ABSTRACT

The primary objective of a Computer-Aided Manufacturing (CAM) system is to precisely produce an engineering machinery parts. In order to achieve this objective, the Computer-Aided Design (CAD) drawing being used must be free from even a slightest defect to provide a perfect representation of the parts that need to be built. However, a perfect CAD drawing is hard to achieve and defects could occur in the drawing because of human carelessness while doing the drawing. The defects are gaps and extension on the edge connections which hinder the precise extraction of data from the CAD drawing to be used in the CAM. Minimum Spanning Tree (MST) algorithm has been used by previous researchers to solve the problems. However, the algorithm could not detect a close object when the last edge of the object is connected to the first edge. Furthermore, the algorithm could not detect the error within the edge connections and subsequently, could not correct the error. Therefore, this research aims to provide an algorithm to manage these defects. MST algorithm has been redefined and enhanced by incorporating the error detection and error correction methods where both methods have been developed using simultaneous and locus equations. This enhanced algorithm is known as Close Spanning Tree (CST). An experiment is conducted using 15 CAD drawings that contain part of a leaf spring which is depicted in a close object. The results reveal that the percentage of detecting the errors for both MST and CST are 46.66% and 53.34% respectively. This proves the CST algorithm is superior to MST in terms of error detection.

ABSTRAK

Sistem *Computer-Aided Manufacturing* (CAM) berfungsi menghasilkan dengan tepat produk kejuruteraan mesin. Demi mencapai tujuan tersebut, lukisan *Computer-Aided Design* (CAD) yang digunakan perlu bebas daripada sebarang ralat untuk menyediakan illustrasi sempurna terhadap produk yang akan dihasilkan. Namun, kecuaian manusia semasa melukis menyebabkan berlakunya ralat pada lukisan. Ralat didefinisikan sebagai sela dan lebihan pada percantuman garisan dimana ianya menghalang proses pengekstrakan data dari lukisan CAD dengan tepat bertujuan untuk digunakan dalam sistem CAM. Penyelidik terdahulu telah menggunakan algoritma *Minimum Spanning Tree* (MST) untuk mengatasi masalah tersebut. Walau bagaimanapun, algoritma tersebut gagal mengesan lukisan objek penuh bilamana garisan terakhir objek bercantum pada garisan pertama objek. Tambahan lagi, algoritma tersebut tidak mampu mengesan ralat yang berada pada percantuman garisan dan selanjutnya tidak mampu membetulkan ralat. Maka, matlamat penyelidikan ini adalah untuk membangunkan algoritma yang mampu menangani masalah tersebut. Algoritma MST telah didefinisikan semula dan ditambahbaik dengan menggabungkan kaedah mengesan dan membetulkan ralat dimana kedua-dua fungsi tersebut dibangunkan menggunakan persamaan serentak dan persamaan lokus. Algoritma yang telah ditambahbaik ini dinamakan sebagai *Close Spanning Tree* (CST). Pengujian terhadap 15 lukisan keratan CAD yang terdiri dari pegas daun telah dilaksanakan. Hasil pengujian telah menunjukkan peratusan pengesanan ralat pada lukisan oleh kedua-dua algoritma MST dan CST adalah masing-masing 46.66% dan 53.34%. Ini membuktikan bahawa algoritma CST adalah lebih baik berbanding algoritma MST dari aspek pengesanan ralat.

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

1.1 Introduction

CAD/CAM is a synthesis technology between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). According to Nafis (2001), CAD is a tool for a designer to design an engineering drawing and CAD has its own database. While, CAM is a tool for manufacturing a product using a computer and CAM also has its own database. His statement shows that CAD and CAM are separated tools because they have their own database (Nafis *et al.*, 2001). Therefore, by assuming to integrate both tools for using a single database will help to connect CAD and CAM. However, to integrate CAD and CAM is a major challenge (Napsiah *et al.*, 1997). Before further explanation about the challenge, this research needs to understand CAD/CAM fundamentals. Figure 1.1 shows the fundamental of CAD/CAM to explain the connection between CAD and CAM technology.

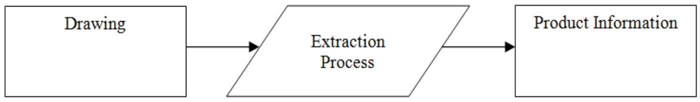

Figure 1.1: CAD/CAM Fundamental

Figure 1.1 shows that drawing is an important source for extraction process. In this research, drawing means CAD drawing or engineering drawing. Thus, to understand the drawing is the initial step in this research. Basically, the drawing consists of geometry and non-geometry entities. Generally geometry entities consist of lines, arcs and vertexes while non-geometry entities consist of text, dimension and symbols (Nafis *et al.*, 2001). Connection among geometry entities produce shape or object in the drawing. Meanwhile, non-geometry entities became additional information in the drawing such as dimension, height or width of the object.

Extraction process is a process to retrieve data. In this research, data were extracted from the drawing. Extraction is a key player to create a connection between CAD and CAM, but by simply extracting information from a CAD drawing does not promise the system will produce the correct information for CAM. This is because CAD drawing was drawn by a human such as designer or engineer and to avoid errors during drawing process is impossible (Huang *et al.*, 2008).

Hence, errors in the drawing are another issue before the extraction process can be done. Huang (2008) has reported that errors in drawing will affect the generated information. From the wrong information, wrong product will be produced. Therefore, errors in the drawing are an important issue that needs to be solved.

1.2 Problem Background

In CAD/CAM field, extraction is a process to extract CAD data from CAD drawing. The purpose is to produce useful CAD information for manufacturing process in order to assemble the product. In order to produce CAD/CAM system, many extraction approaches have been proposed such as Feature-Based approach (Emad S. Abouel Nasr *et al.*, 2006; Nafis *et al.*, 2001; Rameshbabu *et al.*, 2009; Xionghui *et al.*, 2007; Ji *et al.*, 1997), Boundary Representation approach (B-Rep) (Napsiah *et al.*, 1997; Adem *et al.*, 2007), Graph Theory Based approach (Huang *et al.*, 2008), Pattern Recognition approach (Lai *et al.*, 2008).

Although many approaches have been proposed, there are still issues that need to be solved. The main issues are translation from CAD data into CAM information, information accuracy and errors in drawing as illustrated in Figure 1.2.

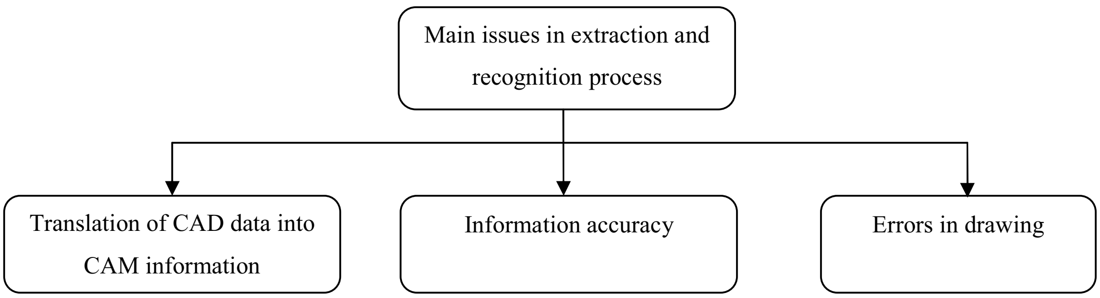

Figure 1.2: Main issues in extraction and recognition process

In CAD/CAM field, translation issue from CAD data into CAM information is very critical as there is no common database structure between CAD and CAM (Nafis *et al.*, 2001). It is very difficult to directly translate CAD data into CAM information (Huang *et al.*, 2008). In CAD/CAM field, manufacturing is fully dependent on CAD drawing. If the translation process goes wrong, it will affect the production part in manufacturing and also the final product. Feature based approach has been proposed by Nafis (2001) in order to extract and recognise the geometry features in the drawings. However, the approach encountered difficulties because of the limited definition of CAD drawing features defined. Meanwhile, Adem (2007) has developed a CAD features library in his proposed algorithm, however the proposed algorithm cannot be used as the algorithm is focused only on solid drawing also known as 3D drawing. Based on this study, the drawing used in this research is a 2D CAD drawing. In addition, the approach is still weak because each researcher's defined features in CAD drawing are different. (Ji *et al.*, 1997).

According to Nafis (2001), any wrong information generated will affect the product produced by the machine. The statement highlighted the accuracy issue of the generated information after extraction and recognition process. The statement is proved to be true by Adem (2007) in his testing and by proposing Part Recognition algorithm, he has solved the problem. However, the proposed algorithm can not be applied because the algorithm only focused on a solid 3D drawing, while data use in this research is a 2D CAD manufacturing drawing which is acknowledged by the industry as a complex drawing. The problem for the industry is the unavailability of a standard template for a manufacturing drawing. Thus, the extraction process had difficulty to extract the accurate information from the drawing.

Before any detailed explanation, it is good to know the source of errors. Human behaviour is the main error contributor in the drawing. According to Huang (2008), it is impossible for human to avoid errors during designing process. The reason is based on human behaviour studies that most human cannot avoid from being careless. If the designer is careless during the drawing process there is a possibility for the designer to commit errors on the drawing especially when the designer needs to draw more than one design per day.

Another possibility to commit errors in drawing is during the translation or conversion process. According to Autodesk Inc., drawings or DXF files from other CAD applications will not open in AutoCAD because of file translation problems. This is because different CAD application or formats have different file structure.

Thus, there is a possibility that the drawings can be corrupted during the translation or conversion process because the process will change the structure and format of the drawings. As a result, the drawing might be corrupted or the drawing will contain errors such as connection changes between the entities.

According to observation, copying drawing file from storage to other storage is a common cause of the drawing files being corrupted as the drawing might be copied into a storage drive that contains damage sectors, causing the drawing to become unreadable.

After knowing the source of errors, the next phase in this research is to study and recognise the CAD drawing. According to Nafis (2001), basic CAD drawing consists of lines, vertexes and arcs. Huang (2008) had defined basic drawing such as single line consisting of two vertexes as start and end vertexes. An arc consists of middle vertex, radius and two angles defined as start and end angles at start and end vertexes of the arcs. Therefore, the extraction process is a process to extract and recognise the features contained in CAD drawing to translate it into information. The information of shapes or geometries was produced from the combination or connection or intersection between features contained in CAD drawing. However, the extraction process would fail because of errors. It is impossible for humans to avoid mistakes during the drawing process (Huang *et al.*, 2008).

Generally there are several types of errors. A gap on the connection between entities is one type of error. In this study, based on manufacturing drawings, where logically, is different from floor plan drawing. The drawing does not contain any opening part such as door or window. Basically the drawing consists of complete object or geometry. Therefore, manufacturing drawing should not contain any gap on the connection between the entities. Meanwhile other types of errors are an extension on the connection between the entities, any unnecessary symbols in the drawing and additional or redundant entities on the drawing.

There have been several solutions proposed to solve errors. The first proposed solution was enhancing the CAD features library in CAD application system. This solution has been used by Prabhu (2001) in order to remove unnecessary symbols in drawing. Implementing Minimum Spanning Tree (MST) algorithm is another solution that can be used. Huang (2008) has applied MST in order to recognise the connection between the entities. Boundary Representation (B-Rep) is also another solution that can be applied to solve the errors. This technique will recognise the boundary of the object and extract it while the unnecessary object inside the drawing will be ignored. Finally, this study had decided MST algorithm as an approach to be used to solve this error issue.

1.3 Problem Statements

Error in the drawing is an important issue that needs to be solved. Currently error in drawing was detected manually before the manufacturing operation started or after the wrong product has been produced. Therefore, this research had focused more on detecting and correcting the error by implementing Minimum Spanning Tree (MST) algorithm. The MST algorithm can not recognise error of the drawing when the object could not close.

The MST algorithm can be enhanced by using simultaneous equation and locus equation to recognise the error and do some correction. The research question is:

How to improve the MST algorithm by integrating error detection method and error correction method by implementing simultaneous equation and locus equation for 2D drawing?

1. How to define simultaneous equation and locus equation in order to detect and make a correction of the error?
2. How to develop the algorithm for detecting and correcting error in the drawing?
3. How to prove the algorithm could detect and correct errors in the drawing?

1.4 Research Aim

This research aim is to enhance the Minimum Spanning Tree (MST) algorithm to manage error in the drawing for close object.

1.5 Research Objectives

The aim is expressed in a set of specific objectives to give directions for this research. The objectives for this research study are listed as follows:

1. To define locus equation and simultaneous equation in order to detect and correct the errors for enhance MST algorithm by using vector graph.
2. To develop an algorithm for managing error in 2D drawing for close object.
3. To implement the algorithm by developing the prototype for testing and evaluation.

1.6 Research Scope

The scope of this research is as follows:

1. In order to extract CAD drawing, this research can assume that the drawing is always perfect and free from errors. In real world situation, there are many unpredictable possibilities that can happen to the drawing. Therefore, this research is focused on developing an algorithm to handle errors in 2D CAD drawing. However, this research only deals with two types of error in the drawing which is gap and extension in the connection between entities.

2. Type of data is a main factor in research. Therefore this research had focused on Drawing Exchanged Format (DXF) files. While the drawing only focus on leaf spring part which is known as a mechanical drawing. The drawing was retrieved from one of the local manufacturing industry in Malaysia.

3. Recently many approaches and methods had been proposed to extract CAD drawing and to recognise the CAD information. However, there are no approaches that really focus on errors detection in the drawing. Furthermore, most of the previous approaches focused on solid model instead of 2D drawing. In this research, the graph theory will be improved to detect errors and correction in the CAD drawing.

4. In the evaluation and testing phase, a prototype will be developed for testing and evaluation purposes. A prototype of the improvement of graph theory will be developed to manage the errors. In addition, 2D CAD drawing in the DXF files format will become the input for testing

and evaluation purposes. Finally, the result from the prototype will be compared with the previous graph theory approach that has been developed by Huang (2008) to calculate the percentage of the accuracy.

1.7 Justification and Benefits

This topic will justify the benefits of Close Spanning Tree (CST) algorithm. Currently, the algorithm will benefit the local manufacturing industry especially the leaf spring industry. Generally, the algorithm can be applied to the mechanical design industry. In research, the algorithm can be looked into and improved to increase the accuracy of error detection and correction to any file format or to decrease the processing time and make the algorithm more intelligent to detect and correct the error for any type of drawings or images.

1.8 Thesis Structure

The thesis is organized in six chapters. This chapter gives an overview of the fundamentals of CAD drawing structure and CAD drawing extraction and recognition process. The goal, objectives and the scope of the research are clearly defined.

In Chapter 2, detailed descriptions of the background study are discussed. It explains the data extraction in CAD/CAM, errors in CAD drawings, error detection and correction approaches, locus equation and simultaneous equation. Methodology of the research is discussed in chapter 3 which includes the framework of the study and other contributing factors in this research study.

Chapter 4 describes all the fundamentals or definitions used in this research. This chapter discusses how the implementation of the Close Spanning Tree (CST) algorithm which is an enhancement from the MST algorithm at designing stages in the conceptual model, logical model and physical model. This chapter also describes the loading algorithm, CAD drawing data format and visualising the algorithm as a system.

Testing is done to test the algorithm and the results of the experiments are analysed and discussed in Chapter 5. First, error detection is discussed; from the 2D CAD drawing and implementing in the testing phase. The next discussion is on the results of error correction and accuracy of geometry detection. This chapter discusses the capability of the error detection and correction by using the improved graph theory and its detection impact. Results were also compared with the previous graph theory approach develop by Huang (2008) to clarify the contribution of the research. Finally, chapter 6 concludes the thesis and suggest for the future work.