A Feature Library as a Process Planners' Knowledge Management System

Hendry Muljadi[†] , Hideaki Takeda[††] and Koichi Ando[†††],

[†]Transdisciplinary Research Integration Center, Research Organization of Information & Systems, Tokyo, Japan
[††]National Institute of Informatics, Tokyo, Japan
[†††]Department of Information Science & Engineering, Shibaura Institute of Technology, Tokyo, Japan

Summary
In manufacturing, features can simply be defined as a geometric shape and its corresponding manufacturing information to create the intended shape. For the generation of process plans based on manufacturing feature, it is normal to expect that the corresponding manufacturing information will reflect the knowledge of process planners. This paper proposes a feature library that is able to manage the knowledge of process planners. By enabling the management of the knowledge of process planners, the proposed feature library may be useful to support the generation of process plans. In this paper, the implementation of Semantic Wiki for the development of the prototype feature library is described.

Key words:
Manufacturing feature, Feature library, Feature ontology, Semantic Wiki, Process planning

1. Introduction

In the competitive worldwide manufacturing market, smooth integration of design and manufacturing is critical for manufacturer survival. One of the most important link for design and manufacturing integration is process planning [1]. Process planning comprises in details the selection and sequencing of processes and operations to transform raw material into the desired form. Process planning also plays an important role in the management of an enterprise, since almost any industrial inquiry concerning the manufacturing process such as floor space, due dates, lead time, work in process, etc, addresses process planning as the data source [2].

In order to generate process plans, process planners must possess a variety of skills and knowledge. They must possess the ability to interpret engineering drawings, the knowledge of materials for manufacture, the knowledge of manufacturing processes, the knowledge of jigs and fixtures, etc [3]. Manual process planning is time consuming, labor intensive, and may involve human errors [4].

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Computer Aided Process Planning (CAPP) has emerged as a means to support human effectively to generate process plans, and has been a research topic for over 35 years [5]. CAPP system offers the ability to integrate Computer Aided Design (CAD) system and Computer Aided Manufacturing (CAM) system. In order to allow the CAD system to interface with the CAPP system, feature technology has emerged as the enabling technology to convert CAD product data to manufacturing information [6]. Feature recognition is considered as a front-end of process planning. Many different approaches have been developed to extract features from the CAD product data [7], [8]. However, the manufacturing information typically used in process planning is rarely incorporated into feature recognition [9].

In manufacturing, features can simply be defined as a geometric shape and its corresponding manufacturing information to create the intended shape. As manufacturing features are used to generate process plans, it is normal to expect that the corresponding manufacturing information will reflect the knowledge of process planners. In other words, for the generation of process plans, it is necessary to develop a feature library that is able to manage the knowledge of process planners. In this paper, a feature library that is able to manage the knowledge of process planners is proposed. Semantic Wiki is used for the development of the proposed feature library.

The structure of this paper is as follows. In section 2, the role of feature library in process planning is discussed. Section 3 describes the structure of the feature library. The implementation of Semantic Wiki for the development of the prototype feature library is presented in section 4. Section 5 states the conclusion of this paper.

2. The role of feature library in process planning

2.1. Organizing the manufacturing knowledge

Manufacturing features can be associated with manufacturing process models, and process models can be associated with manufacturing resources, such as machines, tools, etc [10]. Linking manufacturing features, process models and resource models may lead to the manufacturing knowledge repository organization [11]. Fig.1 illustrates a feature-based manufacturing knowledge repository. In this paper, the feature-based manufacturing knowledge repository is called the feature library.

2.2. Managing the knowledge of process planners

Process planning also involves deciding the sequence of manufacturing operations for manufacturing a part [12]. A feature library can be useful to manage the knowledge of process planners in a higher degree compare to the existing feature library shown in Fig.1 by

(1) enabling the manufacturing features to be associated directly with the manufacturing process sequences to create the shape of the feature,
(2) enabling the manufacturing process sequences to be associated with the manufacturing resources, such as machines, tools, etc.

The knowledge of process planners can be managed by managing the links between the manufacturing features and the manufacturing process sequences, and the links between the manufacturing process sequences and the manufacturing resources.

And as manufacturing features are linked with the corresponding process sequences and other manufacturing information, the extraction of manufacturing features with their corresponding manufacturing information can be made possible. Thus, the proposed feature library is able to manage the knowledge of process planners and also plays an important role for the generation of process plans.

3. The structure of the feature library

The feature library consists of manufacturing feature ontology and collections of process sequences, materials, machines, tools, etc. To develop the feature library, first, a manufacturing feature ontology needs to be created, and then the relation between the manufacturing feature ontology and the corresponding manufacturing information needs to be created.

3.1. Creation of manufacturing feature ontology

Fig.2 shows the manufacturing feature ontology. The lightweight ontology of manufacturing features is created as

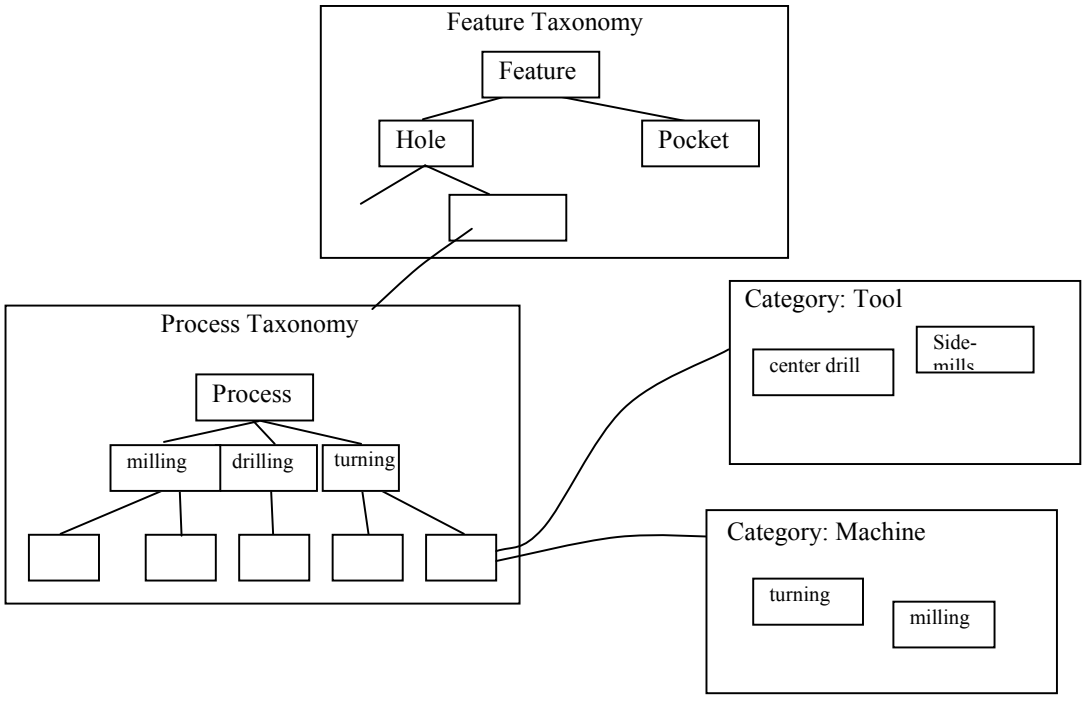

Fig.1 A feature-based manufacturing knowledge repository

follows.

(1) Level 0: Ontology name
(2) Level 1: Features such as step, thru-slot etc are listed up. Features used in this research are based on the library proposed by CAM-I [13].
(3) Level 2: Sub-classes of the manufacturing feature classes in level 1 are created by describing the manufacturing methods to create the shape of the parent classes. A thru slot can be created by milling, electrical discharging, etc. Thus, the sub-classes of the thru-slot feature class can be named as milled thru-slot feature class, electrical discharged thru-slot feature class, etc.
(4) Level 3: Whenever a manufacturing method described in level 2 can be specified further, sub-classes of the class in level 2 are created. The sub-classes' name may refer to the specific tool type used. For example, milled thru-slot feature can have end-milled thru-slot feature, plain-milled thru-slot feature, etc as its sub-classes. Some feature classes in level 2 may have no sub-class.
(5) Instances of the lowest level of the manufacturing feature classes are created based on size of the shapes and material types.

3.2. Relation between manufacturing feature ontology and the corresponding manufacturing information

Fig.3 illustrates the relation between manufacturing feature instances and the corresponding manufacturing information. An instance of the manufacturing feature ontology is linked with the material data and the process sequence to create the shape. A process sequence is associated with machines, tools, etc, by describing explicitly the sequence of the tools and machines used to create the shape. Machines and tools are also linked to each others. The links show which tools are attachable to a particular machine.

3.3. Discussion

By developing the feature library based on the proposed structure, the structured feature library is useful to manage the knowledge of process planners to create the shape of the features, as well as to support the extraction of manufacturing features with their corresponding process sequences and other manufacturing information for the generation of process plans. Thus the development of the feature library is a very crucial step towards the realization of a feature-based process planning system.

However, it takes effort to organize the knowledge of process planners. Moreover, manufacturing technology is progressing and facilities available in an industrial plant may differ to other plants. The feature library itself may need to be changed or updated. For these reasons, developing and managing the feature library requires an easy-to-modify environment.

4. THE PROTOTYPE FEATURE LIBRARY

4.1. MediaWiki with simple semantics

Since its birth in 1995, Wiki has become more and more popular. It is a simple publishing system that is easy to learn and quick to use. In Wiki, people can create or edit a Wiki page using a simple syntax to write content [14]. The popularity of Wikipedia.org, the online encyclopedia, has proven how Wiki provides an easy-to-modify environment. Wiki has been considered for the development of a knowledge management system [15],[16]. It has gained significant attention from industry as well [17].

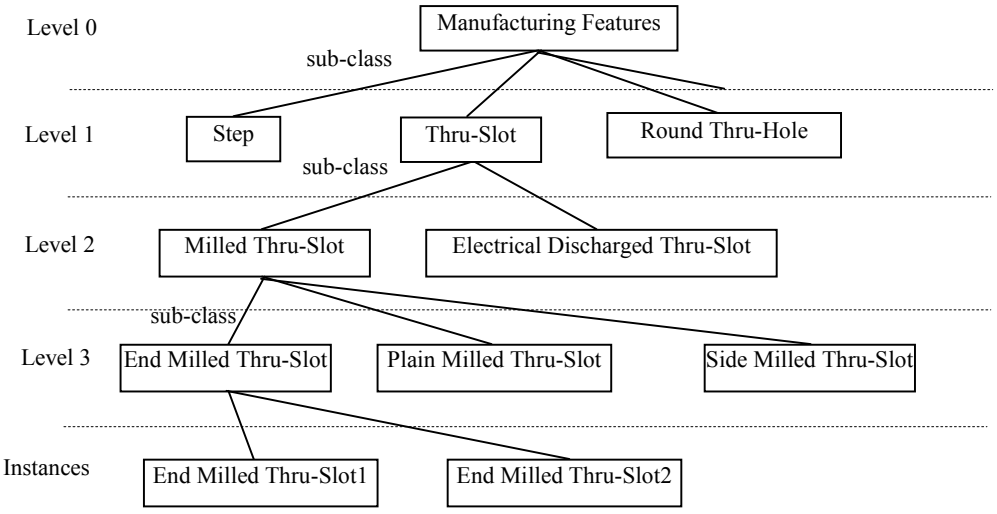

Fig.2 Manufacturing feature ontology

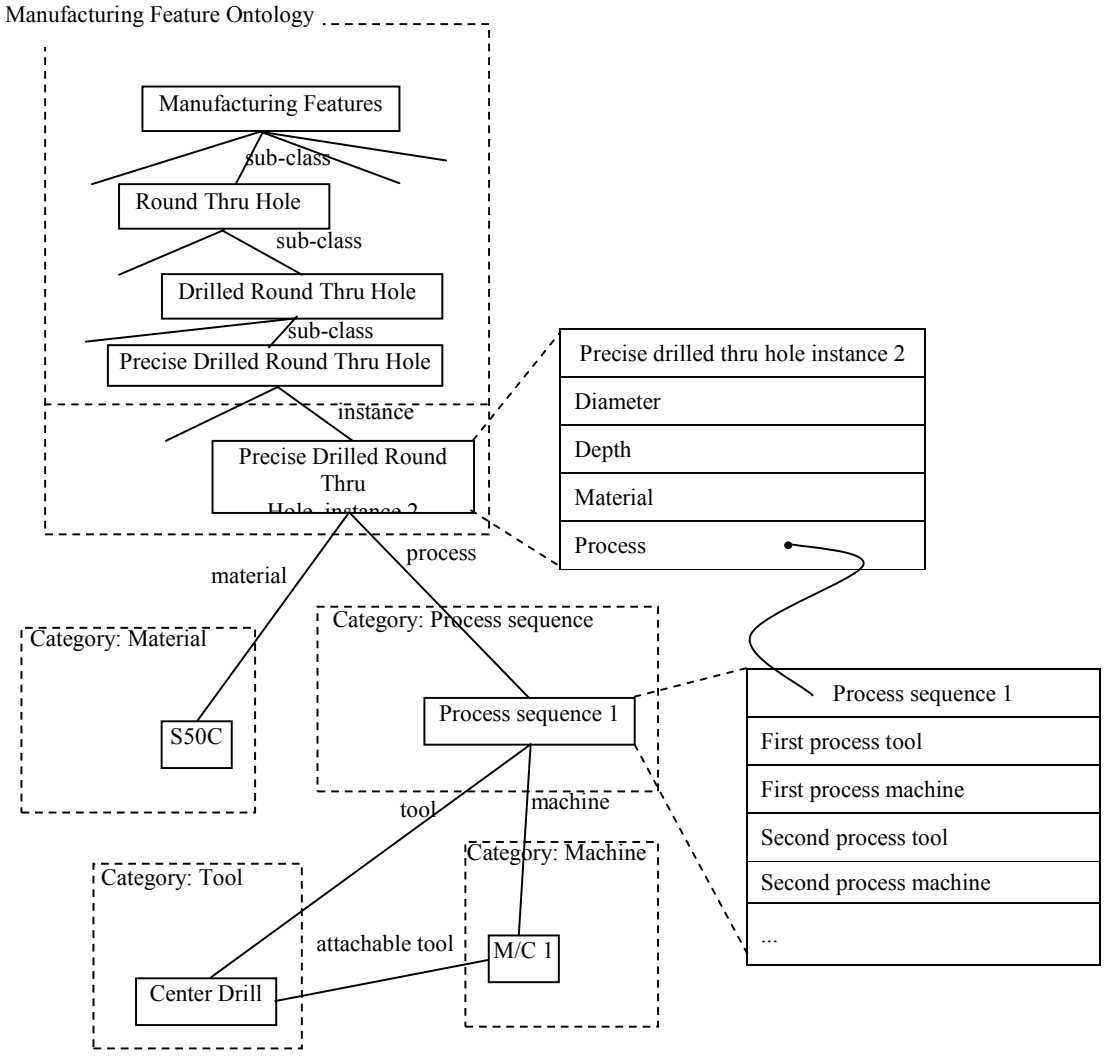

Fig.3 Relation between manufacturing feature ontology and the corresponding manufacturing information

Nowadays there are so many Wiki engines available. One of the famous Wiki software is MediaWiki, which is being used to run Wikipedia. It is a Wiki software that is written in PHP and uses MySQL database.

An extension of MediaWiki to enable the writing of the labeled link has been proposed in other report [18]. This extension has enabled the Wiki to write Resource Description Framework (RDF) statement. RDF is a language to express metadata that is suitable for processing by applications [19]. It has a simple data model that is understandable by human and is easy for computer applications to process and manipulate. As shown in Fig.4, the RDF statement consists of subject-predicate-object triple.

Fig.5 shows the overall structure of MediaWiki with Simple Semantics (MewKISS). MewKISS, as an extension of MediaWiki, has all the benefit of having all the functions available in MediaWiki as a content management system, and also can be used as an editor of metadata according to simple RDF statement. The RDF triples which are stored in a table, can be exported to RDF Database for mapping to other Semantic Web applications. The running system of the extended MediaWiki is available at http://semanticwiki.jp.

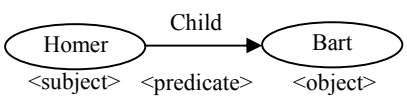

Fig.4 RDF Triple

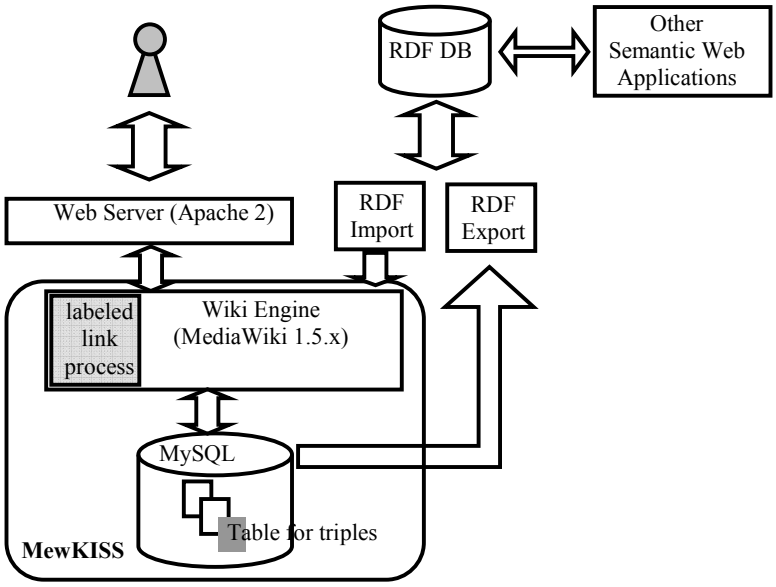

Fig.5 Overall structure of MewKISS

4.2. Semantic Wiki-based feature library

As mentioned in section 3.3, an easy-to-modify environment is necessary to develop and manage the feature library. The MewKISS can provide the solution. To develop the prototype feature library, the MewKISS is customized. A new namespace is created. Namespace ("MF:") is created to deal with the manufacturing feature ontology. A new table is also created in the Wiki database to deal with the new namespace.

4.2.1. Creation of manufacturing feature ontology

For the creation of the manufacturing feature ontology, the Wiki syntax [[MF:feature_sub-class|subclass]] is used (see Fig.6). When the Wiki syntax is written on the parent class page, the Wiki engine will store the RDF triple into a table which deals with the namespace ("MF:") in the Wiki database. By directly querying the table, the labeled link relation will be displayed as follows.

(1) On the parent class page: -> subclass -> feature_sub-class (see Fig.7).
(2) On the feature_sub-class page: <- subclass <- parent class (see Fig.8).
(3) On the sub-class page: parent class -> feature_sub-class (see Fig.9).

As shown in Fig.9, the "MF:subclass" page can be used to see all the class-sub-class relations of the manufacturing feature ontology.

For the class-instance relation in the manufacturing feature ontology, the Wiki syntax [[Term:instance_page|instance]] is used (see Fig.10). When the Wiki syntax is written on the manufacturing_feature_class page, the Wiki engine will display the labeled link relation as follows.

(1) On the manufacturing_feature_class page: -> instance -> feature_instance (see Fig.11).
(2) On the feature_instance page: <- instance <- manufacturing_feature_class (see Fig.12).
(3) On the feature_instance page: manufacturing_feature_class ->instance_page

The "instance" page can be used to see all the created instances in the feature library.

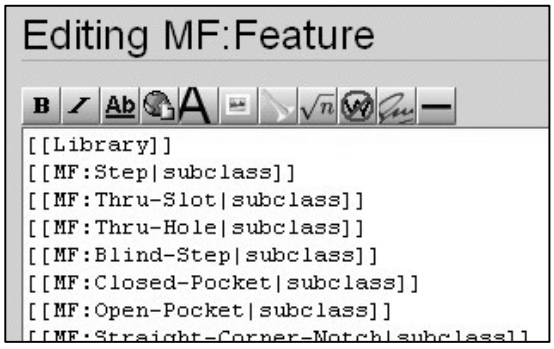

Fig.6 Writing the Wiki syntax [[MF:feature_sub-class|subclass]]

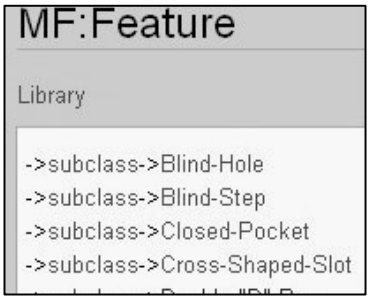

Fig.7 Display on the parent class page

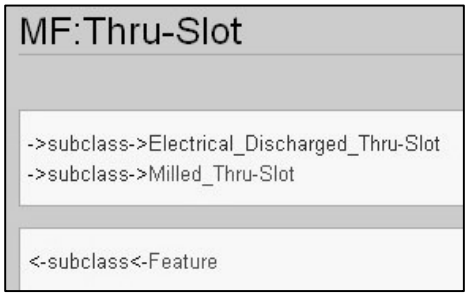

Fig. 8 Display on the feature_sub-class page

Fig. 9 Display on the "MF:subclass" page

Fig. 10 Writing the Wiki syntax [[Term:instance_page|instance]]

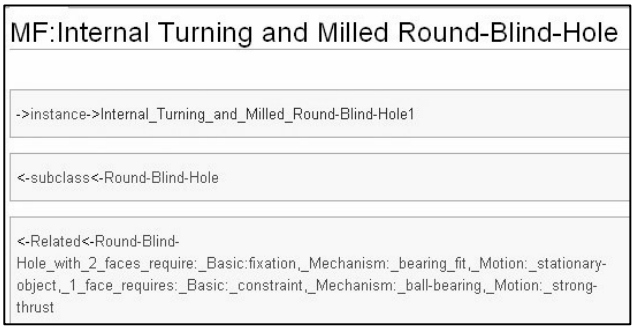

Fig.11 Display on the lowest level class of the manufacturing feature ontology's page

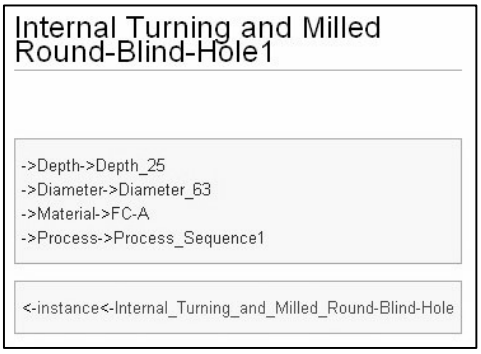

Fig.12 Display on a feature instance page

4.2.2. Creation of links between instances of manufacturing feature classes and manufacturing information

Fig.13 illustrates the relation between an instance of a manufacturing feature class and the corresponding manufacturing information.

As shown in Fig.12, an instance of a manufacturing feature class contains links to size data, material data, and process sequence information. Fig.14 shows the editing page of an instance of a manufacturing feature class. The Wiki syntax [[Term:object|predicate]] is used to write the links on the page of the manufacturing feature instance.

Fig.15 shows the editing page of a process sequence page. The tool sequence and machine sequence are explicitly described on the process sequence page. Fig.16 shows the display on a process sequence page.

And as illustrated in Fig.13, on a machine page, tools which are attachable to the machine are explicitly described to create the relation between tools and machines. The relation between tools and machines is useful for manual validation of whether the selection of machines and tools to create a shape of a feature is correct or not.

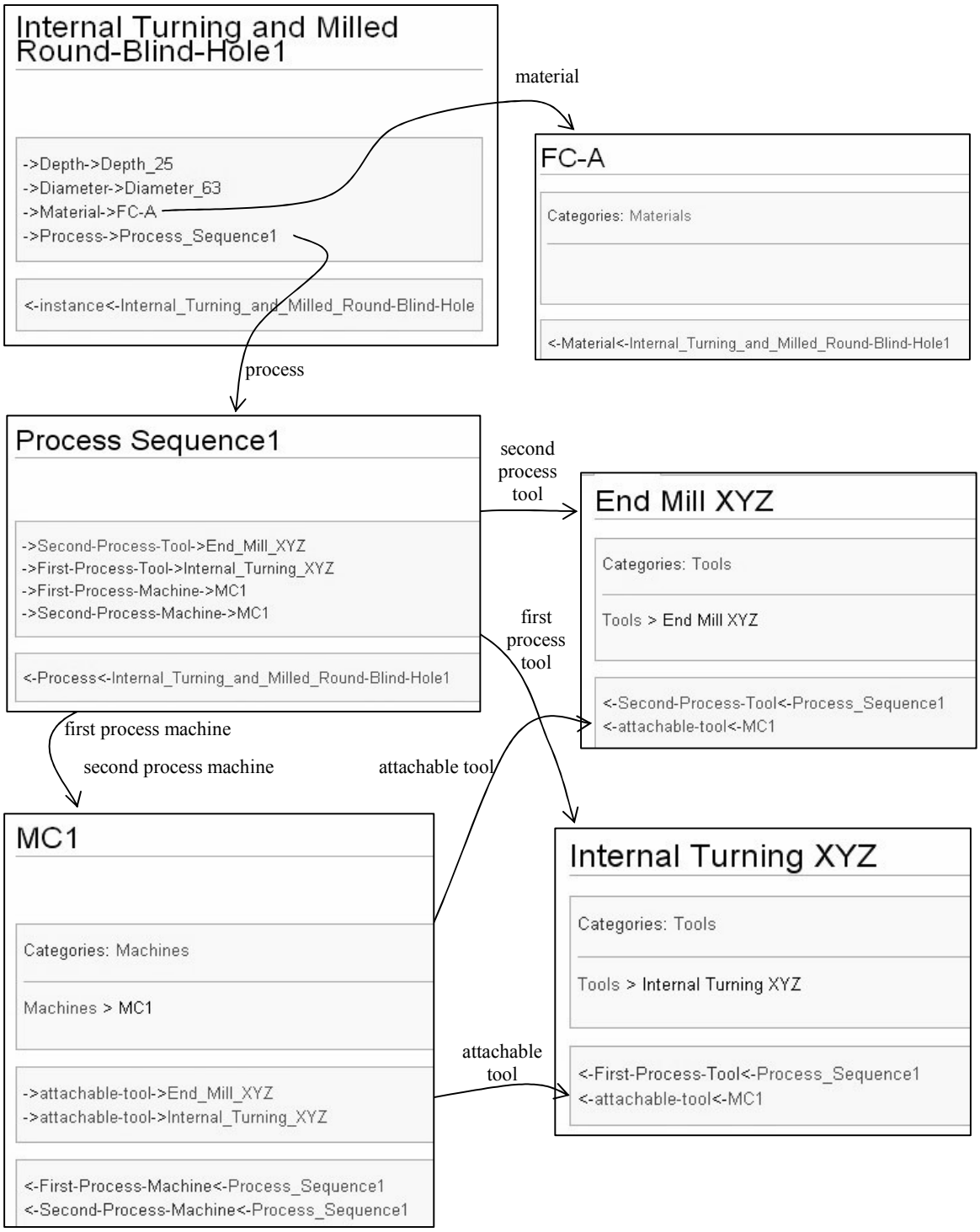

Fig.13 An illustration of the relation between an instance of a manufacturing feature class and the corresponding manufacturing information

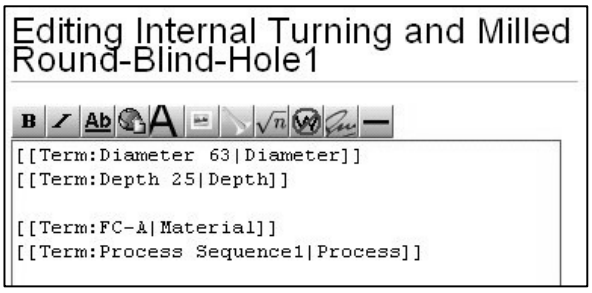

Fig.14 The editing page of an instance of a manufacturing feature class

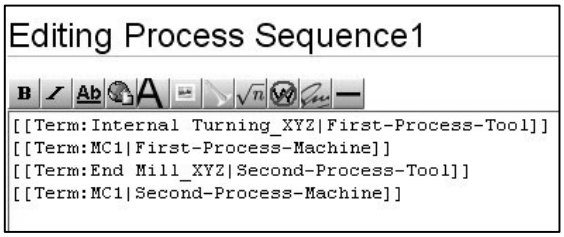

Fig.15 The editing page of a process sequence page

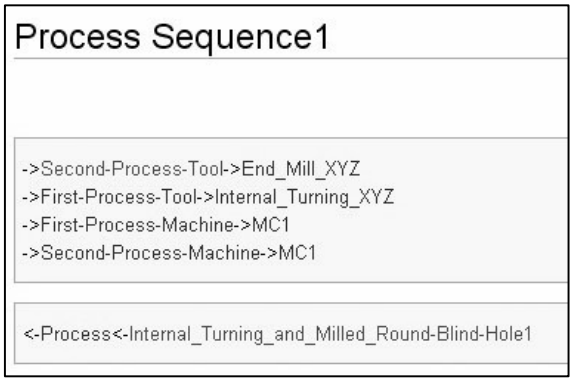

Fig.16 The display on a process sequence page

4.3. Discussion

The prototype feature library provides an easy-to-modify environment to manage the knowledge of process planners based on manufacturing features. Fig.13 illustrates that the prototype feature library allows each instance of the manufacturing feature class to be associated with the corresponding process sequence, and the process sequence with other manufacturing information. Creating such relations will allow the prototype feature library to support the extraction of manufacturing features with their corresponding process sequences and the other manufacturing information for the generation of process plans. And it is worth to note that since the stored knowledge of process planners is written in RDF format, it can be processed or manipulated by other computer applications, or even mapped to other computer applications.

5. CONCLUSION

The results from this research can be summarized as follows.

(1) This paper proposed that manufacturing features can be associated directly with the manufacturing process sequences to create the shape of the features. The process sequences can be associated with manufacturing resources, such as machines, tools, etc. The management of the knowledge of process planners is done by managing the links between the and the manufacturing process sequences, and the links between the manufacturing process sequences and the manufacturing resources.

(2) The feature library consists of manufacturing feature ontology, and collections of process sequences, materials, machines, tools, etc. By linking instances of manufacturing feature classes with the corresponding process sequence, which are associated with other manufacturing information, the feature library is able to manage the knowledge of process planners, and can be useful to support the extraction of manufacturing features and their corresponding process sequences and the other manufacturing information for the generation of process plans.

(3) A Semantic Wiki is used to develop the prototype feature library. The prototype feature library provides an easy-to-modify environment to manage the knowledge of process planners based on the manufacturing features.

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