DEVELOPMENT OF FEATURE LIBRARY FOR A PROCESS PLANNING SYSTEM

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ABSTRACT

For the generation of process plans of a part type based on the manufacturing features recognized from the product design information, a feature library where manufacturing features can refer to their corresponding manufacturing information is needed. In this paper, we describe the creation of ontology of manufacturing features for the development of a feature library. The creation of manufacturing features ontology is done by considering the designer's intention described in the functional data of the face elements that construct the features. The goal of this ontology creation is to make the feature library be useful for the automated extraction of proper manufacturing information for the generation of process plans.

1. INTRODUCTION

In a manufacturing stage such as a Flexible Manufacturing System (FMS) line where multiple part types are machined, dynamic changes such as increased production, part type changes, machine breakdowns etc are ordinary occurrences. To deal with these dynamic changes, we presupposed the need to integrate design, manufacturing and scheduling activities. Our research puts its goal in the generation of a CAPP system that can integrate process planning, scheduling and manufacturing activities (Sakurai et al. 2000). The CAPP system is named the Feature-Based Flexible Process Planning System (FBFPPS). Figure 1 shows the overview of the proposed FBFPPS. The system consists of 3 steps.

Step 1: manufacturing features recognition from the product design data.

Step 2: generation of multiple process plans of a part type based on the recognized manufacturing features.

Step 3: determination of optimal set of process plans for product mix.

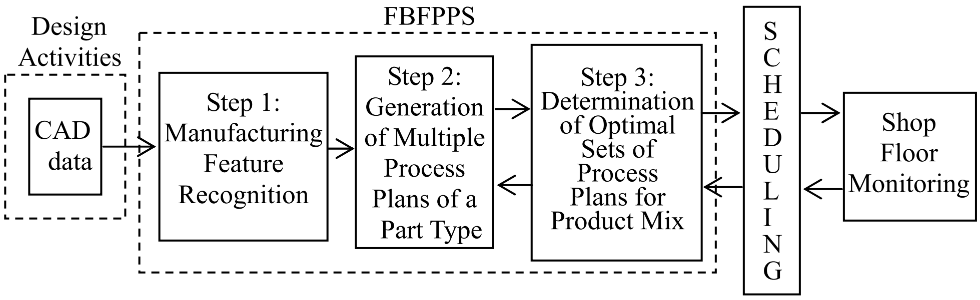


Fig. 1 Overview of the proposed Feature-Based Flexible Process Planning System

Generation of multiple process plans of a part type in Step 2 of the FBFPPS is considered to provide alternative plans in the determination of optimal sets of process plans for product mix in the scheduling stage. During the shop floor monitoring, re-scheduling may occur to handle the dynamic changes in the manufacturing stage. For re-scheduling, a new optimal set of process plans for the present shop floor or production planning condition may be required from the Step 3 of the FBFPPS.

In order to bring the proposed FBFPPS to realization, we have proposed a manufacturing feature recognizer that can lead to the generation of multiple process plans (Muljadi et al. 2002). For the development of the manufacturing feature recognizer, we implemented Super Relation Graph (SRG) Method (Kao et al. 1995). We did some modification to the SRG Method and proposed the Modified SRG Method. So, the manufacturing feature recognizer uses the Modified SRG Method to extract manufacturing features from the product design information. We have further modified the Modified SRG Method, and proposed the Extended SRG Method that is able to extract not only single depression features, but also protrusion and compound features (Muljadi et al. 2003). Protrusion and compound features can also be extracted by the Extended SRG Method since these features can be represented by the Extended SRG. The Extended SRG representations of manufacturing features are stored in the feature library.

For the development of the feature library for the FBFPPS, we collect and store manufacturing features, their corresponding Extended SRG representations and the manufacturing information needed to create the shape of the manufacturing features. However, we found that instances of same type of manufacturing features may require different manufacturing methods. Thus, it is possible to create subclasses to the manufacturing feature types based on the required manufacturing methods to create the manufacturing features, so that each instances of the subclass will have the same possible manufacturing methods.

In this paper, for the development of the feature library, we propose the creation of ontology of manufacturing features by considering the designer's intention described in the functional data of the face elements that construct the features. The goal of this ontology creation is to make the feature library be useful for the extraction of proper manufacturing information to create the manufacturing features that are extracted by the Extended SRG Method.

The structure of this paper is as follows. In order to make this paper self-contained, the Extended SRG Method is described briefly in Section 2. In Section 3, we discuss the creation of ontology of manufacturing features for the feature library. In Section 4, a case study is used to show the validity of the proposed manufacturing features ontology to enable feature library to extract proper manufacturing information from the extracted manufacturing features.

2. EXTENDED SUPER RELATION GRAPH METHOD

In Extended SRG Method, feature extraction is made possible by using three relations between faces, super-concavity relation, face-to-face relation and convexity relation, and also by using the edge elements which construct the features. Super-concavity relation, face-to-face relation and convexity relation can be defined by Eq.1, Eq.2 and Eq.3 respectively.

$$n_{f_i}^{+} . n_{f_j}^{+} \neq -1;\ f_i \cap S(f_j)^{|+|} \neq \emptyset \text{ and } f_j \cap S(f_i)^{|+|} \neq \emptyset \qquad (1)$$

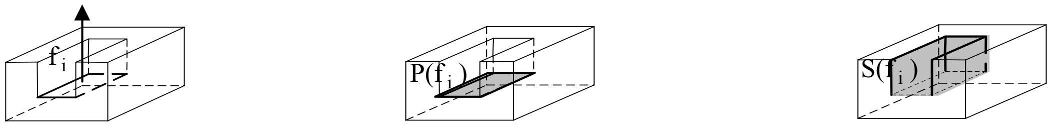
$$n_{f_i}^{+} . n_{f_j}^{+} = -1;\ f_i \subset S(f_j)^{|+|} \text{ and } f_j \subset S(f_i)^{|+|} \qquad (2)$$

$$n_{f_i}^{+} \cdot n_{f_j}^{+} \neq 1;\ n_{f_i}^{+} \cdot n_{f_j}^{+} \neq -1;\ f_i \cap S(f_j)^{|+|} = \emptyset;\ f_j \cap S(f_i)^{|+|} = \emptyset; E_{f_i} \cap E_{f_j} \neq \emptyset \qquad (3)$$

where $n_{f_i}^{+}$ is the positive face normal of face f_i (figure 2(a)), and the strict positive half space of face f_i, $S(f_i)^{|+|} = \{x \mid n_{f_i}^{+T} x > k\}$ is the positive half space which exclude the embedding plane of face f_i, $P(f_i) = \{x \mid n_{f_i}^{+T} x = k\}$ (figure 2(b),(c)), E_{f_i} is the set of edges of face f_i. $n_{f_j}^{+}$, $S(f_j)^{|+|}$ and E_{f_j} are defined similarly as above.

Figure 3 and figure 4 show the Extended SRG representation of a stepped-hole feature and rectangular boss feature respectively. A node with one circle in the Extended SRG corresponds to a plain face of the feature. A double circle node corresponds to a curve face. Dotted links are used to represent face-to-face relations. Solid links are used to represent super-concavity relations and face-to-face relations. To distinguish these two relations, 0 is used as the attribute of the solid links to represent super-concavity relations and 1 to represent convexity relations. Solid links with no attribute are used to represent the face-edge relations. Plain edges are represented by e_n and curve edges are represented by e_n^+. The Extended SRG Method has the ability to extract not only single depression features, but also protrusion and compound features, since protrusion and compound features can have their Extended SRG representations too.

In the development of feature library, a collection of manufacturing feature types, their corresponding Extended SRG representations and the possible manufacturing information to create the manufacturing features is stored. In the next section, we discuss the creation of manufacturing features ontology to make the feature library be useful for the extraction of proper manufacturing information of manufacturing features extracted by Extended SRG Method.



(a)Positive Face Normal of Face f_i (b)The Embedding Plane of f_i (c)Strict Positive Half Space of f_i

Fig. 2 Explanation of terms used in Extended SRG Method

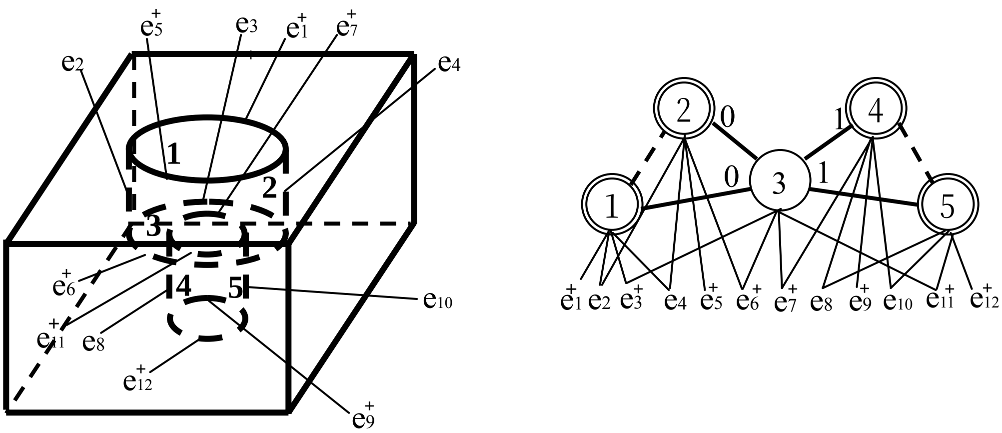


Fig.3 Stepped-hole feature and its Extended SRG representation

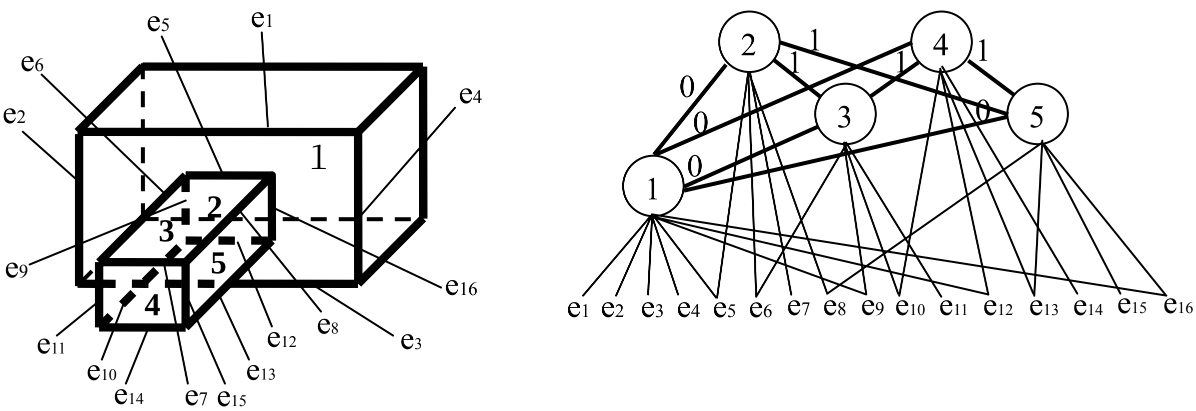


Fig.4 Rectangular Boss feature and its Extended SRG representation

3. DEVELOPMENT OF THE FEATURE LIBRARY

3.1 The Role of Feature Library in Process Planning System

A manufacturing feature can be defined simply as a geometric shape that has its manufacturing information to create the shape. This definition means that when a manufacturing feature is extracted from the product design information, the possible manufacturing information to create the shape is also extractable at the same time (Kanamaru et al. 2004). The linkage between manufacturing features and their corresponding possible manufacturing information is stored in the database, which we call as a feature library.

Thus, a feature library plays a big role in FBFPPS for the generation of process plans based on manufacturing features. As manufacturing features are extracted, the manufacturing information can also be extracted from the feature library.

3.2 Considering Designer's Intention for the Creation of Manufacturing Features Ontology

Manufacturing features are extracted from the product design information. However, to recognize the functions of the manufacturing features, we have to know why the designer designs the geometrical shapes, or in other words, we have to understand the designer's intention. Understanding the designer's intention is very important to extract the proper manufacturing information to create the manufacturing features. Since normally designer does not design a part using manufacturing features, we suppose that it is better to understand the designer's intention by considering the functions of the face elements that construct the manufacturing features.

The functional data of face elements can be described as basic function, mechanism utilized for realization of the basic function and condition and direction of the motion. The detail explanation of the functional data of face elements is given in other reports (Yoshikawa et al. 1987) (Ando et al. 1989). Table 1 shows the contents of functional properties of face elements that are used for the creation of manufacturing features ontology.

Table 1 Contents of Functional Properties

Basic Function	Mechanism utilized for realization of the basic function	Condition and direction of the motion
Transmission of motion	1: friction-mech., 2:gear-mech., 3:link-mech., 4:cam-mech.	1:liner, 2: smooth-liner, 3:very-smooth-liner, 4:round, 5:smooth round, 6:very smooth round
Constraint of motion	1: rigidity-mech., 2: ball-bearing-mech., 3: sliding-mech.	1: liner, 2:weak-radial, 3:strong-radial, 4:weak-thrust, 5: strong-thrust
Fixation of motion	1: bolt-and-nut, 2: bolt-only, 3: friction-mech., 4: bearing-fit, 5: key-fit, 6: river-fit, 7: shrinkage-fit	1: stationary-object, 2:revolutionary-object

3.3 Creation of Manufacturing Features Ontology

Figure 5 shows the manufacturing features ontology and the functional data ontology. New classes for manufacturing features ontology are created to have their relation with the functional data ontology. The relation between the class of the manufacturing features ontology and the functional data ontology is defined as how the manufacturing features should be manufactured to fulfill the required functions. Here, each new class of the manufacturing features ontology will refer to a collection of possible manufacturing information that can be used to create the shape of the instances of the feature class. In figure 5, a "threaded drilled thru hole" class is created to relate the thru hole feature type in the manufacturing features ontology with the "fixed with bolt and nuts and is a stationary-object" class of the functional data ontology. This is done since a threaded drilled thru hole can fulfill the required mentioned functions. And for the "threaded drilled thru hole" feature class, a collection of possible manufacturing information for the instances of the "threaded drilled thru hole" feature class should be prepared so that when a manufacturing feature extracted by the Extended SRG Method falls to this class to fulfill the required functional data as intended by the designer, a proper manufacturing information can be extracted automatically. Thus the creation of manufacturing features ontology will make the feature library be useful for the extraction of proper manufacturing information that can lead to the generation of process plans of a part.

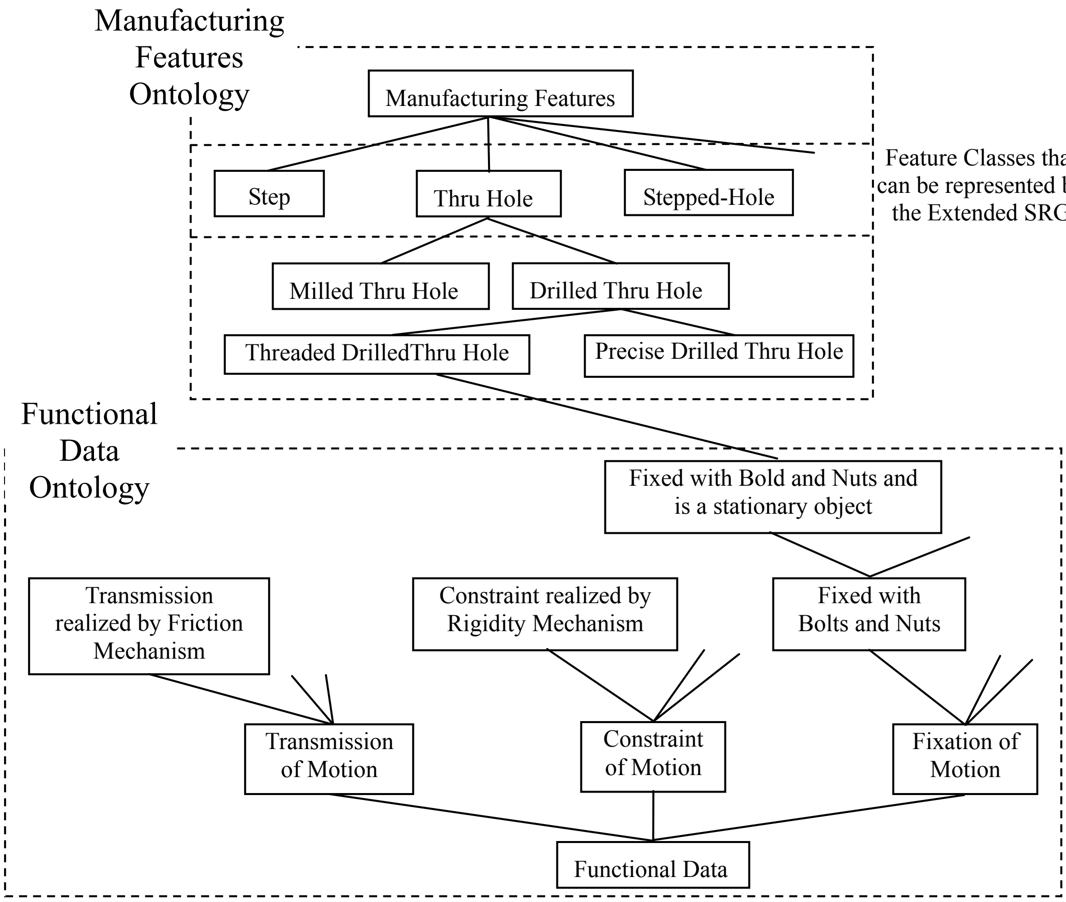


Fig.5 Ontology of Manufacturing Features and Functional Data

4. CASE STUDY

Figure 6 shows a sample part for the case study and the functions of the face elements of the sample part.

First, Extended SRG Method is applied to extract manufacturing features from the sample part. There are 5 thru hole features extracted. Then using the function data as the input, the extracted features find the matched feature class from the feature library. Here, one thru hole feature falls to the "grinded thru hole" feature class, and four thru hole features fall to the "threaded drill thru hole" feature class. Then, as illustrated in figure 7, manufacturing information for each thru hole features are extracted by referring the instances of the feature classes. The thru hole feature that falls to the "grinded thru hole" feature class extracts a manufacturing method where cylindrical grinder is required to manufacture the shape. The four thru hole features that fall to the "threaded drill thru hole" feature class extract a manufacturing method where threading is required to manufacture the shape. Thus, by considering the designer's intention described in the functional data of the face elements that construct the features for the development of the feature library, the automated extraction of manufacturing information is made possible.

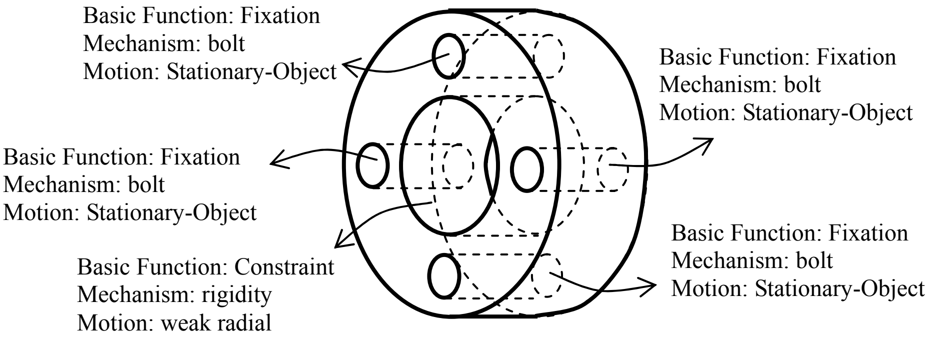


Fig.6 A Sample Part and the Functions of the Face Elements

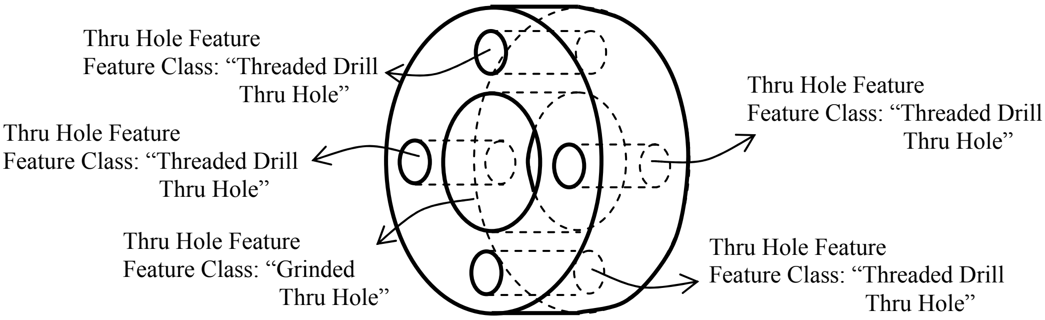


Fig.7 Extracted Manufacturing Features and Their Proper Feature Classes

5. CONCLUSION

In this paper, we presented the creation of ontology of manufacturing features for the development of a feature library by considering the designer's intention described in the functional data of the face elements that construct the features. New classes for manufacturing features ontology are created to have their relation with the functional data ontology. Each new class of the manufacturing features ontology will refer to a collection of possible manufacturing information that can be used to create the shape of the instances of the feature class. As shown in the case study, the creation of manufacturing features ontology will make the feature library be useful for the automated extraction of proper manufacturing information for the generation of process plans.

REFERENCES

Ando, K., Yoshikawa, H., 1989, "Generation of Manufacturing Information in Intelligent CAD", Annals of CIRP, Vol.38/1, 133-136

Kanamaru, M., Ando, K., Muljadi, H., Ogawa, M., 2004, "Manufacturing Feature Library for the Machining Process Planning", Proceedings of the JSPE Autumn Conference (in printing)

Kao, C.Y., Kumara, S.R.T., Kasturi R., 1995,"Extraction of 3D Object Features from CAD Boundary Representation Using the Super Relation Graph Method", IEEE Transaction on Pattern Analysis and Machine Intelligence, 17(12), 1228-1233

Muljadi, H., Ando, K., Ogawa, M., 2002, "Feature Recognition and Organization for Making Multiple Process Plans", Proceedings of 7th International Pacific Conference on Manufacturing & Management, 934-939

Muljadi, H., Ando, K., Ogawa, M., 2003, "Practical Application of Manufacturing Feature Recognition Method", Proceedings of the International Conference on Leading Edge Manufacturing on 21st Century, 813-818

Sakurai, T., Muljadi, H., Ando, K., Ogawa, M., 2000, "Research of Dynamic, Flexible and Integrated Process Planning System", Proceedings of the JSPE Spring Conference, 44 (in Japanese)

Yoshikawa, H., Ando, K., 1987, "Intelligent CAD in Manufacturing", Annals of CIRP, Vol.36/1, 77-80