEP file as input and take into consideration the geometry and topology of a part [28]. CAPP / CAM Systems [29] proposed a heuristic approach for Automated Process planning. It focused on minimization of setup time. It choosed the machine, fixture, and tools and sequence of operations.

The design and setup of a computer aided process planning for prismatic parts were used in the batch production of electric tools [30]. The system had different modules for component of feature recognition; machines, tools and different parameters can be selected. An object-oriented approach for selection of features can be machined depending on process plan [31]. Their approach uses a feature for prismatic parts.

The optimization of cutting conditions for rotational components was generated depending on genetic algorithms approach [32]. It reduced the machining time under the constraints of maximum cutting tool forces and maximum power of the machine tool but it was limited for roughing operations. A comprehensive review of literature on computer aided process planning was presented in [33]. It discussed the advantages and disadvantages of variant and generative computer aided process planning systems. The literature on computer aided process planning had classified into twelve areas of interest [34]. Automatic feature recognition and tool path planning for rotational parts were discussed using Delphi 7 programming language [35]. It focused on feature recognition and sequence of operations. The integration of a computer aided design and a knowledge based system analyzed the concepts for the selection of cutting tools [36]. It presented an integrated system which was containing three programs designed to process the IGES data for roughing and finishing operations and finally to generate the output files.

A hybrid approach for automatic generation of G code program that communicates with the computer aided design system to recognize machining features was presented in [37]. The integration between AutoCAD and Mastercam using generative process planning interface programs was written in Auto lisp [38]. It was applied on turning and milling parts.

The automatic generation of G code programs for parts of 2.5 dimensions from a wireframe CAD model was developed to interface the system to any CAD system. Drawing annotation information was allocated to solid model entities through pattern matching techniques in Prolog. The resulting operation sequence was communicated to a module that produces G code program.

The proposed system takes drawing of the part from any CAD file in STEP format and use case based reasoning to generate the feature recognition and g code program for rotational.

1.3 Structure of the presented project

This report consists of five chapters as following:

Chapter 1: provides a historical review of Feature Recognition and Feature-based and Solid Model-based Process Planning. It also shows the development of Feature Recognition related to computer aided design and computer aided manufacturing.

Chapter 2: illustrates the different types of artificial intelligence techniques including the applications of techniques in design and manufacturing with discussion on the most effective techniques thereby.

Chapter 3: focuses on the basics and the importance of Computer Aided Design. The importance of data exchange between Computer Aided Design and computer aided manufacturing systems. The chapter also contains the details of standards for the exchange of product data (STEP) and its structure. Furthermore, the different types of rotational features are discussed.

Chapter 4: displays the matching of features and a case study for rotational parts including a method to match between features and the proposed program for generation feature recognition for rotational parts.

Chapter 5: discusses the main issues arising from this work, capability of the developed feature recognition system and the results obtained from this study. The recommendations for further work are also presented.

CHAPTER TWO

BACKGROUND OF ARTIFICIAL INTELLIGENCE AND ITS IMPACT ON CAD/CAM

This chapter contains the meaning of artificial intelligence (AI) and different types of AI techniques used in industry. The applications of AI in design and manufacturing are also discussed.

2.1 Artificial Intelligence and its Techniques

Artificial Intelligence (AI) is a part of computer science concerned with systems that exhibit the characteristics usually associated with intelligence in human behavior, such as learning, reasoning, problem solving, understanding language, and so on. The main goal of AI is to simulate human behavior on the computer. The knowledge and the use of knowledge are the key characteristics. The art of bringing relevant principles and tools of AI together for solving difficult application problems is therefore sometimes referred to knowledge engineering.

Manufacturing systems in industrialized countries have dramatically changed as a result of advanced manufacturing technologies employed in today's factory. Factories are now striving to attend and maintain a world-class status through automation that is made possible by sophisticated computer programs. The development of CAD/CAM systems is evolving towards the phase of Intelligent Manufacturing Systems (IMS).

The AI techniques has contained multi techniques with applications in manufacturing like; Expert Systems, Artificial Neural Networks, Genetic Algorithms, Petri nets, simulated annealing and Fuzzy Logic.

2.1.1 Expert Systems (ES)

An expert system known by a knowledge-based system is a computer program which uses knowledge-base and reasoning algorithms to solve problems that are difficult enough to solve by human. An expert system is able to solve or shows the specific problem solution [47]. Expert systems applications examples involve airline scheduling of flights, personnel, and gates, manufacturing job-shop scheduling, and manufacturing process planning. Also, can it be used in modular house building, manufacturing, and other problems involving complex engineering design and manufacturing. Also, expert systems help to assess the risk presented by the customer and to determine a price for the insurance. A typical application in the financial markets is in foreign exchange trading [48].

One of the main differences between the conventional and expert systems is that the knowledge is separated from the algorithms and is readily accessible at a run time in expert systems, while data and algorithm are executed together in conventional programming. An expert system generally consists of the components that are shown in Figure (2.1). They are; data base of facts, user interface, a knowledge base, an inference engine, and explanation mechanism.

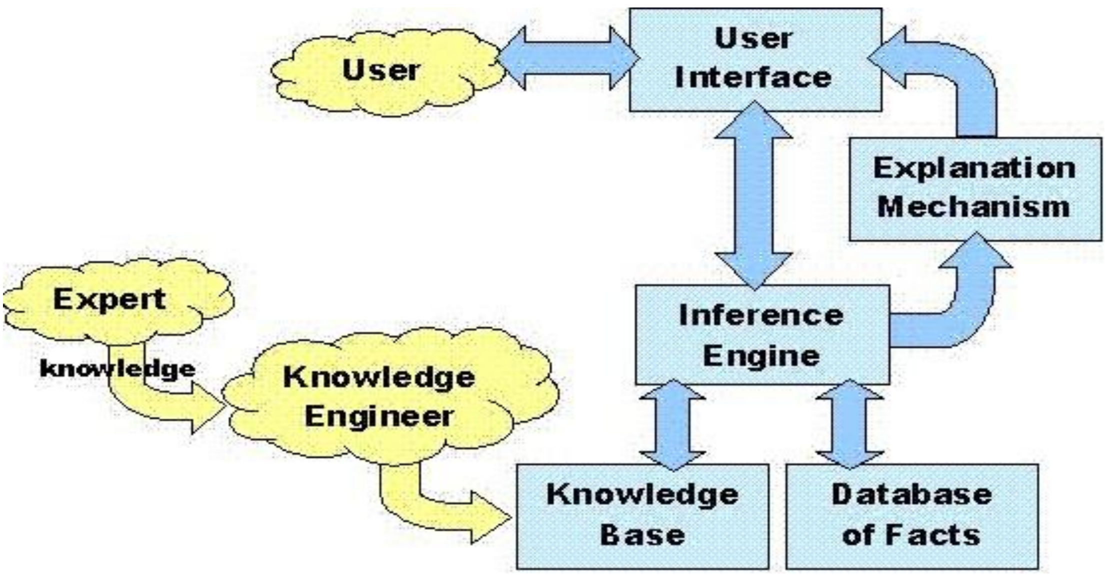

Figure 2.1 General Structure of an Expert System [47].

The user interface is designed to communication between the user and the inference engine. It prepares the knowledge to be entered into the knowledge database. Thus, the user of the system who tries to find a solution of a problem can explain text of his problem to the system.

As knowledge plays a key role in the functioning of expert systems, they are also known as knowledge-based systems. The knowledge base is expressed in computer program, usually in the form of IF < Condition> THEN < Action>, with a series of questions.

The advantages of expert systems include availability which means expert systems are available easily due to rapid in production software. Also, the cost of providing expertise is not expensive and it can be used in any risky environments where humans cannot handle. Moreover, it can respond at great speed due to the inherent advantages of computers over humans [46].

The disadvantages of Expert systems can be summarized as follow:

- Debugging and maintenance of a large (or complex) ES is very difficult
- Building the expert system depends on human expertise.
- The High development costs
- Only work well in narrow domains
- Cannot learn from experience
- Not all problems are suitable
- The execution time in a large and complex application of the system can also take a long time.

There are numerous ES's being developed for almost any manufacturing activity [49]. Many major applications of ESs can be found in the manufacturing area. ES is widely used in design, process planning, scheduling, material handling, quality control, machine diagnosis, machine layout and other operations.

2.1.2 Artificial Neural Networks

Artificial Neural Networks are a models based on the neural structure of the brain. The brain of human learns from experience. These biologically inspired methods of computing are thought to be the next major advancement in the computing industry [49].

Neural networks have been inspired both by biological nervous systems and mathematical theories of learning, information processing and control. A neural network is considered as a box that can take a series of input data and produce from it the outputs [50]. A neural network consists of input layers, hidden layers and output layers as shown in Figure (2.2).

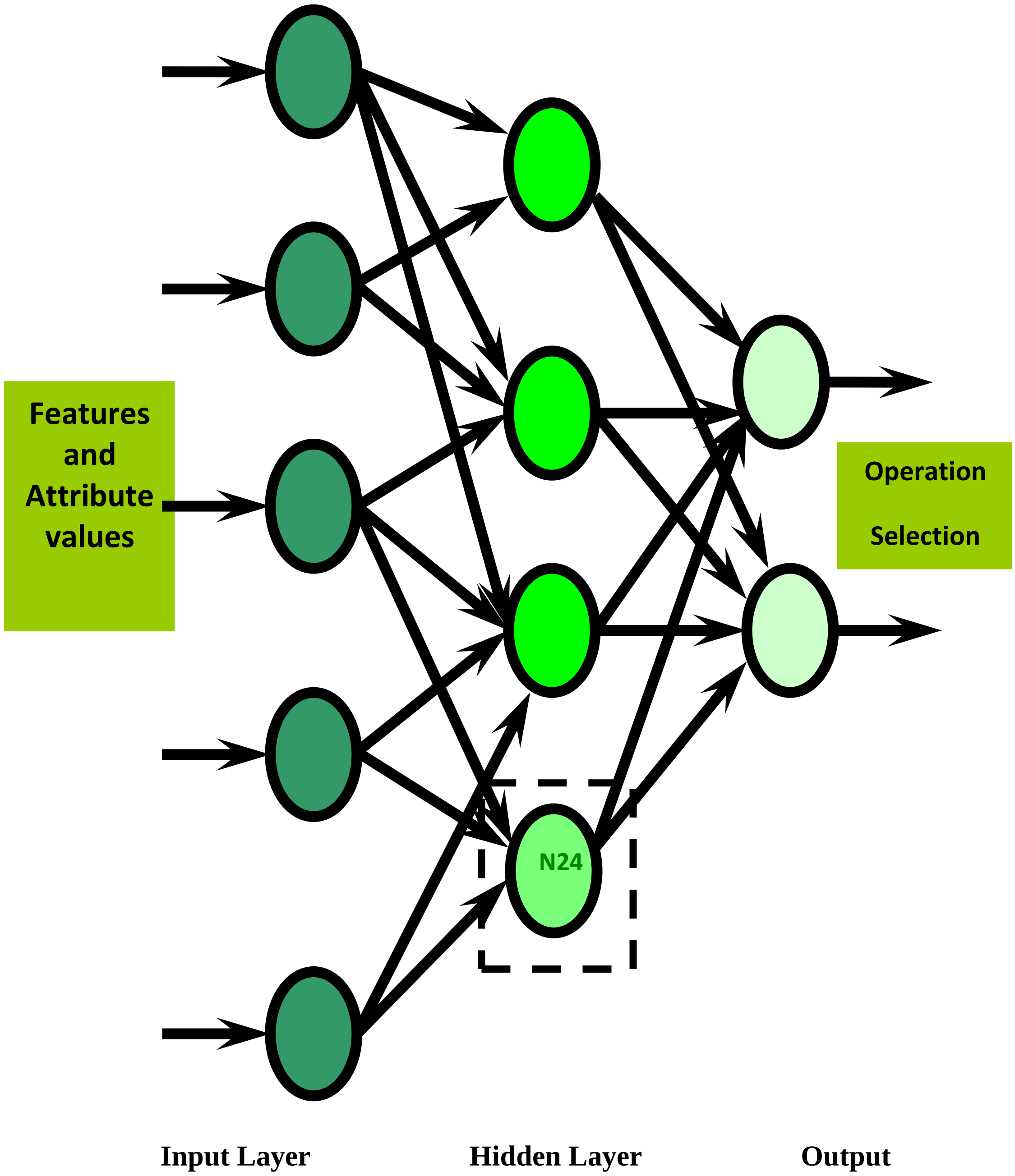

Figure 2.2 A Typical ANN Structure.

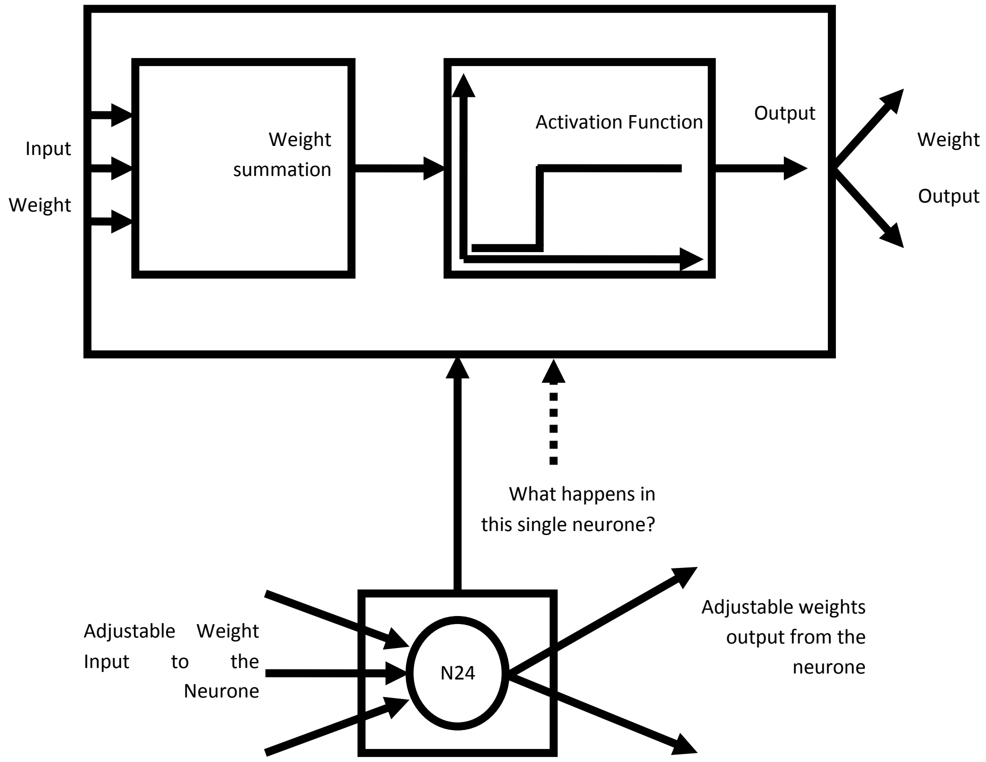

Figure 2.3 An Example of an Artificial Neurone Unit [51].

The various inputs to the network are represented by the mathematical symbol. Each of these inputs is multiplied by an input weight. In the simplest case, these products are summed, fed through a transfer function to obtain the result, and then output. This electronic implementation is still possible with other network structures which utilize different summing functions as well as different transfer functions. What happens in a single neurone (e.g., Neurone: N24) is shown in Figure (2.3). The artificial neural networks models are usually used with fixed weights [51].

The advantage of artificial neural networks can be summarized as follow:

- More like a real nervous system of the human.
- Parallel organization permits solutions to problems where multiple constraints must be satisfied simultaneously.
- Graceful degradation.
- Rules are implicit rather than explicit.

The main limitation of artificial neural networks is difficulty with infinite recursion and structured representations. No doubt that artificial neural network play an important role in the development of Computer Integrated Manufacturing systems (CIM), in order to shorten the reaction time of the system, to increase the product quality, to make the systems more reliable and to enhance their intelligence by the knowledge representation and learning abilities of AI methods.

The application area of neural networks in CIM 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. The majority of approaches relates to sensor processing, especially multi-sensor integration. Robotics applications form a very large field of neural network research and application. It can generally be used in the following applications; Quality Control, Pattern Recognition, Resource Allocation, Constraints satisfaction (Optimization), Scheduling, Maintenance and Repairing, Process Control and Planning, Database Management, Simulation, and Robotics Control.

2.1.3 Fuzzy Logic

Fuzzy logic is a form of many-valued logic. It deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets where variables may take on true or false values, fuzzy logic variables may have a truth value that ranges in value between 0 and 1. Fuzzy logic has been extended to a few, almost all, more or less, very important, good, poor, appropriate, acceptable, etc [52]. Figure (2.4) presents a diagram of the three major parts of a fuzzy controller – fuzzy fication, inference, and defuzzi fiction [52].

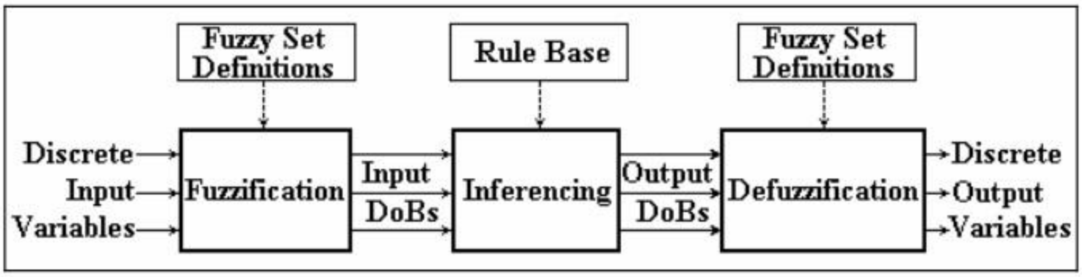

Figure 2.4 Major components of a fuzzy logic controller [52].

There are many examples of real-life, practical fuzzy sets. Here are a few others:

- Automobile changing lanes while passing.
- The position of the shoreline during tidal inflow or outflow.
- A door being closed or opened.
- A water valve being opened or closed.
- A glass of water (Is it half-full or half empty?).
- The mixing together of two primary colors.
- The age of a young customer in a bar.
- The waiting time in a queue.

The advantages of fuzzy logic can be summarized as follow:

- Uses linguistic variable
- Permits fuzzy thresholds
- Relates input to output in linguistic terms, easily understood
- Allows for rapid prototyping because the system designer doesn't need to know everything about the system before starting
- Cheaper because they are easier to design
- Simplify knowledge acquisition and representation
- A few rules encompass great complexity
- Can achieve steady state in a shorter time interval

Disadvantages of Fuzzy Logic are too hard to develop a model from a fuzzy system and require finer tuning and simulation before operational [53].

2.1.4 Genetic Algorithms (GAs)

Genetic Algorithms (GAs) are the most approach among combinatorial algorithms like simulated annealing and case-based reasoning. Genetic Algorithms are search algorithms based on the mechanics of natural selection and genetics. Genetic Algorithms are finding more widespread applications in CAD/CAM area recently. These systems are computationally simple and powerful in their search for improvement and are limited by restrictive assumptions about the search space [60]. Genetic Algorithms are different from other optimization and search procedures in many ways. They work with a coding of the parameter set and search from a rich population of strings. They use only objective function called fitness information, not derivatives or any other auxiliary knowledge. They use probabilistic transition rules, not deterministic rules.

2.1.5 The Case-Based Approach

A case-based system reuses previous experience automatically to generate new solutions. The proposed case-based process planner combines the advantages of the generative and variant approaches by reusing old solutions automatically or planning generatively when no appropriate old solution exists. Case-based reasoning (CBR) is a fast emerging AI technique. Its foundation lies in the psychological theory of human cognition [54].

A CBR system essentially comprises a case retrieval module, case adaptation module and case library module. The case retrieval module is the most important one in the CBR systems. The function of the case retriever is to extract the case from the case library that resembles the input case most closely. This case in called the “most similar case”. The case retriever works upon this case by suitably altering it to adapt the case to suit the user’s requirements. The system uses a case matching methodology which is multi parametric (i.e. it checks several parameters to sort out a match) and absolute (i.e. the features are said to match only if all its parameters fall within a certain range). The case adapter, in the traditional CBR system, makes a list of those features of the part input which do not match the features of the most similar case. Thereafter, these features are taken out from other cases stored in the library and their subprocess plans are used. Once the current problem has been solved through the retrieval and adoption of a historical case, the current case can be integrated into the case library as a new historical case. This has the effect of continuously improving the CBR system.

A case-based process planner should be able to retrieve old experience from the plan memory, modify the old solution for the new part, and abstract and store the newly generated solutions in the plan memory. The process planner must use both abstract and detailed information about the part, and the knowledge of the processes and the tools automatically to generate a plan to manufacture the component. To achieve the tasks in a case-based approach to process planning, the planner should be able to compare the old plans and decide on the extent of their effectiveness. A case-based process planner should also be able to abstract the detailed information relating to particular solutions and partition the abstracted solution into smaller reusable chunks. The system requires the user to enter the features of the new part. Thereafter, according to a set of sequencing rules, it carries out a loose preliminary sequencing of the features that are to be machined. Then, the case retrieval sequence is brought into action. This makes use of the library database, the process library database and the similarity-checking module to extract the most similar case. The extracted case is tailored to meet the manufacturing requirements of the part input, using the case modifier. The process plan generated is then displayed. The system also has the provision for generating alternative plans by matching and retrieving the next similar cases. From the above description, it can be inferred that the proposed system offers the advantages of both the variant and generative approaches of process planning.

There are some new approaches that have been introduced in the case retriever as well as in the case adapter. The case retrievers of earlier CBR systems did not consider the matching of the materials hardness, tolerances, surface finish, etc, of the part input with the corresponding parameters of the case. Some of the earlier systems included these parameters by adding weakening or strengthening factors to the similarity index [55]. The similarly index refers to the extent to which the new case resembles a case available in the library.

All case-based reasoning methods have in common the following process as shown in Figure (2.5):

- Retrieve the most similar case comparing the case to the library of past cases.
- Reuse the retrieved case to try to solve the current problem.
- Revise and adapt the proposed solution if necessary.
- Retain the final solution as part of a new case.

جامعة أم القرى

كلية الهندسة و العمارة الاسلامية

قسم الهندسة الميكانيكية

تكامل التعرف علي الملامح الهندسية و الطوبوغرافية المميزة لمنطقة محددة من الشكل و توليد شفرة التحكم الرقمي باستخدام الحاسب الآلي للأشكال الدائرية في بيئة نموذجية للتصنيع باستخدام الحاسب الآلي

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اعـــداد

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Umm Al-Qura University
College of Engineering & Islamic Architecture
Mechanical Engineering Department

Integration of feature recognition and CNC code generation for rotary parts in a typical CIM environment

A Graduation Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

Submitted by:

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Dr: Mohammed Abdel Gawad Mostafa

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