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Interoperable STEP-NC Enabled Process Planning for Intelligent Machining

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Abstract. As the next generation of CNC standard, STEP-NC can be used to solve the current problem of information integration in digital manufacturing. With the characteristic of the STEP-NC data structure, the key technologies to approach the process planning by workingstep features based on STEP-NC are studied. Geometric information translating, feature information extraction, process planning, STEP-NC file generating are all involved. The detail of the lexical analysis of the AP203 files, the operating of the geometric information database and the translating from AP203 to geometric information database are studied. Applied the STEP-NC enabled technology, the system of process planning by features is established. The conclusion is useful for 3D process planning and the intelligent machining. The interoperable and integrated information between CAD/CAM is reached.

Introduction

The intelligent machining is the physical base of the intelligent manufacturing. To fix effectively and manipulate virtually the machining procedure, the intelligent manufacturing must know all the information of the part to be machined. But CNC programs with the traditional G, M code was the program with on/off controlling, and oriented to motion. The program was lack of the corresponding information so that makes it become the bottleneck of the CNC intelligent machining [2]. To resolve the problem, the ISO 14649, a data model name STEP-NC (Standard for the Exchange of Product Model Data-compliant Numerical Control data interface) was developed as the next generation of CNC standard. It extended STEP standard to the rock-bottom equipment of the automation manufacturing [1]. STEP-NC is a new data model, which can be translated between CAD/CAM and CNC, so as to establish a complete high way for the manufacturing network [2~4]. It provides a valid way to reach the intelligent machining and intelligent manufacturing. STEP-NC applies the object-oriented conception of "workingstep", not the machine tool's motion, to decide the process planning., to overcome the drawback of ISO 6983. The "workingstep" is corresponding to the high-level machining feature and its parameters and the CNC system will translate the "workingstep" into the axis's motions and the tool's manipulate.

Previous Work

The representative research projects on STEP-NC are the European STEP-NC project (1991), the American Super Modal (2002), the Japanese Digital Master, and so on. There are organizations such as the NRL-SNT（Nationl Research Lab for step NC Technology）of POHANG Science and Technology University in Korea, the IMRC of BATH and Loughborough University in UK, University of Stuttgart in Germany, AIST in Japan, etc.

X. W. XU and S. T. NEWMAN presented a comprehensive review of STEP-NC developments for a range of CNC processes [2]. In Germany, STEP compliant CAPP/CAM systems and NC controllers was developed and implemented. Two German institutes--ISW in Stuttgart and WZL RWTH in Aachen, and a CNC system vendor, Siemens--have been the main players in the European STEP-NC

project. A prototype system named STEPturn has been developed at ISW (Storr and Heusinger 2002). This adopts STEP and STEP-NC standards for turned parts. Generally speaking, STEPturn is a CAPP system bridging CAD and CAM. STEPturn first reads geometry data from a STEP AP-203 Part 21 file and then performs normal process-planning tasks such as feature recognition and Workingstep sequencing in order to generate a STEP-NC physical file.

Architecture of the Process Planning System with STEP-NC Features

According to STEP-NC standard, to realize the process planning, the part model established in CAD system must be saved as STEP neutral format file. Currently the major output file is AP-203/AP214 (3D geometry) file or AP-224 (feature) file. As shown in Fig.1, before process planning, the model's geometry and process information will be extracted and translated by reading and scanning every paragraph of the STEP file. STEP-NC program is expressed by machining features. So, if the part geometry information is provided by AP-203 format, the system must be designed to identify the features (including visuallization, machining features identification and validate testing). But if there's AP-224, the feature converting (design feature-machining feature) must be carried out before process planning. Thus, the system must have the function of feature identification and feature converting. By identifying and extracting feature, process based on feature can be planned: after the plane or the hole to be planned is selected, the process information of cutting method, cutting values, tool model, feed rate, machining procedure will be manually input to the system. Finally, according to the primary principle of process planning, the process information will be arranged into the machining process file. In the system, all of the features, process methods, process routes and the parameters of tools and cutting values are expressed by STEP-NC data model. The format of STEP-NC CNC machining process file generated by the process planning system is fit with AP-238 standard.

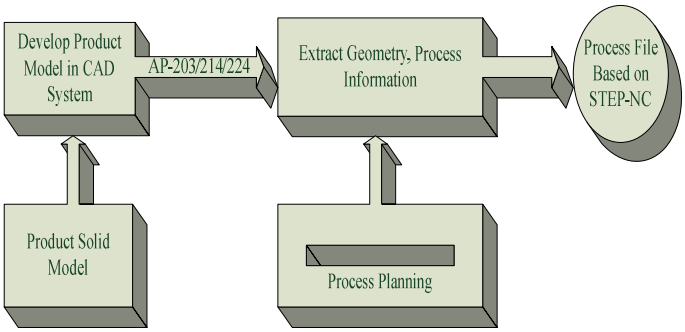

Fig 1. Procedure of Process Planning Based on STEP-NC

In this paper, the output of the CAD part model is STEP-203 neutral file. There are 4 function moduls in the system to reach the process planning (Fig 2.). These moduls are: geometry information extracting, feature information extracting, process planning and STEP-NC file generating. In addition, the system is supported by two databases: geometry information database and process resource database.

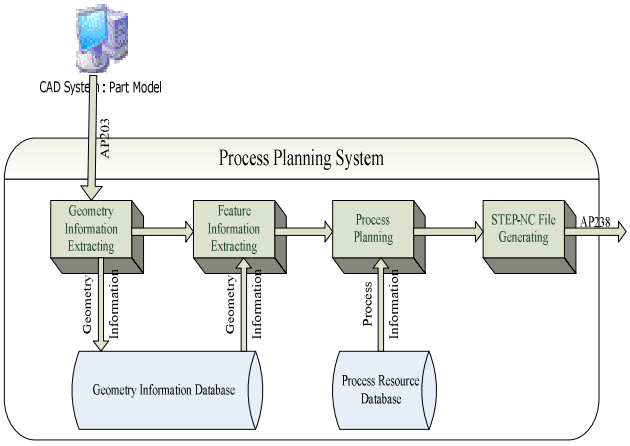

Fig 2. Framework of the Process Planning System Based on STEP-NC

The Interoperable Part Information Based on STEP

To save the geometry information from STEP file into the geometry information database, STEP file must be analyzed so that data information can be extracted by program developed by C++ firstly. Then the geometry information will be saved into database. So, the system must convert the EXPRESS data type into C++ data type first. Then it saves the C++ data type into SQL Server data type.

Translation of the Data Types Translation of the Data Types. It's much easier to translate the simple data type **expressed** by EXPRESS to C++ data type and SQL Server data type. The translating relationship is shown in Table 1.

Table 1. Data Type Translating Between EXPRESS and C++, SQL Server

EXPRESS Data Types	C++	SQL Server
NUMBER	ini	CAHR INT,REAL
REAL	Float,double	REAL,FLOAT
INTEGER	ini	INT,SMALLINT
STRING	char string	CAHR,VARCHAR
BOOLEAN	bool	BIT,INT
LOGICAL	ini	INT
BINARY	ini	INT

The Information Database and Its Structure. Geometry information analyzed from STEP file is saved in the geometry information database. The geometry information is the basic of feature extracting, process planning, and STEP-NC file generating. There are three factors needed by the geometry information database: The first one is the defining method of the entity in STEP file. The second one is the quotation relationship and the heritage relationship among each entity when the part's geometry contour is expressed by STEP file. The last one is the mapping relationship of the EXPRESS entity data type and the SQL Sever data type.

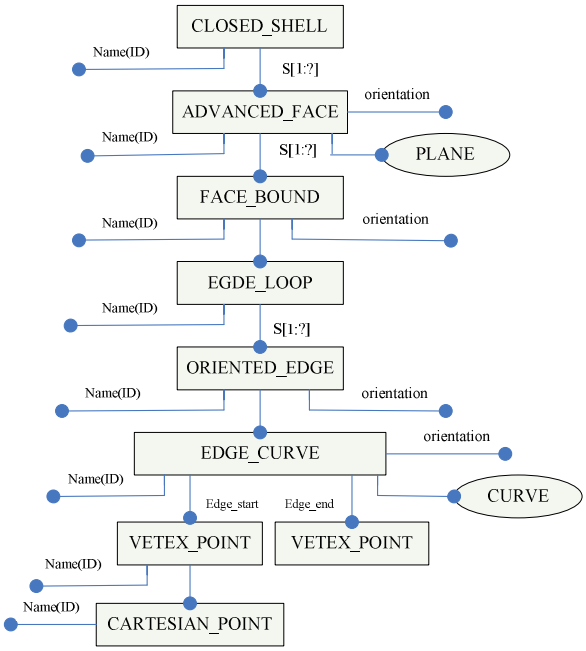

Fig 3. Quotation and Heritage Relationship Among the Entities in STEP File

Fig.3 shows the quotation and heritage relationship among the entities when the part's geometry contour is expressed by STEP file. It is known from the fig that each entity data table involved in the geometry information database must correspond to each entity involved in STEP file. It is also known that the quotation relationship of the entity data in SQL Server must be defined by the quotation and heritage relationship among the entities in the fig.

Lexical Analysis and Information Extracting. Part information is the basic of process planning. By analyzing part's STEP file, the file name, file description, file mode information in the head section, the entity information used to express part's geometry contour in the data section of the STEP file can be extracted. This information will then be saved into the geometry information database.

Lexical analysis is the program that extracts the entity, property information from STEP file by analyzing STEP file, to match the defined C++ entity class. Each sentence in STEP file represents an entity and constructs an entity sentence section. For each sentence section, lexical analysis extracts entity name, entity ID, and every property of the entity from the entity sentence section. The key of lexical analysis is analyzing the word sequence in the entity sentence section to match C++ entity class.

Process Planning Based on STEP-NC

Extracting Feature Information. To extract feature information during process planning, it is needed to match the geometry information of the machining feature to the geometry information in the geometry information database. Thereby the ID number of the corresponding geometry representation section in STEP file can be obtained. Thus, in the system, to plan the machining process, after the designer selected the entity information of a machining feature, the feature extracting modular will extract feature and obtain the feature's ID number.

STEP (AP203) applies B-rep to describe the solid 3D model of part. In the system, the machining process is planned interactively. One can select machining feature in the 3D model interactive interface. After the key geometry information of the feature was obtained, the feature information will be extracted.

Process Planning. As the machining feature information was extracted, the machining process for the part's machining feature can be planned. The process includes a series of workingsteps. Working procedure arranging, tool machine selecting, tool selecting, fixing and holding plan determining, cutting parameters defining and so on are all involved in process planning. People firstly interactively decide the feature to be machined and select the feature's boundary geometry information in the 3D

interface. After feature extracting, the process information such as tools, cutting speed, axis speed and safe plane will be selected and added to the feature. At last, the detailed process information will be set in the process parameter setting interface till all the machining features have set the process information.

Generating STEP-NC File. After a part's process planning has been finished, the part's geometry information and the process information generated by the process planning must be written into STEP-NC file according to AP238. AP238 is the technical specification of STEP-NC standard, completely integrate with other applications of STEP. It translates the milling information requirement of ISO14649 into the integrated specification of other application protocols. The geometrical definitions of AP238 are the same as those of AP203 and AP214 while its machining feature is the same as AP224, testing information is the same as AP219. AP238 defines or treats information for CNC system, covering the complete part's information from conception to product [9,10]. The STEP-NC file generating is the procedure to write the workingstep information generated by process planning system into STEP-NC file according to STEP-NC protocol.

Demonstration of the Prototype System. Based on the above theory, a process planning prototype system based on STEP-NC was developed. When running the system, STEP file should be opened firstly. The system will then analyze STEP file by lexical analysis to obtain the entity's ID number and its property information and save them into geometry information database. Following this operation, people can select machining feature in the 3D model interactive interface and determine workingsteps and set process parameters for the feature. The STEP-NC file can be generated as soon as the process planning is finished.

Conclusion

It is very important to develop a stable and general process planning system based on STPE-NC and oriented to object and feature for the application of STEP-NC standard. It is also the basic of intelligent manufacturing and intelligent machine. This paper analyzes the theory of the system based on the above requirement. The key technologies of the process planning system based on STPE-NC and oriented to object and feature are studied. The study puts emphasis on establishing the geometry information database and the translating between STEP file and the database. Finally, a prototype system is demonstrated to test the feasibility of the set of theory.

Acknowledgements

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References

[1] John Callen. STEP-NC is an advancement still searching for its markets. Tooling & Production; Dec 2005; 71, 12; ABI/INFORM Trade & Industry pg. 21

[2] S H Suh; D H Chung; B E Lee; J H Cho; et al. Developing an integrated STEP-compliant CNC prototype. Journal of Manufacturing Systems; 2002; 21, 5; ABI/INFORM Global pg. 350

[3] Suh, Suk-Hwan; Cho, Jung-Hoon; Hong, Hee-Dong, 2002, On the architecture of intelligent STEP compliant CNC. Int. Journal of CIM,V.15. no. 2. 168- 177.

[4] R. D. ALLEN, J. A. HARDING and S. T. NEWMAN. The application of STEP-NC using agent-based process planning. International Journal of Production Research, Vol. 43, No. 4, 15 February 2005, 655–670

[5]R. Liu, C. Zhang, S. T. Newman. A framework and data processing for interfacing CNC with AP238. International Journal of Computer Integrated Manufacturing, Vol. 19, No. 6, September 2006, 516–522.

[6] X. Xu, P. Klemm, F. Proctor, S. H. Suh. STEP-Compliant Process Planning and Manufacturing . International Journal of Computer Integrated Manufacturing, Vol. 19, No. 6, September 2006, 491–494.

[7]A. Nassehi, S.T. Newman, R.D. Allen. The application of multi-agent systems for STEP-NC computer aided process planning of prismatic components. International Journal of Machine Tools & Manufacture 46 (2006) 559–574

[8] X W X, H Wang J Mao, S T Newman. STEP—Compliant NC Research: the Search for Intelligent CAD/CAPP/CAM/CNC Integration. International Journal of Production Research,Vol. 43, No. 17, 1 September 2005, 3703–3743

[9] X.W.XU, Q.HE. Striving for a total integration of CAD, CAPP, CAM and CNC[J]. Robotics and Computer-Integrated Manufacturing, 20 (2004) 101-109.

[10] M. Hardwick, D. Loffredo. Lessons learned implementing STEP-NC AP-238. International Journal of Computer Integrated Manufacturing, Vol. 19, No. 6, September 2006, 523 – 532.

[11] Newman, S. T., Allen, R. D., & Rosso Jr., R.S.U. (2003). CAD/CAM solutions for STEP-compliant CNC manufacture. International Journal of Computer Integrated Manufacturing, 16(7-8), 590-597