UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF HOLE RECOGNITION SYSTEM USING RULE-BASED TECHNIQUE

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By

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This work is dedicated to my beloved parents, brother and sisters

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

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Chairperson: Napsiah Ismail, Ph.D.

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The effective integration of CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) is a cornerstone of automation progress. The 'islands of automation' such as CAD, CAPP (Computer Aided Process Planning) and CAM are facing the ineffective communication problem. The CAM cannot be integrated directly into CAD due to the lower level geometrical data in CAD and the higher level manufacturing data in CAM. It is important that each 'island of automation' be linked together in order to achieve the goal of integrated CAD/CAM systems. For the past decades, feature-based representation has become a basic part of research in the CAD/CAM integration. The work on feature-based modelling has developed two main approaches, namely, design by features and feature recognition. The feature recognition approach is developed to extract the manufacturing information that is recognized from the CAD database into the CAM database. The features can be used to subtract higher level manufacturing data from lower level or geometrical computer aided data. The Hole Recognition System is developed to solve the communication problem between CAD and CAM. Kappa-PC

expert system is used in developing the rule of holes. In this work, the Hole Recognition System is retrieves the geometrical data from the UniGraphics (UG) CAD/CAM system indirectly. The Hole Recognition System is designed to generalise and recognise the feature from neutral format file such as Data Exchange File (DXF), Initial Graphics Exchange Specification (IGES) and Standard for the Exchange of Product Model Data (STEP). The neutral format file can be created by CAD/CAM system such as UG, CATIA, ProEngineer, etc. For this work, the neutral data transfer standards, namely STEP is used. The STEP file is post processed by UG CAD/CAM system after the solid model has been created. A filtering program is developed to extract the geometrical data feature recognition process. The filtering program has been developed because the Kappa-PC expert system cannot read the STEP file directly. The output from the filtering program is fed to the Hole Recognition System. The rule-based technique is applied to recognise holes. There are two features, namely, blind hole and through hole to be considered. The work presented in this thesis and the Hole Recognition System developed is able to overcome the communication problem in CAD/CAM. The output from the Hole Recognition System is useful for multiple downstream manufacturing activities such as machine tool selection and cutting tool selection.

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

PEMBANGUNAN SISTEM PENGECAMAN LUBANG MENGGUNAKAN TEKNIK BERDASARKAN PERATURAN

Oleh

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Pengerusi: **Napsiah Ismail, Ph.D.**

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Keberkesanan integrasi di antara rekabentuk berbantu komputer dengan pembuatan berbantu komputer adalah sebagai batu loncatan pada kemajuan pengautomatan. 'Kepulauan pengautomatan' seperti rekabentuk berbantu komputer, perancangan proses berbantu komputer dan pembuatan berbantu komputer menghadapi masalah komunikasi. Pembuatan berbantu komputer tidak dapat berintegrasi dengan Rekabentuk berbantu komputer disebabkan oleh rekabentuk berbantu komputer mengandungi tahap data geometri yang rendah dan data pembuatan yang bertahap tinggi dalam Pembuatan berbantu komputer. Ia adalah penting bahawa setiap pulau pengautomatan berhubung di antara satu sama lain untuk mencapai objektif sistem rekabentuk berbantu komputer/pembuatan berbantu komputer. Untuk sepuluh tahun yang lepas, perwakilan yang berdasarkan bentuk telah menjadi asas penyelidikan dalam integrasi di antara rekabentuk berbantu komputer dan pembuatan berbantu komputer. Kerja yang dijalankan terhadap permodelan berdasarkan bentuk telah membangunkan dua modul yang penting iaitu rekabentuk dengan bentuk dan pengecaman bentuk. Pengecaman bentuk dibangunkan untuk mendapatkan informasi yang diperlukan dalam pembuatan

dari pengkalan data rekabentuk berbantu komputer dan dimasukkan ke dalam pengkalan data pembuatan berbantu komputer. Bentuk boleh digunakan untuk mendapatkan data pembuatan yang bertahap tinggi daripada data geometri berbantu komputer. Sistem pengecaman lubang dibangunkan untuk menyelesaikan masalah komunikasi di antara rekabentuk berbantu komputer dan pembuatan berbantu komputer. Sistem pakar Kappa-PC digunakan dalam pembangunan peraturan untuk lubang. Dalam kerja tersebut, sistem pengecaman lubang mendapatkan data geometri secara tidak langsung dari sistem rekabentuk berbantu komputer/pembuatan berbantu komputer UniGraphics (UG). Sistem pengecaman lubang direka secara kepelbagaian dan mengecam bentuk dari fail berformat neutral seperti DXF, IGES dan STEP. Fail berformat neutral dapat dihasil oleh sistem rekabentuk berbantu komputer dan pembuatan berbantu komputer seperti UG, CATIA dan ProEngineer. Untuk kerja tersebut, piawaian pemindahan data neutral yang bernama STEP adalah digunakan. STEP adalah diproses oleh sistem rekabentuk berbantu komputer dan pembuatan berbantu komputer UG setelah model yang jitu dihasilkan. Satu aturcara penapisan dibangunakan untuk mendapatkan data geometri yang diperlukan oleh proses pengecaman bentuk. Aturcara penapisan adalah dibangunkan sebab sistem pakar Kappa-PC tidak dapat menbaca STEP secara langsung. Keluaran dari aturcara penapisan akan dimasukkan ke dalam sistem pengecaman lubang. Teknik berdasarkan peraturan digunakan untuk mengecam lubang. Terdapat dua bentuk iaitu lubang tidak tembus dan lubang tembus diimplementasi dalam sistem pengecaman bentuk. Kerja yang dibentangkan dalam tesis tersebut dan sistem pengecaman bentuk yang dibangunkan dapat menyelesaikan masalah komunikasi dalam rekabentuk berbantu komputer dan pembuatan berbantu komputer. Keluaran dari sistem pengecaman lubang adalah berguna untuk pelbagai aktiviti pembuatan bawahan seperti perancangan proses berbantu komputer.

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I certify that an Examination Committee met on 13th November 2001 to conduct the final examination of Tan Chee Fai on his Master of Science thesis entitled "Development of Hole Recognition System Using Rule-Based Technique" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

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

Name: Tan Chee Fai
Date: 26/11/2001

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AFNOR	: French national standards body
AI	: Artificial Intelligent
API	: Application Protocols
ASVP	: Alternating Sum of Volumes with Partitioning
B-rep	: Boundary Representation
CAD	: Computer-Aided Design
CAD/CAM	: Computer-Aided Design/Computer-Aided Manufacturing
CADD	: Computer-Aided Design Database
CAE	: Computer-Aided Engineering
CAM	: Compute-Aided Manufacturing
CAPP	: Computer-Aided Process Planning
CAQC	: Computer-Aided Quality Control
CIM	: Computer Integrated Manufacturing
CSG	: Constructive Solid Geometry
EBC	: Edge Boundary Classification
ES	: Expert System
FFRS	: Form Feature Recognition System
GUI	: Graphical User Interface
HRS	: Hole Recognition System
IGES	: Initial Graphics Exchange Specification
IPO	: IGES/PDES Organization
ISO	: International Standardization Organization
NC	: Numerical Control
OEM	: Original Equipment Manufacturers
OOP	: Object-Oriented Programming
SDAI	: Standard Data Access Interface
SET	: Standard d'Echange et de Transfert
STEP	: Standard for the Exchange of Product Model Data
UG	: UniGraphics
VDA/FS	: Verband der Automobilindutrie-Flachen-Schnittstella

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the new millennium, computer-aided engineering will focus on its original objective, the integration of engineering functions and in particular, the co-ordinating function of manufacturing engineering. Engineering and its associated technologies are necessity evolving into a production support function, in which internal customers represent the end user in terms of quality (ease of manufacture), cost (robust designs and processes), and delivery (efficient communication) (Hetem, 2000).

There are various technologies that have been developed for manufacturing companies for the purpose of continuous improvement in product performance and quality. The low cost of computer and the development of software technologies enable the development of intelligent systems especially in design and manufacturing. Computers are essential tools for engineers. It will enhance human abilities to bring better and more cost effective products to market quickly and effectively (Regli, 1995).

The development of computer technology in conjunction with software technology has made computer-aided system and automation readily available. Computer aided systems that are being used today include Computer-Aided Design (CAD), Compute-

Aided Manufacturing (CAM), Computer-Aided Engineering (CAE), Computer-Aided Process Planning (CAPP) and Computer-Aided Quality Control (CAQC).

Effective communication is a cornerstone of human progress. While technology strives to make our lives easier, it also has the reverse effect due to ineffective communication. Computer systems such as CAD, CAPP and CAM are classified as 'islands of automation' and it is important that each system linked together to achieve information exchange without taking into consideration the dissimilar formats being used by various systems (Lau et al., 1998).

The integration of CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) is the important aspects for automation system. The CAD/CAM integration leads to Computer Integrated Manufacturing (CIM) where this is a primary system in realising the development of agile manufacturing, concurrent engineering, information technology and production processes. The CIM system is the automated computer system for the whole manufacturing processes. Basically, a CIM system includes CAD, CAM and CAPP (Yan et al., 2000).

Advancement in design efficiency can be achieved using feature-based design approach. Feature-based product modelling is a concept and technique that has gained a large number of commercial advocates in CAD/CAM development since the late 1980s. A complete product description consist of various feature types, e.g. form features, tolerance features, assembly features, functional features and material features. A complete product definition can be created using the feature-based

approach to provide an intuitive design environment for engineers (Trappey et al., 2000).

In conjunction with the feature-based model, the feature recognition approach has been developed. The feature recognition process is a bridge between CAD and CAM. The feature recognition approach is used to extract the information that is needed in the manufacturing from the CAD database. The goal of feature recognition is to succeed the design activity by converting the CAD model into CAM model where it contains the complete semantic part information based on features that required by CIM system.

1.2 Problem Statement

There are many researches being done to integrate the design and manufacturing functions in CAD/CAM systems through information sharing. The major obstacle for this integration is the incompatible data and information maintained by each system to support its requirements. The CAM system cannot comprehend the language of The CAD system thus making information sharing difficult (Ismail, 1998). In conjunction with communication problem between the CAD and the CAM systems, the feature based modelling approach has been developed. One of the key elements in feature-based approach is the feature recognition. The feature recognition approach can be used as a bridge between the CAD and the CAM. The feature recognition system can be developed to identify the manufacturing data either direct from CAD system or from neutral file format such as STEP (Standard for the

Exchange of Product Model Data). The majority of the products have several holes features. Holes are used either for assembly with fasteners or to provide access inside a part. The hole making is among the most important operations in manufacturing (Kalpakjian, 1995). Hole is one of the simplest features to be recognized. Thus hole recognition is chosen as the initial step to be developed for CAD and CAM integration.

1.3 Research Objectives

The main objectives of the project reported in this thesis are:

(i) To develop feature recognition algorithm using rule-based technique.

(ii) To develop a Hole Recognition System.

1.4 Thesis Outline

Chapter One discusses the background of the research, the objectives and how the thesis is organised. It outlines in brief the scenario leading to the necessity for carrying out this research.

In Chapter Two, the definitions of feature and form feature are described. Beside that, the feature-based modelling that consists of design by feature and feature recognition also being described. The different approach of feature recognition from CSG models and B-rep models also highlighted in this chapter. After that, the neutral

format file exchange and standard for the exchange of product model data (STEP) are described. The Kappa-PC expert system also described in this chapter.

In Chapter Three, it describes the methodology of the project. The chapter describes the method of the development of the Hole Recognition System (HRS).

In Chapter Four, it describes the development of the filtering program and the result from the filtering program.

In Chapter Five, the development of the Hole Recognition System is described. The architecture of the Hole Recognition System also described in this chapter.

In Chapter Six, the discussions of the result for Hole Recognition System and the verification of the HRS are highlighted.

In Chapter Five, it is the conclusion of the project. At the same chapter, a list of recommendation of the project is highlighted.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the feature and form features in general. Then, the application that is related to the feature, namely feature-based modelling is described. The two types of feature recognition approach are described in the next section. After that, the neutral format file exchange especially the STEP file is described in detail. In the last section, the information about the Kappa-PC expert system is described.

2.2 The Definitions of Feature

The features have many definitions and there is no consensus on a common definition. The term feature is derived from the Latin word "facture" which means the act of making or formation" (CAM-I, 1981).

Abdalla (1994) defines a feature is an entity or geometric form. Its attributes (dimensions, shape, etc.) are very important for various industrial functions, such as analysis, evaluation, and process planning. The feature attributes must be represented explicitly in terms of forms that match available manufacturing knowledge.