UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF INTERSECTING AND NON-INTERSECTING VOLUMETRIC FEATURE RECOGNITION TECHNIQUES IN A PLATFORM-DEPENDENT SYSTEM

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DEVELOPMENT OF INTERSECTING AND NON-INTERSECTING VOLUMETRIC FEATURE RECOGNITION TECHNIQUES IN A PLATFORM-DEPENDENT SYSTEM

By

MOHAMMAD HAYASI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the Requirements for the Degree of Master of Science

August 2008

DEDICATION

I dedicate this project to my wife who was patient most times in accompanying me in getting through this research.

ABSTRACT

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

Development of Intersecting and Non-Intersecting Volumetric Feature Recognition Techniques in a Platform-Dependent System

By

MOHAMMAD HAYASI

August 2008

Chairman: **Associate Professor Wong Shaw Voon, PhD**

Faculty: **Engineering**

The feature recognition process has been considered as the input for Computer-aided Process Planning through two different standpoints in implementation, one is nonfeature-based and the other is feature-based .The first one is done via accessing to the information of part (e.g. edges, faces,…) from within standard files with neutral data format (DXF/IGES/STEP) and then is conducted by connecting to the objects library of design-by-feature solid modeler. The second method has currently received extensive attention due to accessing to significant information effortlessly and handling intersecting and non-intersecting features. In this thesis, the feature-based design is exploited for converting design feature into manufacturing feature aimed to recognize the various intersecting and non-intersecting volumetric features. The rule-based, graph-based, and mathematical algorithms are used to recognize the intersecting and non-intersecting features with their volume. The ability and robustness of proposed methods in identifying the protrusion/subtractive features which are made on slanting/planar surfaces, is represented by implementing software on a commercial Computer-aided design package, Autodesk Inventor.

ABSTRAK

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

Pembangunan Teknik-Teknik Pengecaman Ciri-Ciri Isipadu Bersilang dan Tidak Bersilang Dalam Sistem Platform Bersandar

Oleh

MOHAMMAD HAYASI

August 2008

Pengerusi: **Profesor Madya Wong Shaw Voon, PhD**

Fakulti**: Kejuruteraan**

Proses pengecaman ciri-ciri telah dipertimbangkan sebagai input untuk perancangan proses terbantu komputer melalui dua cara pelaksanaan yang berbeza; iaitu berdasarkan ciri-ciri dan tidak berdasarkan ciri-ciri. Cara yang pertama dilaksanakan dengan mencapai maklumat bahagian (contohnya: pinggir, muka,…) daripada fail piawaian dengan format data yang neutral (DXF/IGES/STEP) selepas proses dilaksanakan dengan menyambung kepada perpustakaan objek-objek pemodel pejal rekabentuk berdasarkam ciri-ciri. Cara yang kedua pula mendapat perhatian kerana dapat mencapai maklumat yang signifikan dengan baik dan dapat menguruskan ciri-ciri bersilang dan tidak bersilang. Dalam tesis ini, rekabentuk berdasarkan ciri-ciri telah dieksploitasikan untuk menukar ciri-ciri rekabentuk kepada ciri-ciri pembuatan yang bertujuan untuk mengecam pelbagai ciri-ciri isipadu bersilang dan tidak bersilang. Algoritma-algoritma berdasarkan peraturan, graf dan matematik telah digunakan untuk mengecam ciri-ciri bersilang dan tidak bersilang dengan isipadunya. Kebolehan dan kekuatan cara yang dicadangkan dalam mengecam ciri-ciri berlebihan /berkurangan yang dibuat ke atas permukaan yang condong rata; diwakili dengan mengimplementasikan perisian ke atas pakej rekabentuk terbantu komputer, komersial, Autodesk Inventor.

ACKNOWLEDGEMENTS

First I would like to thank my supervisor Dr.Wong who his very useful guidelines throughout doing the project helped me to get through the thesis well. Without his support this work would not have been possible. I am also very grateful to my co-supervisor, Dr.Napsiah, for supporting my ideas.

APPROVAL

I certify that an Examination Committee has met on 26 August 2008 to conduct the final examination of Mohammad Hayasi on his Master of Science thesis entitled "Development of Intersecting and Non-Intersecting Volumetric Feature Recognition Techniques in a Platform-Dependent System" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

Members of the Examination Committee are as follows:

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APPROVAL

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.
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Date: 13 November 2008

DECLARATION

I declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institutions.

Mohammad Hayasi

Date:

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LIST OF ABBREVIATIONS

AAG: Attributed Adjacency Graph.

AAM: Attributed Adjacency Matrix.

API: Application Programming Interface

B-rep: Boundary Representation.

CAPP: Computer-Aided Process Planning.

CIF: Clustered Intersecting/Non-Intersecting Feature

CloseP: Closest Point

CSG: Constructive solid geometry.

DXF: Data Exchange Format.

EAAM: Extended Attributed Adjacency Matrix

ep: end point

ERD: Entity-Relationship Database

IGES: Initial Graphics Exchange Specification.

MAA: Modified Attributed Adjacency.

ob: outer boundary

RAAG: A Modified the Attributes Adjacency Graph.

rb: rectangle box

sp: start point

STEP: Standard for the Exchange of Product model data.

TAD: Tools Accessing Direction

VBA: Visual Basic for Application

RP: Rapid Prototyping

CHAPTER 1

INTRODUCTION

This chapter gives an introduction to the present research – an overview on feature recognition, dependent and independent platforms for feature recognition, the problem statement, objectives of the research, and the scope of the study. The organization of the dissertation is also presented at the end of this chapter.

1.1 An Overview on Feature Recognition

Many researches have been conducted into the integration of the CAD and the CAM to build the CIM system [1]. Feature recognition plays a significant role in facilitating this integration. A feature represents the engineering meaning or significance of the geometry of a part or assembly. A feature can be characterized as follow:

- It is a physical constituent of a part.
- It is map able to a generic shape.
- It has engineering significance.
- It has predictable properties.

The various types of features could be classified as follow:

- Form features, on the other hand, originate naturally from the reasoning processes used in various design and manufacturing activities [2] and they represent more detailed characteristics of the shape aspects of a part.

- Tolerance Features: properly product definition must not only provide a complete and unambiguous description of a product's nominal shape but must also contain non-geometric property attributes, such as tolerance specifications and functional descriptions. This information is required to successfully support advanced fabrication applications throughout the product life-cycle. To support these applications, non-geometric property attributes, called "Tolerance Features", must actually be associated with solid model entities and/or features of the solid model.
- Assembly Features: An assembly feature is defined as a generic solution referring to two groups of parts that need to be related by a relationship so as to solve a design problem. The concept of assembly feature encompasses the notions of design intent, technical function, technological solution and manufacturing process as well as it provides a justification for the use of part features.
- Functional Features: They include both the purpose of the design object such as support, stability, or strength and the behavior that the design object performs like lifting, gripping, or rotating [3].
- Material Features: Material feature is defined as the specified material distribution of a certain region within heterogeneous solid.

Note that the form features are taken into account in this research. Creating an understandable language (feature) for integrating CAD/CAM is considered to be a vital activity in the industry. Subsequently, many efforts have been successful in interpreting the CAD data for extracting some local shapes within either a predefined taxonomy or un-predefined volumetric shapes. The extraction of these shapes, also called features, is classified into two parts: non-intersecting and intersecting.

1.2Feature Recognition in Platform-Dependent and Platform-Independent Area

Many algorithms and methods have contributed to the intersecting/ non-intersecting features recognition. Generally speaking, feature recognition methods have been implemented in either platform-dependent or platform-independent areas. An platform-independent area is where the design data (topology and geometry information of a part) existing in files with neutral format file (DXF/IGES/STEP) are accessed through programming language, such as C++, VB, etc. while the other is where the direct access of part information provided within a design-by-feature solid modeler is done. Even though utilization of tools in the platform-dependent area is costly, but their many benefits could overcome its various drawbacks. These include:

- easy access to the vast objects library of design features;
- obtaining and comprehensively organizing the geometry and topology entities of parts as object-oriented and organized;
- And exploiting the built-in functions (API) from within the solid modeler in order to facilitate the application of the feature recognition rules.

It has been become evident that the development of tools in the platform-independent area could not be completed successfully due to indirect conversion of features into manufacturing information. On the contrary, in the platform-dependent area the feature-based information along with strength embedded functions are well-organized and could pave the way for feature recognition and provide assistance in solving problems which are still difficult to handle. Figure 1.1 schematically highlighted the comparison mentioned above at present section 1.2. In terms of design data conversion into manufacturing aiming to recognize the features, as seen in Figure 1.1(a), the data conversion process in the platform-independent area is required taking more steps using the existing approaches (e.g. rule-based , neural networks, hint-based,…). On the contrary, as seen in Figure 1.1(b), the steps for accessing to initial design data are eliminated using the facilities, such as built-in functions and numerous useful object data, provided by that platform. All the approaches which are employed in the platform-independent area are also considered to be implemented in the platform-dependent area too.

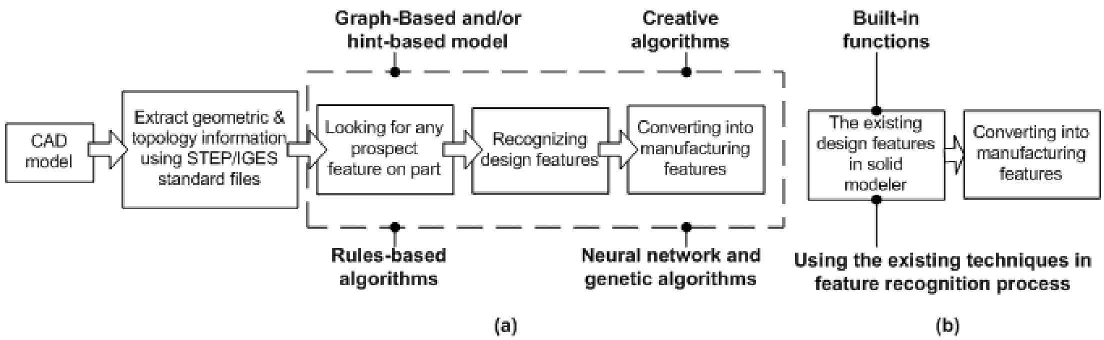

Figure 1.1: Comparison of the efficiency between two different viewpoints in feature recognition a) Feature recognition process using platform-independent tools b) Feature recognition process using platform-dependent tools

1.3 Problem Statement

As resulted from comparison for feature recognition in platform-independent and platform-dependent areas in section 1.2, the robust tools provided in platform-dependent area encourage researches to employ the comprehensive tools within this area in order to recognize the features. However, fact that majority of the works on feature recognition in the platform-dependent area, have been focused on design-driven approach to extract a feature shape which is used in the manufacturing activities. In design-driven approach basically a profile of a design feature, namely a closed loop of the entities, such as line, circle, ellipse, and etc., is analyzed for recognizing a feature shape. For example, a work of Lee and Kim [4] extracted machining features from a feature-based design model, which was based on an integrated geometric modeling system that supported both feature-based modeling and features. In this approach, the system was capable of handling the majority of complex features, but because of the high dependence on the design-driven approach, it was not successful in designing the feature of a part from different viewpoints. The other work in the platform-dependent area was presented by Woo [5]. He proposed a system for recognizing a set of machining (or maximal) features in a designed part. This was done by decomposing the delta volume, which was the difference between the stock and the part.

Li et al. [6] proposed a methodology for recognizing manufacturing features from a design feature model by using the design-by-feature solid modeler. They reported analyses of design features in the form of a 2D profile for conversion into manufacturing features. The limitations of their work was in creating a complex 2D profile and extending it in its extrusion direction for showing out another complex un-designed feature and changing the initial profile of the design feature during the extension. Sadiah [7] identified the feature as the input for the CAPP. This system records feature information of models that are designed in SolidWork solid modeler. In this research, the designer's interaction with the solid modeler was reflected into a text file. This could be unacceptable when there are different designing scenarios. Considering the profile alone may not be the unique way which could contribute in identifying these features. This is because a designer may create a 2D sketch on a surface where some basic entities such as lines stay out of the profile boundary which belongs to the design feature. The intersection between design features in different directions may also result a feature(s) whose profile was completely changed. As resulted from the literature, analyzing the design features of a part model through their profiles called "design-driven approach", in order to recognize the manufacturing features, could not always become a successful approach. Thus, to fill the gap, which happened in platform-dependent area using design-driven approach, the vast usage of tools existing in the platform-dependent area along with the hybrid algorithms could be acceptable approach for the feature recognition process in the platform-dependent area.

1.4 Objectives

The major objective of this research is to convert design data into manufacturing information in a platform-dependent area using the rule-based, graph-based, and mathematical algorithms. The conversion of design data into manufacturing information is aimed to first recognize non-intersecting manufacturing features, and then recognize intersecting manufacturing features.

1.5 The Scope of the Study

In this study prismatic parts are taken into consideration for feature recognition purpose. Based on the approach proposed in this thesis, firstly, non-intersecting manufacturing features, such as hole, blind hole, counterbore, countersink, slot, blind slot, step, blind step, pocket, blind pocket, fillet, chamfer, and corner notch are recognized. Secondly, non-freeform orthogonal intersecting manufacturing features are identified.

1.6 Thesis Overview

This thesis is organized into five parts, as shown in Figure 1.2:

Part I: (Chapters 1-2) Introduction and literature review

- Chapter 1 introduces the background, problem statement, objectives of the research, and the scope of the study.
- Chapter 2 takes the various feature recognition into consideration and gives a review of earlier studies on feature recognition in both platform-dependent and platform-independent area. The existing state-of-the-art has been compared and summarized according to their applied methods.

Part II: (Chapters 3) applied methodologies in recognizing the features

- Section 3.1 gives a perspective of the approaches used in recognizing the features. Section 3.2 describes the technology used in implementing the methods used in thesis and section 3.3 deals with taxonomy of features, which fit with the desired output.
- Section 3.4 discusses the reasons why we should eliminate the fillet(s)/chamfer(s) features at the beginning of feature recognition process.
- In section 3.5 the benefits of clustering intersecting and non-intersecting design feature into groups as separately is first discussed then dedicated approach is introduced.
- Sections 3.6.1, 3.6.2, and 3.6.3 present the applied rules-based methods and algorithms for identifying the diversity of non-intersecting form features and converting them into volumetric features.

- In section 3.6.4 a new method in converting a complicated through-pocket feature into volumetric and identifying is introduced.
- Section 3.7 introduces a new methodology for identifying orthogonal intersecting features.
- Section 3.8 and 3.9 deal with the implementation of the approaches and the representation of the system architecture that exploited for entire system.

Part III: (Chapter 4) the achieved results in study

- Section 4.1 Sample Part for Testing the Algorithms.
- From section 4.2 through section 4.7 is chiefly highlighted the results achieved by running the software whose output is demonstrated for further clarification and discussed the achievements.
- Section 4.8 discusses about the results and explains the use of achieved results.

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Part IV: (Chapter 5) conclusion.

Part V: Reference and appendixes.

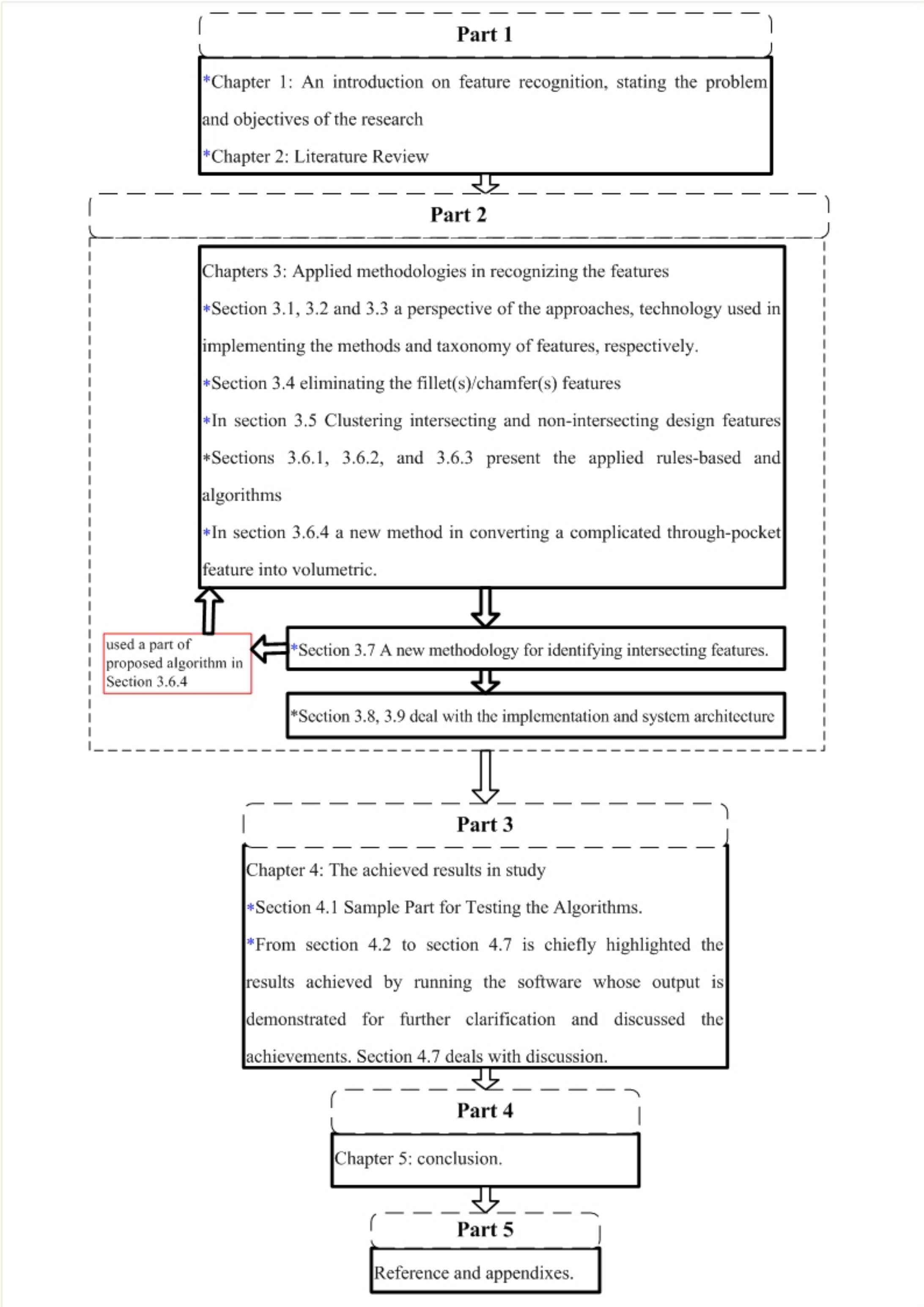

Figure 1.2: Diagram of thesis overview