MACHINING FEATURE-BASED SYSTEM FOR SUPPORTING STEP-COMPLIANT MILLING PROCESS

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For my beloved my father, mother, wife, daughter, family, supervisor and friends.

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ABSTRACT

STEP standards aims at setting up a standard description method for product data and providing a neutral exchanging mechanism that is independent of all the information processing systems for product information model. STEP Part 21 is the first implementation method from EXPRESS language and implemented successfully in CAD data. However, this text file consists of purely geometrical and topological data is hardly to be applied in machining process planning which requires machining features enriched data. The aim of this research is developing a new methodology to translate the EXPRESS language model of CAD STEP data into a new product data representation and enriched in machining features which is more beneficial to machining process planning. In this research, a target Database Management System (DBMS) was proposed for developing this system by using its fourth-generation tools that allow rapid development of applications through the provision of nonprocedural query language, reports generators, form generators, graphics generators, and application generators. The use of fourth-generation tools can improve productivity significantly and produce program that are easier to maintain. From this research, a new product data representation in a compact new table format is generated. Then this new product data representation has gone through a series of data enrichment process, such as normal face direction generation, edge convexity/concavity determination and machining features with transition feature recognition. Lastly, this new enriched product data representation is verified by generating to a new STEP standard data format which is according to ISO1030-224 standard format and providing an important part of solution for supporting STEP-compliant process planning and applications in milling process.

ABSTRAK

Tujuan STEP adalah berfungsi sebagai kaedah deskripsi piawaian kepada data produk dan juga menyediakan mekanisma neutral penukaran yang bebas daripada semua jenis sistem pemprosesan maklumat informasi model produk. STEP Part 21 merupakan kaedah pelaksanaan pertama daripada bahasa EXPRESS dan berjaya dilaksanakan dalam data CAD. Walau bagaimanapun, fail teks ini adalah sukar untuk dimanfaatkan dalam proses pembuatan lain kerana kandungannya hanya terdiri daripada data geometri an topologi sahaja. Dalam kajian ini, satu sistem pangkalan data telah dicadangkan untuk menterjemahkan model bahasa EXPRESS CAD STEP data kepada satu sistem pangkalan produk baru dengan menggunakan peralatan penjanaan generasi keempat yang cepat dalam pembangunan aplikasi melalui bahasa query nonprocedural, penjanaan laporan, penjanaan form, penjanaan aplikasi. Penggunaan peralatan penjanaan generasi keempat ini mampu meningkatkan produktiviti dan menghasilkan program yang senang diuruskan. Seterusnya, satu jadual data produk dapat dijana daripada sistem pangkalan data dan ia berguna dalam membantu mengintegrasikan CAD/CAPP/CAM, terutama dalam proses pengesanan maklumat berciri pemesinan secara automatik yang melibatkan langkah ekstrak maklumat bercirikan geometri daripada model STEP CAD, perwakilan bahagian dalam format pangkalan data, dan penentuan algoritma untuk pengenalan maklumat berciri mesin. Kajian ini telah menguji kesahihan dan ketepatan sistem pangkalan data baru ini melalui pelaksanaan penterjemahan file CAD STEP Part 21 daripada sistem CAD komersial kepada produk sistem pengkalan data format, pengayaan data, penjanaan jadual data produk baru, pelaksanaan pengesanan maklumat berciri pemesinan secara automatik, dan akhir sekali, penjanaan data STEP baru mengikut AP224 format yang berguna dalam perancangan proses dan aplikasi pembuatan yang berasaskan STEP. Kesemua ini telah diuji melalui kajian kes.

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LIST OF ABBREVIATIONS

AFR	-	Automatic Feature Recognition
ANSI	-	American National Standard Institute
API	-	Application Programming Interface
B-rep	-	Boundary-representation
CAD	-	Computer aided design
CADD	-	Computer aided design and drafting
CAE	-	Computer aided engineering
CE	-	Concurrent engineering
CATD	-	Computer aided tool design
CAP	-	Computer aided planning
CAPP	-	Computer aided process planning
CIM	-	Computer Integrated Manufacturing
CSG	-	Constructive Solid Geometry
DBMS	-	Database Management System
DDL	-	Data Definition Language
DXF	-	Data eXchange File
DML	-	Data Manipulation Language
ENIAC	-	Electronic Numerical Integrator and Computer
EBFs	-	Edge Blend Faces
FBD	-	Feature-Based Design
FEM	-	Finite Element Method
FTP	-	File Transfer Protocol
FTP	-	File Transfer Protocol
GPPE	-	Generative Process Planning Environment
HTTP	-	Hyper Text Transfer Protocol
IGES	-	Initial Graphics Exchange Standard

ISO	-	International Organisation for Standardisation
IT	-	Information Technology
MS	-	Microsoft
NC	-	Numerical Control
PDES	-	Product Data Exchange Specifications
RAMP	-	Rapid Acquisition of Manufactured Part
RDMS	-	Relational database management system
SCRA	-	South Caroline Research Authority
SDAI	-	STEP Data Access Interface
STEP	-	Standard for an exchange of product data
SQL	-	Structured Query Language
TADs	-	Tool Access Direction
QBE	-	Query-By-Example
VBFs	-	vertex BFs
2D	-	two-dimensional
3D	-	three-dimensional

CHAPTER 1

INTRODUCTION

This chapter discusses about the background of computer application in manufacturing, problem statement, objectives, scopes of research, and thesis structure outline.

1.1 Background of research

The first computer named Electronic Numerical Integrator and Computer (ENIAC) was conceived, designed, and built in 1946 at the University of Pennsylvania's Moore School of Electrical Engineering. Since then, the use of computer in manufacturing is significant and its impact on almost all walks of our lives has been readily recognizable [1]. Computers have been playing an important role for the modern manufacturing industries that exist today. Indeed, applications of computer have been found in the entire spectrum of the product development process, ranging from conceptual design to product realization and even recycling [1].

One of the issue have to solve in a heterogeneous computer system environment is data interoperability. To achieve interoperability and product data sharing/exchanging within CAD/CAPP/CAM, there are two broad categories of approaches, data-centric approach and process-centric approach. With a data-centric approach, all software applications use the same data syntax to achieve integration, whereas with a process-centric approach, integration is achieved at the process level with multiple data format allowed. In data-centric approaches, software vendors have to use a number of methods, e.g. use of propriety data format, neutral data format and international standard formats.

In data-centric approaches, data exchange not only between CAD packages but also between CAD, CAPP, and CAM systems can be effectively done through a neutral standard format. Among many data exchange formats developed, Drawing Transfer File (DXF), Initial Graphics Exchange Standard (IGES) [2] and Standard for the Exchange of Product (STEP) [3] model data are the most widely accepted. In contrast to DXF and IGES, STEP is aimed to define a standard file that includes all information necessary to describe a product from design to production. It supports multiple application domains, for instance, mechanical engineering, electronics, architecture. STEP AP224, mechanical part definition for process planning using machining features, contains all of the information needed to manufacture the required part, including materials, part geometry, dimensions and tolerances, applicable notes and specifications, and administrative information [4].

The STEP standard was initially designed to offer a neutral data exchange method in replacement of IGES. The two APs that have been established to mainly support design data exchanging and sharing are the AP for configuration controlled 3D designs of mechanical parts and assemblies (AP 203) (ISO 10303-203, 1994), and AP for the core data for automotive mechanical design processes (AP 214) (ISO 10303-214, 1994). Currently, most of the commercial CAD systems can output STEP AP 203 and/or AP 214 files via STEP translators. STEP is used as a neutral format to exchange wireframe and surface data between commonly used commercial CAD systems, it fares better than IGES. This indicates that STEP is ready to replace IGES. However, the STEP standard is much more than a neutral data format that translates geometrical data between CAD systems. The ultimate goal of STEP is provide a complete computer-interpretable product data format, so that users can integrate business and technical data to support the whole product life cycle: design, analysis, manufacturing, sales and customer services.

By implementing STEP AP-203 and STEP AP-214 within CAD systems, data exchange barriers are removed in a heterogeneous design environment. Yet data exchange problems between CAD, CAPP, CAM and CNC systems remain unsolved [5]. CAD systems are designed to describe the geometry of a part precisely. CAPP/CAM systems, on the other hand, focus on using computer systems to generate plans and control the manufacturing operations according to the geometrical information present in a CAD model and the existing resources on the shop-floor. According to Kretz et al. [6], there is a necessary to innovate the product design under the focus of automated process planning and an efficient product development. Relating to this, application protocol (AP) 224 has the potential as the missing solution for integrating the product life cycle.

Qin et al. [7] have also done a research on the status, comparison, and issues of computer-aided design model data exchange methods based on standardized neutral files and web ontology language file. They have mentioned on the well-known problem of STEP AP 203/ AP 214 neutral file-based exchange method is that this method is limited to exchange geometric data, where those nongeometric data related to design intent, such as construction history, constraint, and feature, are completely lost after exchange. Hedberg et al. [8] explored a concept called the lifecycle information framework and technology (LIFT) to develop and integrate technology and standards to enable a novel and straight forward product life-cycle management.

Meanwhile, Xu [1] reported that CAD does little in helping a designer in a more creative and intuitive way such as generation of possible design solutions, or in those aspects that involve complex reasoning about the design. For example in assessing, by visual examination of drawing, whether a component may be made easily, or whether it matches the specifications. In practicing concurrent engineering, there is a pressing need for CAD systems to interface or integrate design with all the down-stream activities, e.g. manufacturing and marketing.

1.2 Problem statement

Although there are already 22 application protocols of STEP has been rated as international standard [9], only a few protocols are established in practice. Kretz et al. [6] have analyzed different CAD systems like Autodesk Inventor, CATIA and Part Solutions. The results were sobering. STEP is mostly associated with AP 203 because it is regularly supported by leading CAD vendors. AP 203 contains a pure boundary representation and does not satisfy our needs. The problem can be explained with its strong specialization and the long term development of this protocol and not established in practice [6]. The first major challenge in STEP-based manufacturing system is to establish a concurrent engineering environment across all manufacturing activities. A key element in this environment is feature which allows integration between CAD (as in AP203) and CAPP (as in AP224 and AP238) data.

However, recognizing AP224 features from an AP203 model is still being research [10]. Based on previous research, there are only a few limited simple features have been explored but none of them concentrates on converting complex features of AP203 to AP224 [10]. Some methods have been implemented in feature recognition concepts by other researchers. Those who have implemented ideas have focused either on internal approach by focusing on native CAD data or direct using programming language C, C++ or FORTRON for writing feature recognition algorithm or even neglected the importance of interacting features and transition features like chamfers and fillets.

Although EXPRESS is a powerful object-oriented data modal descriptive language for STEP standard and independent of any platform, it is a kind of descriptive language rather than a programming language. This brings difficulty to implement the EXPRESS data model on a computer and it also undoubtedly brings a big problem with the STEP data model processing so that EXPRESS language model has to be translated into a certain programming language model. STEP Part 21 is the first implementation method and implemented successfully in CAD data. However, this text file is hardly to be applied in manufacturing processes since it consists of purely geometrical and topological data. Whereas, manufacturing process requires more machining feature-based data.

In this research, an external and more generic approach have been adopted by taking CAD STEP Part 21 file as the object of research, and convert this data to a new and enriched product data table before applying QBE (query-by-example), a nonprocedural database language to retrieve important information for machining feature recognition. All those advantages could be gained from current database systems. Besides that, transition features and compound features are included in machining feature recognition module of this system.

Database Management System (DBMS) was proposed for developing this system by using its fourth-generation tools that allow rapid development of applications through the provision of nonprocedural query language, reports generators, form generators, graphics generators, and application generators. The use of fourth-generation tools can improve productivity significantly and produce program that are easier to maintain. Thus, this is timely to develop a new product database system which is able to extend the application of CAD STEP Part 21 file data to downstream manufacturing processes by generating important information for computer aided process planning (CAPP) and generating new STEP Part 21 file according to ISO10303-224 standard format. In this research, a new product database system model was developed to translate the EXPRESS language model of CAD STEP Part 21 data to a database format with a nonprocedural approach. Within the newly developed product database system, a nonprocedural approach of data enrichment is implemented and subsequently a new product data table is generated. This newly generated product data table is useful in providing an important part of solution for the interrelated tasks of STEP based total integration between CAD/CAPP/CAM, especially used in automated machining feature recognition and process planning.

1.3 Objectives

At the end of this research, there are several objectives have been set to be achieved. The objectives are as follows:

i. To develop a product database system which could extract geometric and topological data from CAD STEP Part 21 file automatically.
ii. To propose an algorithm which could conduct a series of data enrichment processes for generating a new enriched product data representation, preparing for simple and compound machining features with edge blend features recognition automatically.
iii. To propose an efficient algorithm for simple and compound machining features with edge blend features recognition automatically.
iv. To verify the machining features enriched product data representation by generating in a new STEP Part 21 file according to ISO 10303 AP224 standard format.

1.4 Scopes of research

The scopes of this research are:

i. CAD STEP Part 21 file is selected as input for a product database system development.

ii. A series of data enrichment process and feature recognition processes conducted by the developed product database system which is beneficial to milling process.

iii. A new STEP Part 21 file is generated from the developed product database system which is according to ISO10303-224 format.

iv. Microsoft Access is the tool that used for building the product database system and mechanism for manufacturing feature extraction and recognition process.

1.5 Thesis structure outline

This thesis is a documentary to deliver the generated idea, the concepts applied, the research result and discussion. The thesis consists of five chapters. A brief summary of each chapter is organized as follows:

Chapter 1 discusses about background of the research, objectives, problem statement, scopes of work and thesis outline.

Chapter 2 contains literature review about the applications of computer in industrial manufacturing, feature technology, manufacturing feature recognition, and background of STEP and a need for effective database. Additionally, this chapter also includes the recent research in feature recognition technology from year 2002 until 2017 and researchers view on this research.

Chapter 3 contains project methodology. The design flow and construction of the project is introduced. It gives brief description about each procedure in completing the project. This chapter includes a list and approaches used in the project. It details the method to design a product database system for CAD STEP Part 21 data extraction from express entities. Furthermore, this chapter also would discuss more detail in product database design, database systems, mapping CAD STEP Part 21 data to Microsoft Access, design of express entity database, data enrichment and finally, generating a new complete product data table.

Chapter 4 propose a new methodology of machining feature recognition from newly generated product data representation in table format. This chapter also shows the important of QBE method, which not only shows its query programming, but every query is accompanied with its result.

Chapter 5 concentrates on the details of the developed product database system by showing its implementation processes, running with samples of CAD STEP files. The result is analysed and discussed.

Finally, Chapter 6 presents the conclusion and recommendations. Significant of research obtained from previous chapters are summarized. The possibilities for future directions are discussed.

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