An Ontology-based Knowledge Management System for the Metal Industry

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ABSTRACT
Determining definite and consistent measurement and computation of materials and operations is of great importance for the operation procedures in metal industry. The effectiveness and efficiency of such decisions are greatly dependent on the domain understanding and empirical experience of engineers. The complexity and diversity of domain knowledge and terminology is the major hurdle for a successful operation procedure. Fortunately, such hurdles can be overcome by the emerging ontology technology. The establishment of ontology is usually the first step towards knowledge management. In this paper, we introduce a three-stage life cycle for ontology design and apply it to a real case with Taiwan's metal industry. The resulting ontology is represented as information ontology and domain ontology. To facilitate the knowledge management in the industry, we develop an ontology-based knowledge management system with the KAON API environment. The proposed system is built upon the Java J2EE distributed component environment and provides the capability of semantic match, and assists engineers in the activities of knowledge management. It facilitates the promotion of the industry from traditional to the so-called "knowledge-driven" industry service. Furthermore, it is generic and applicable to different domain applications.

Categories and Subject Descriptors
I.2.4 [**ARTIFICIAL INTELLIGENCE**]: Knowledge Representation Formalisms and Methods – *Representation languages,Representations;* D.2.12. [**SOFTWARE ENGINEERING**]: Interoperability - *Distributed objects.* H.4.2 [**INFORMATION SYSTEMS APPLICATIONS**]: Types of Systems – *Decision Support*.

General Terms
Management, Documentation, Design, Languages

Keywords
Knowledge management system, ontology, KAON, metal industry, XML, Java EJB

1. INTRODUCTION
Definite and consistent operation procedures play the key role in the metal industry in which measurement and computation of materials and operations are of great importance for the success or failure of a procedure. These measurements and computations such as measuring material size, computing machine stress, and estimating manufacture frequency are usually formalized as mathematic models. In reality, each engineer has his (her) own favorite model in use, and models could be revised or adjusted to be more practical and precise according to different requests of engineers whereas adopting appropriate revise or adjustment is based on the tacit knowledge and empirical experience of engineers or the related knowledge documents they have on hand. However, with the diversity and complexity of conceptual terminology in the metal industry and the lack of proper document management, it is very difficult for engineers to locate the knowledge they need.

In the past few years, the emergence of knowledge management has facilitated the progress for the knowledge demander in searching for knowledge efficiently and effectively [2, 22]. The activity of knowledge management is wide and complex. It can be the management of individual knowledge or the operation of enterprise knowledge. It also includes activities that form the communication of tacit knowledge to the integration of explicit knowledge. In order to achieve the goal of knowledge management, ontology has been considered as an adequate methodology to support a variety of activities of knowledge management, including knowledge retrieval, store, sharing, and dissemination [19]. In one of the most popular definitions, ontology is "the specification of a conceptualization" [27]. For knowledge management system in enterprises, ontology can be regarded as the classification of knowledge [7]. That is to say, ontology defines shared vocabulary for facilitating knowledge communication, storing, searching and sharing in knowledge management systems [17]. Defining ontology is a time-consuming and laborious task. In general, the identification and application of ontology is only for some specific domain, such as medicine, tourism, or the metal industry.

In this paper, we present a collaboration project of the industry and academia whose objective is to investigate the feasibility of applying ontology to the metal industry in Taiwan. In particular, we propose an ontology-based knowledge management system for supporting the activities of knowledge management at Metal Industries Research & Development Centre (MIRDC), a non-profit organization established in October 1963 for researching and developing the leading technology of metal and its related industries in Taiwan. MIRDC aims to promote the growth and upgrading of metal and its related industries in the R.O.C. in order to enable manufacturers to be competitive in the international market. The system can assist engineers in designing a blueprint and determining what formula can be applied to, who has the better solution, and what materials can be used, etc. More importantly, the proposed system facilitates knowledge sharing in MIRDC and endorses the promotion of MIRDC from traditional services such as technical consultation and technology transfer to the so-called "knowledge-driven" industry services.

This paper is organized as follows. Section 2 gives a brief background for this study. The ontology modeling of metal industry is presented in Section 3. Section 4 proposes the ontology-based knowledge management system. Experiments conducted in MIRDC are demonstrated in Section 5. The conclusions and future work are discussed in Section 6.

Table 1. The comparison of several popular ontology tools

	KAON	Protégé 2000	Ontoprise	Ontopia	OilEd
Version	1.2	1.8	3.05	1.3	3.4
Type	Suite	Editor	Suite	Suite	Editor
Ontology storage	Database, files	Database, files	Database, files	Database	Files
Ontology languages	DAML+OIL, RDF(S)	FLogic, OIL, Ontolingua	FLogic, RDF(S)	Topic Map	DAML+OIL, RDF(S)
Open Source	Yes	Yes	No	No	No
Plug-in	Yes	Yes	Yes	Yes	Yes
Inference Engine	Yes	Yes	Yes	Yes	Yes
API	Yes	Yes	Yes	Yes	Yes

2. BACKGROUND

The basic activities of knowledge management are knowledge acquisition, creation, sharing/diffusion, and utilization. There are a variety of technologies have been applied to support these activities, such as e-mail, database and data warehouse, group decision software, intranet and extranet, expert system, intelligent agent, data mining etc. [16, 17]. There also exist different knowledge management systems (KMS) that facilitate the activities of knowledge management [5, 22, 2].

In 1990s, the knowledge reuse and sharing already became the major issue in knowledge engineering [15]. To achieve the goal of knowledge reuse, the concept of object orientation has been introduced to knowledge management systems. In the sense a knowledge entity can be treated as a knowledge object (KO). KOs can be numerical data, text streams, validated models, meta-models, movie clips, or animation sequences [16]. Since enterprises are interested in the integration of existed knowledge bases [27], how to integrate and share KOs among different KMS is of great necessity and is a crucial challenge. In the literature, metadata has been widely used in the integration of existed knowledge bases [26] whereas the ontology has been considered as a meta-level description of knowledge presentation [7]. In [1], a three-level architecture for intelligent decision support has been proposed. It contains, from the top to the bottom, application level, description level, and object level. The object level comprises various information and knowledge sources, the so-called KOs. Ontologies are in the description level, which enable users in the application level to intelligently access object-level sources. Users can precisely select and efficiently access knowledge via the description level from the application level. In other words, ontologies are metadata that provide the search engine with the functionality of a semantic match. It is different from traditional search engines that directly search for the contents of data.

Without doubt, the most popular markup language of metadata is XML. With the mature of the XML development, different definitions of metadata have been proposed, such as Dublin Core [28] and ebXML [6]. From the viewpoint of ontology, XML is not suited to describe the interrelationships of resources in the Internet [8]. Therefore, W3C has recently proposed the resource description framework (RDF) and RDF schema (RDF/S). Since then, many ontology tools have been developed for implementing metadata of ontology by using RDF and RDF/S [25, 20, 18]. Each ontology tool has its characteristics and advantages. Table 1 lists and compares several popularly used tools.

KAON, Ontoprise, and Ontopia [23] provide a complete set of ontology tool suites for building, maintaining and utilizing ontologies. In particular, KAON and Ontopia these tool suites can be deployed onto Java J2EE [21] architecture, a distributed component-based architecture, which makes the ontology-based system more flexible and robust. For this reason and the consideration of open source, KAON is chosen as the ontology development platform in this study.

3. ONTOLOGY MODELING OF METAL INDUSTRY

This section describes how ontology can be built and interacted with a knowledge management system. In this study, we propose a framework of ontology-based knowledge management system for the metal industry in Taiwan. The architecture of the framework is shown in Figure 1. According to [12], the life cycle of ontology design can be summarized as three major stages, i.e. building, manipulating and maintaining. In the building stage, we identify the purposes, scope, and requirements of ontology. When all requirements have been clearly identified, one may start to collect data and information about the metal industry concepts. The resources of concepts are from books, experts, papers and other ontologies. The next step is to analyze the collected data and information. Based on the analyzed ontology, the ontology can be divided into information ontology and domain ontology [1]. This produces the information and domain ontology in the ontology implementation step. The information ontology is a meta model that describes knowledge objects and contains generic concepts and attributes of all information about knowledge objects, such as the title, authors, date, keywords, and other related information. The domain ontology consists of the concepts, attributes, and instances of metal industry. The purpose of domain ontology is to achieve the objective of semantic match when searching for knowledge objects.

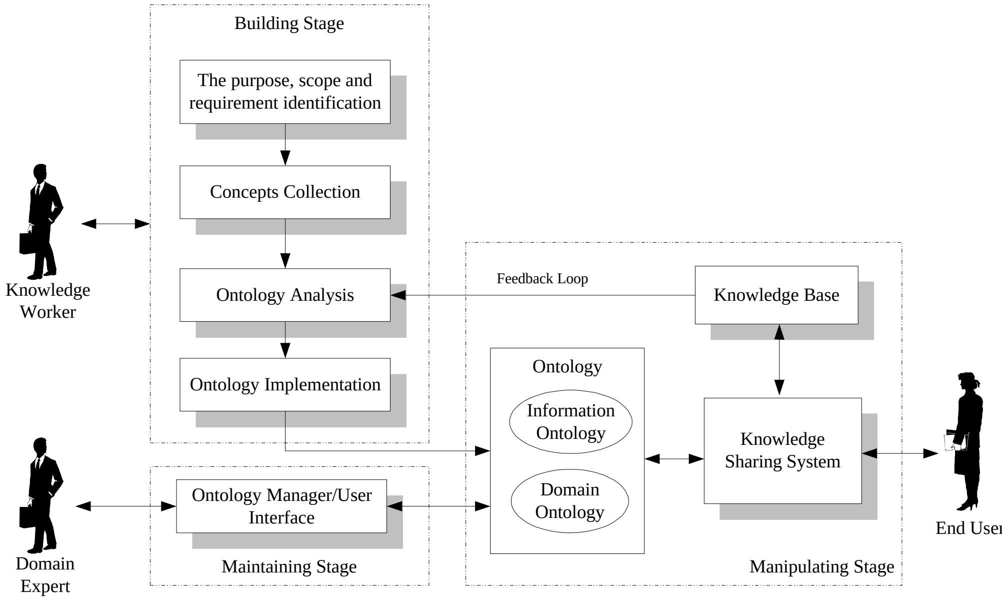

Figure 1. The framework of ontology-based knowledge management system

The ontology is deployed to knowledge management system in the manipulating stage and supports the knowledge management tasks and searching when an end-user accesses the knowledge base. Note that there is a feedback loop between knowledge base and ontology via both ontology analysis and ontology implementation. With more and more various types of knowledge objects in knowledge base, the feedback loop provides the capability of expanding information ontology. In the maintaining stage, domain experts can add, update, and remove ontology via a user interface.

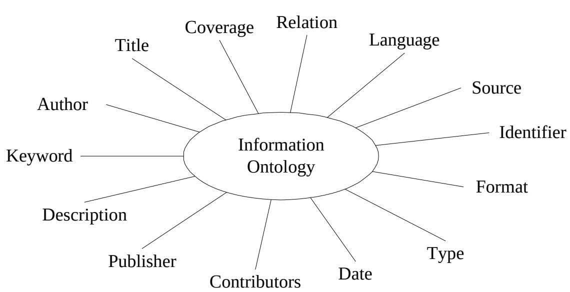

Figure 2. Information ontology

As mentioned previously, the purpose of information ontology is to describe the information of knowledge objects, which can be an electronic file, a record in database, a book, or a solution of problems. Dublin Core is pretty suitable for describing this kind of knowledge objects. Therefore, we make use of Dublin Core as the information ontology consisting of a set of 15 elements which are shown in Figure 2. Figure 3 shows parts of the domain ontology of metal industry that we constructed in the building stage. As the figure indicates, there are two relations between concepts: subclass and relationship. The subclass relation, denoted by an arrow, means that the concept is part of the super concept. If two concepts have more than one relation, a dash line with arrow is needed to present such a relationship, and the relationship is named by a term beside the arrow.

In this example, Component is the parent class of the Bolt, Spring, and Die components. The Die Set is the child of the Die Component and there are two subclasses in the Die Set: Die Holder and Punch Holder. All these demonstrate the hierarchical relation of the metal ontology.

For the Die Component, in addition to the hierarchical classification, there exist a number of structural relations, behavior relations and/or functional relations among components. For example, in order to provide firm support, blanking punches are assembled into a punch plate as usual, so there is a structural relation, fitIn, between a blanking punch and a punch plate. For lifting material strip within a required distance, lifters are raised by springs, thus the relation, derivedBy, between a lifter and a spring is defined.

4. ONTOLOGY-BASED KNOWLEDGE MANAGEMENT SYSTEM

We presented a framework of ontology-based knowledge management system in the previous section. In this section, we discuss the architecture of the proposed system in detail. Figure 4 depicts the layered architecture of the system, which is composed of three layers: Presentation Layer, Business Logic Layer, and Data Layer.

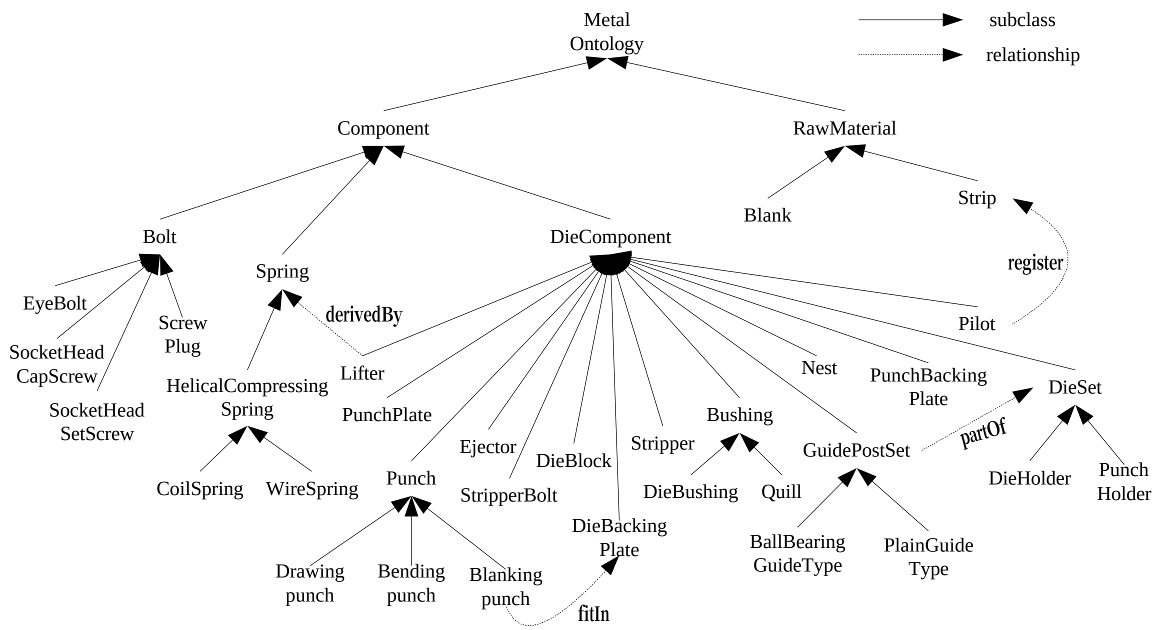

Figure 3. Parts of domain ontology

4.1 Presentation Layer

The presentation layer contains several JSP pages and Java servlets (lightweight Java applications in the server side). The major components are News, Forum, System Manager, Personal Knowledge Manager, and Knowledge Search Engine. News and Forum provide basic functions that users can use to read news, discuss topics and post articles in the forum. All information in the forum can be treated as a part of information ontology. Thus, the Forum component also saves information ontology via the Publisher component, which locates in the Business Logic Layer when users issue a topic for discussion.

The component of System Manager provides the system administrator several administrative functions, for example, maintaining users data, publishing news, creating a forum, and managing knowledge objects. When the administrator publishes news, the News component will also store information ontology as the Forum component did. Users can manage their knowledge via the Personal Knowledge Manager component, which also allows users to share personal knowledge. Therefore, when users search for knowledge objects via the Knowledge Search Engine component, it does not only look for public knowledge objects but also personal knowledge objects.

4.2 Business Logic Layer

The proposed knowledge management system is built upon the Java J2EE environment, a distributed component-based platform. The J2EE server is deployed in Business Logic Layer. It contains three major components: basic components, knowledge management components, and ontology management components. The functionality of each component is discussed as follows.

(1) Basic components

Basic components contain Publisher, UserManager, NewsEntity, ForumEntity, and UserEntity. The Publisher component is a Java session bean, which is responsible for publishing and maintaining news and articles via the NewsEntity and ForumEntity components. The NewsEntity and ForumEntity are Java entity beans that take care of the news and forum tables in System Database. The UserManager component provides the functionality for adding, removing, modifying, and searching users' data via the UserEntity component that is a Java entity bean.

(2) Knowledge management components

Knowledge management components manage two types of knowledge objects: personal knowledge object and common knowledge object. Personal knowledge object is maintained by the PKOManager component, which is a Java session bean that can create, share, browse, and remove personal knowledge objects through the PKOEntity component. The PKOEntity component maintains tables about personal knowledge in the format of memorandum, personally collected information, and other documents in the Personal Knowledge Database. Common knowledge object is managed by the KOManager component. The KOManager is also a Java session bean as the PKOManager component. It provides the functionality for public knowledge to create, share, remove, and browse via the KOEntity component, which is a Java entity bean. For knowledge searching, the KOSearch component provides an ontology-based search engine, which can search the domain and information ontology base through the DOManager and IOManager components, JAXB (Java Architecture for XML Binding) [11], and KAON service, to be discussed later. In other words, the search model of the KOSearch component is different from traditional content-based search. It is based on meta-model search and has better performance than the traditional search approaches.

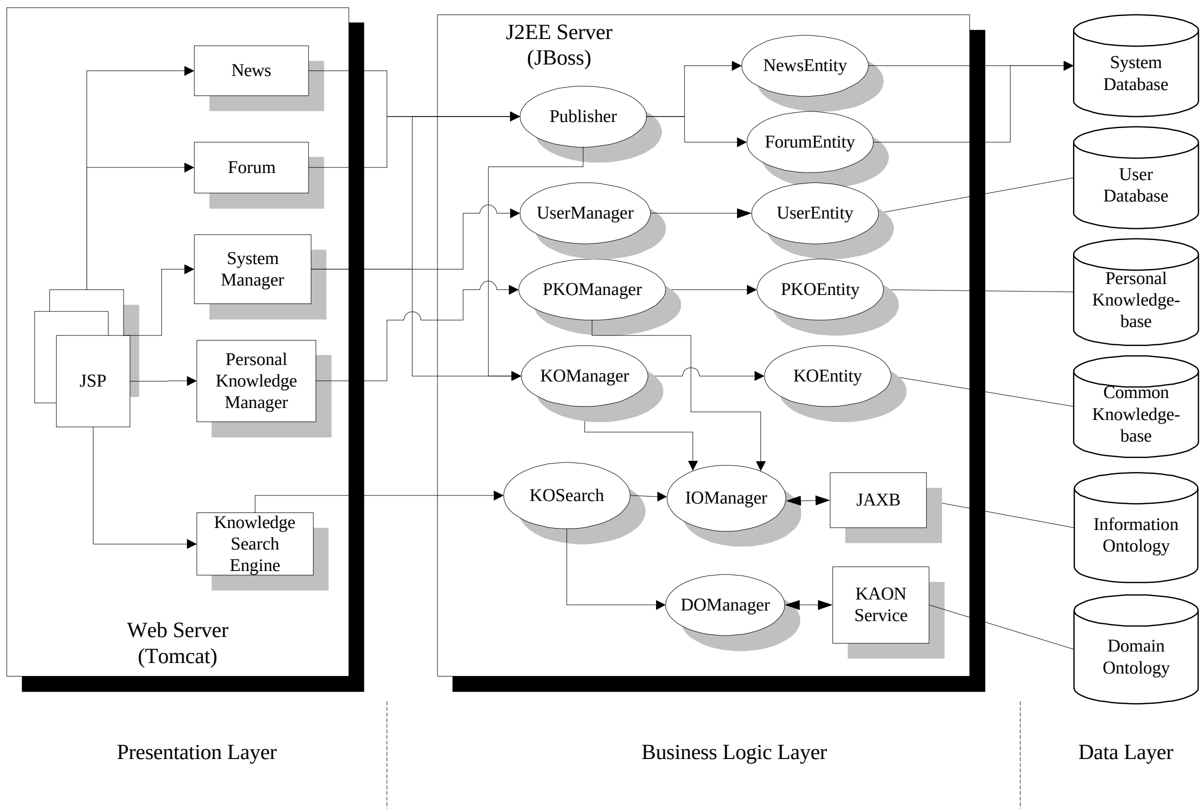

Figure 4. The architecture of ontology-based knowledge management system

(3) Ontology management components

As mentioned, DOManager and IOManager components are responsible for ontology management. These components can add, remove, modify, and search the ontology base. They manage domain ontology and information ontology, respectively. The DOManager component is implemented by KAON API that provides the functionality for concepts operation and inference. This component also communicates with the KAON service. The KAON service is a RDF server, which enables persisting RDF models in a relational database and is realized within J2EE [24]. Information ontology is stored as an XML file. JAXB provides a convenient and efficient approach to access XML files. IOManager that is based on the JAXB technology is responsible for maintaining information ontology. JAXB also provides APIs and tools to compile an XML schema into java classes.

4.3 Data Layer

All knowledge objects are stored in Data Layer. It contains several databases: system database, user database, personal knowledge base, common knowledge base, information ontology base, and domain ontology base.

(1) System database and user database

The system database stores the information of visitor, news, and the discussion of forum. The user database contains the basic data of users, e.g. user's name, ID, password, etc. The privileges of the permissions to create, modify, remove, and search knowledge object for users are also recorded in the user database.

(2) Personal knowledge base and common knowledge base

In order to facilitate the access of knowledge objects, the knowledge base stores two types of knowledge objects: personal knowledge object and common knowledge object. The personal knowledge object is maintained by end-users and stored in the personal knowledge base. In other words, users can engage in knowledge management by himself and can determine which knowledge object can be shared. The capability of common knowledge base is the same as the personal knowledge base. However, the knowledge object is public; it stores common documents, cases, and papers.

(3) Information ontology base and domain ontology base

The ontology bases are maintained by KAON service and JAXB. In KAON, one communicates with KAON service via KAON API for accessing domain ontology base. JAXB can easily access information ontology despite the scheme of information ontology is changed. In such way, the maintenance task of ontology base can be significantly simplified.

5. EXPERIMENTS

Currently, we already developed a prototype of ontology-based knowledge management system, which runs on JBoss-3.0.3_Tomcat-4.1.12 EJB server in SUN Ultra 10 Workstation.

The proposed system has been experimented by senior engineers at MIRDC in Taiwan since May 2002. Since most engineers participating in the project are not either computer-related or KMrelated staffs, the system must be designed as easily as it is operated and accessed. Therefore, the system is built on the top of Web-based environment. The snapshots of system demonstration are shown in Figures 5, 6, and 7.

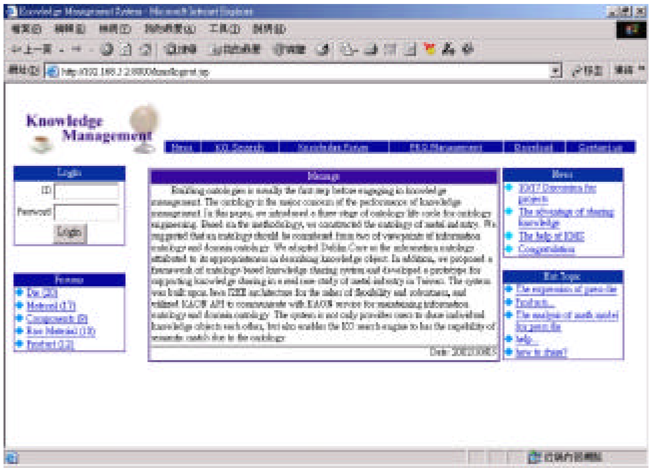

Figure 5. The entry of knowledge management system

Figure 5 is the entry point of the system. The user has to login the system first as an individual member or group member and then start to engage in the activities of knowledge management, including creating, editing, browsing, and searching knowledge objects. The creation of knowledge object with information ontology is shown in Figure 6, which is for the system administrator. As Figure 6 indicates, the user needs to select a knowledge object in advance and then fills up the information ontology by following Dublin Core. Finally, the knowledge object and information ontology will be submitted to the server and saved in the common knowledge base and information ontology base. When searching for knowledge objects, one only needs to fill out parts of Dublin Core, the knowledge search engine on the backend retrieves the matched objects from Information Ontology database.

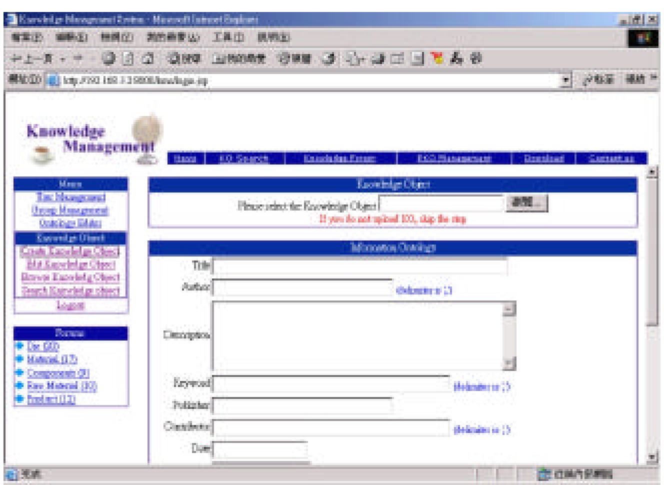

Figure 6. Building a knowledge object with information ontology

Furthermore, a domain ontology editor is developed so that an ontology engineer can conveniently and simply maintain the domain ontology, as shown in Figure 7. The left side in the figure is the hierarchical classification of metal ontology, and the right side is the viewer of concept. It shows the attributes, instances, and relation of a concept. To facilitate knowledge sharing, a Web-based virtual community is also designed which provides on-line forums, news, and hot topics.

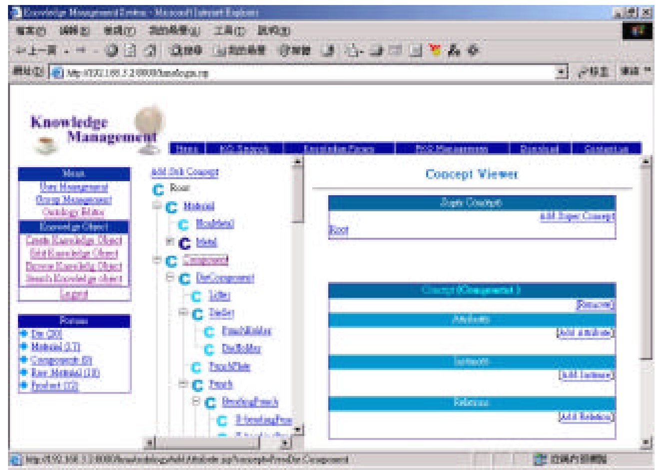

Figure 7. Domain Ontology Editor

6. CONCLUSIONS AND DISCUSSIONS

Building ontologies is usually the first step before engaging in knowledge management activities. The ontology is the major concern of the performance of knowledge management. In this paper, we introduced a three-stage of ontology life cycle for ontology engineering. Based on the methodology, we constructed the ontology of the metal industry. We suggested that ontology should be considered from two viewpoints: information ontology and domain ontology. We adopted Dublin Core as the information ontology attributed to its appropriateness in describing the knowledge object. In addition, we proposed a framework of ontology-based knowledge management system and developed a prototype for supporting knowledge management in a real case study of the metal industry in Taiwan. The system was built upon Java J2EE architecture for the sakes of flexibility and robustness, and it utilized KAON API to communicate with KAON service for maintaining information ontology and domain ontology. The system not only provides users to share individual knowledge objects with each other, but also enables the KO search engine to have the capability of semantic match due to the ontology. The major impact of this study brought to MIRDC a chance for promoting her from the traditional services in technical consultation and technology transfer toward "knowledge–driven" industry service due to her leading position in Taiwan's metal industry. In addition, the proposed component-based system, accompanied by ontology engineering, is generic thus can be applied to different domain applications.

During developing the proposed system, establishing definite and consistent ontology is perhaps the toughest task. The major hurdle is the communication of domain experts and knowledge engineers. It has to take much time and efforts to reach a consensus with all the team members. In addition, high reliance of each other is also of great necessity so that domain experts are willing to contribute the data, information, knowledge or anything that is needed. In this study, one year was spent to establish a common consensus and then to define the initial domain ontology in the metal industry.

From the viewpoint of implementation, there are a variety of ontology development tools available as show in Table 1; however, most of them are for the purpose of academic research; very few are for enterprise applications in practice. Furthermore, although some ontology tools are architectural complete, the lack of resources and supports often makes the development task complicated; for example, the KAON API used in developing an ontology editor and viewer. On the other hand, some ontology tools such as Protégé 2000 have rich resources and community's supports, but they are too complex to be applied.

In this study, we introduced knowledge management into the metal industry in Taiwan, and developed a pioneering prototype of ontology-based knowledge management system. At present, the system focuses on the issue of knowledge sharing and provides a simple way for knowledge searching. It still has enough room for improvement. In the future work, the inference of domain ontology should be incorporated into knowledge searching to support more precise and effective knowledge sharing. The other important issue of knowledge searching is the design of knowledge map, which allows engineers to be aware of the knowledge objects they can retrieve and prompt engineers for the knowledge needed in the next step.

7. ACKNOWLEDGMENTS

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