Journal of Universal Computer Science, vol. 9, no. 6 (2003), 472-480
submitted: 27/1/03, accepted: 17/3/03, appeared: 28/6/03

Managing Operation Knowledge for the Metal Industry

Sheng-Tun Li
(National Kaohsiung First University of Science Technology, Taiwan
stli@ccms.nkfust.edu.tw)

Huang-Chih Hsieh
(National Kaohsiung First University of Science Technology, Taiwan
jack@ai.nkfust.edu.tw)

Abstract: The development of a knowledge management system (KMS) is becoming increasingly important for the metal industry in Taiwan. The ontology design and knowledge search are two major activities of knowledge management. In this paper, we introduce a three-stage life cycle for the ontology design and propose a Java/XML-based scheme for automatically generating knowledge search components to reduce the overhead in developing a KMS. The resulting ontology is classified as information ontology and domain ontology so that the objective of semantic match for knowledge search can be realized. The system is built on the top of the component-based KAON development suite which makes it more flexible and robust. We conduct a case study by applying the system to Metal Industries Research & Development Centre (MIRDC), Taiwan to confirm its effectiveness and efficiency in dealing with KM activities. In addition, the proposed reusable scheme endorses the encouraging feasibility of wide applications to different domains.

Keywords: Knowledge management system, ontology, KAON, metal industry
Categories: H.4.m, I.2.4, K.6.1

1 Introduction

Metal industry plays a crucial role in the development of the manufacturing industries in Taiwan. In addition to tangible products or services, the most important assets are the expertise knowledge such as the measurement and computation of materials and operations. The sources of knowledge are not only from books, technical manuals, and education trainings, but also the accumulation of long-term experience which is usually stored in written documents. Since the diversity and complexity of conceptual terminology in the metal industry and the lack of proper document management, the existing knowledge is hard to be systematically arranged and reserved, even shared, and engineers or knowledge workers have to spend many efforts in searching the knowledge they need. With the increasing importance of knowledge, enterprises have been considered the application of knowledge management (KM) for helping knowledge workers search for knowledge efficiently and effectively.

KM is a complex problem and is related to many issues, such as socio-organizational, financial, economical, technical, human, and legal concerns [Barthés, 96]. The basic activities of KM include identification, acquisition, development, dissemination, use, and preservation of the enterprise's knowledge [Abecker, 98]. No matter what process is, the objective of KM is to promote knowledge growth, knowledge communication and knowledge preservation in an organization [Steels, 93]. In order to achieve the goal effectively and efficiently, the information technology has been considered as an active enabler of KM [Okunoye, 02], and there exist different KMS in facilitating the activities of KM [Abidi, 01][Barthès, 02][Chau, 02]. In order to enable communication and knowledge reuse between different actors interested in the same, shared domain of discourse, the ontology has been considered as an adequate methodology to establish a common consensus of communication [Gruber, 95] [Neches, 91], moreover, and to support a variety of activities of KM, including knowledge retrieval, store, sharing, and dissemination [Pundt, 99]. Defining ontology is a time-consuming and iterative job. In general, the identification and application of ontology is only for some specific domain, such as medicine, tourism, or metal industry.

In this paper, we propose an ontology-based KMS for managing operation knowledge for metal industry, which can assist engineers in sharing, searching, and managing knowledge. It also makes new employees conversant with their work as soon as possible. The proposed system is developed under a cooperation project of industry and academia. The objective of this project is to investigate the feasibility of applying ontology to 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. Different from other related work, we propose a scheme based on Java/XML in designing such a system which can automatically generate the kernel components of the system to reduce the overhead of developing a KMS. The resulting system demonstrates its salient features in the component reusability and facilitation of knowledge creation and search.

2 Ontology Modeling in Metal Industry

Since the ontology has been considered as an enabler of KM, building an ontology is usually the first step of facilitating KM activities. From the viewpoint of a KMS, an ontology can be regard as a meta-level description of knowledge presentation [Guarino, 97]. In [Abecker, 98], a three-level architecture of developing a KMS for intelligent decision support has been proposed, which contains, from the top to the bottom, the application level, the description level, and the object level. Ontologies are defined in the description level which enable users in the application level to intelligently access the object-level sources. In the object level, it comprises diverse information and knowledge sources or entities that are treated as knowledge objects (KOs). KOs can be numerical data, text streams, validated models, meta-models, movie clips, or animation sequences [Nemati, 02]. Based on the three-level architecture, users can precisely select and efficiently access knowledge via the description level from the application level.

Ontological engineering, the process of developing an ontology model, is a laborious and time-consuming task, which involves iterative steps in the life cycle. According to [Kayed, 01], the life cycle of an ontology design can be summarized as three major stages, i.e., building, manipulating and maintaining. The building stage is composed of four steps: specification, conceptualization, formalization, and implementation. The major work of specification is to identify the purpose, scope and requirements of the ontology. The conceptualisation step collects related data, extracts embedded terms, and categorizes them in a conceptual model. In the formalization step, the ontology can be converted from a natural language to a formal language such as conceptual graphs. Implementation, the last step, determines the technology that will be used to implement the ontology. After being built, the ontology could be browsed, searched, or operated, which are the activities supported in the manipulating stage. Finally, in the maintenance stage, ontology engineers should be able to analyze syntactically and lexically the ontology and add, remove, or modify the ontology definitions. In this study, we modify Kayed's life cycle by adding a "concerting" stage, stage of establishing common consensus, prior to the building stage. In particular, we apply it to the case of the metal industry in Taiwan and propose a framework for the ontology modeling as shown in Figure 1.

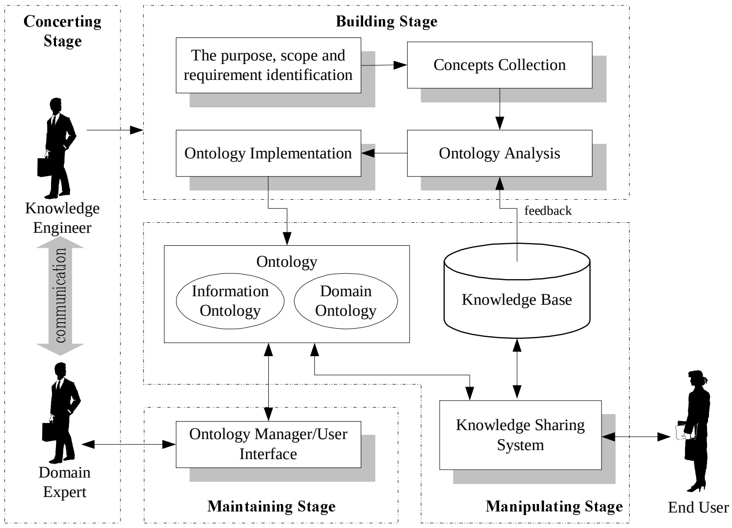

Figure 1: The framework of ontology modeling in metal industry

The major hurdle of ontological engineering results from the communcation of domain-related terms and concepts between knowledge engieers and domain experts. In the concerting stage, the knowledge engineer endeavors to understand what the domain is and what engineers do whereas the domain expert tries to comprehend the meaning of ontology, what ontology can do, what benefit it can bring, etc. The process of this stage is conducted by interview and questionnaires. When the common consensus is reached, we identify the purposes, scope and requirements of ontology in the building stage. Following, one may proceed to collect data and information about the concepts of metal industry. The resources of concepts, gathered from books, verbalized scripts of experts, printed documents and other ontologies, are further assembled, analyzed and converted into ontologies in the implementing ontology. In this study, we follow Abecker's work [Abecker, 98], which classifies an ontology into the information ontology and the domain ontology. 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 titles, authors, date, keywords, and other related information. The well-known Dublin Core, consisting of a set of 15 elements as defined in [Dcmi, 03], is adopted to describe the knowledge objects.

The domain ontology contains concepts, attributes, instances, and relations of metal industry. The purpose of a domain ontology is to support the functionality of semantic match when searching for knowledge objects. Figure 2 shows parts of the domain ontology of metal industry constructed in the building stage.

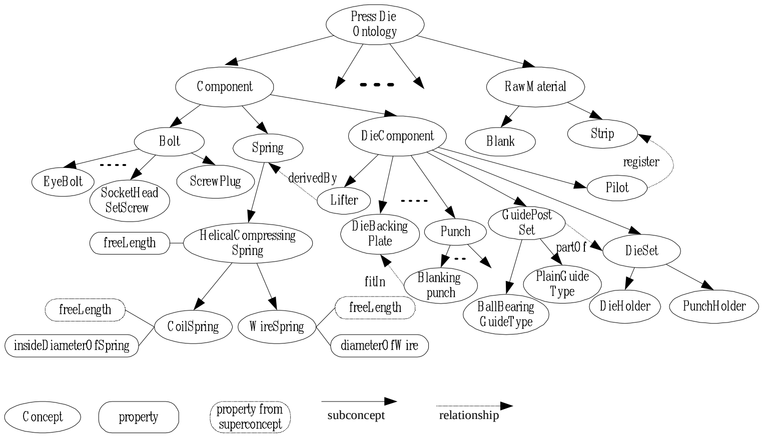

Figure 2: Parts of the domain ontology

As the Figure 2 indicates, there are two relations between concepts: subconcept and relationship. The subconcept relation, denoted by a line arrow, means that the concept is part of its super concept. In addition to the hierarchical relation inherent between subconcepts and superconcepts, structural relations, behavior relations and/or functional relations can be existed and denoted by a dash line with arrow with a term beside it. A concept may be consisted of one or more properties and be represented by a rounded rectangle and a line connected with one concept. Finally, a property may inherit from a superconcept; it will be shown by a dash line rounded rectangle.

As shown in Figure 2, Component is the parent class of Bolt, Spring and Die components. Die Set is the child of Die Component and there are two subconcepts in Die Set: Die Holder and Punch Holder. All these demonstrate the hierarchical relation of the metal ontology. For 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 in usual, thus there is a structural relation, fitIn, between a blanking punch and a punch plate. For lifting material strip within a required distance, since lifters are risen by springs, the relation of derivedBy between a lifter and a spring is defined. The left hand bottom of Figure 2 presents that Helical Compressing Spring has the freeLength property, Coil Spring has the insideDiameterOfSpring property, and Wire Spring has the diameterOfWire property, moreover, Coil Spring and Wire Spring also own the freeLength property because they are subconcepts of Helical Compressing Spring.

The ontology defined above will be deployed to a KMS in the manipulating stage, and support tasks of KM and searching when an end-user accesses the knowledge base. Note that there is a feedback loop between the knowledge base and the ontology via both ontology analysis and ontology implementation. With more and more various types of knowledge objects created in the knowledge base, the feedback loop provides the capability of expanding the information ontology.

In the maintaining stage, domain experts should be able to add, update, and remove the information ontology or the domain ontology via a user-friendly interface. These requirements can be realized generally by developing an ontology editor.

3 Ontology-based Knowledge Management System

To facilitate the KM activities of the metal industry in realizing the ontology model shown in Figure 2, we propose a layered KM system built on the top of KAON environment [Karlsruhe, 03] in this section. KAON provides an ontology development suite. It is open source and can be deployed onto a J2EE [J2ee, 03] architecture, a distributed component-based architecture, which makes the ontology-based KMS more flexible and robust. The ontology, in KAON, consists of concepts, properties, and instances grouped in a reusable units call OI-models (the ontology-instance model) [Motik, 02]. Property can be an attribute of the concept or connect one concept with other concepts to be the relation between concepts. Each property may be marked as symmetric, transitive, or inverse with other concepts, which endorses a lightweight inference mechanism in KAON. In such way, the ontology constructed by KAON tools provides a search engine with the functionality of semantic match in a KM system. Figure 3 depicts the architecture of the proposed system, which is composed of three layers: the Presentation Layer, the Business Logic Layer, and the Data Layer. Due to space limitation, only the kernel components and the design philosophy of the system will be discussed.

In general, managing and searching for knowledge objects play the key role in a KM system. In this study, knoweldge objects are categorized into two classes: the personal konwledge object (PKO) and the common knowledge object (CKO). The PKO belongs to an individual whereas the CKO is contributed by members in the practice of community of MIRDC and is sharable to the community. PKOs are managed by the PKOManager, which is a Java session bean that can create, share, browse, and remove personal knowledge objects through the PKOEntity component. PKOEntity, a Java entity bean, maintains tables about personal knowledge in the format of memorandum, personally collected information, and other documents in the Personal Knowledgebase. On the other hand, CKOs are managed by the KOManager component, also a Java session bean, which provides the functionality for public knowledge creating, sharing, removing, and browsing via an entity bean, KOEntity.

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) [Jaxb, 03], and the KAON Service, to be discussed later. The search approach of the KOSearch component provides two models: the information-ontology that searches knowledge objects by keyword exact-matching and the domain-ontology that expands the keyword by the domain ontology. For example, when users look for knowledge objects that belong to the Die Component concept, KOSearch will retrieve a concept set in which all subconcepts of Die Component in the information-ontology search, and then search for knowledge objects belong to the concept set. In the other words, KOSearch finds out the objects that contain the keywords of the concept set or whose Relation elements in the information-ontology are parts of the concept set.

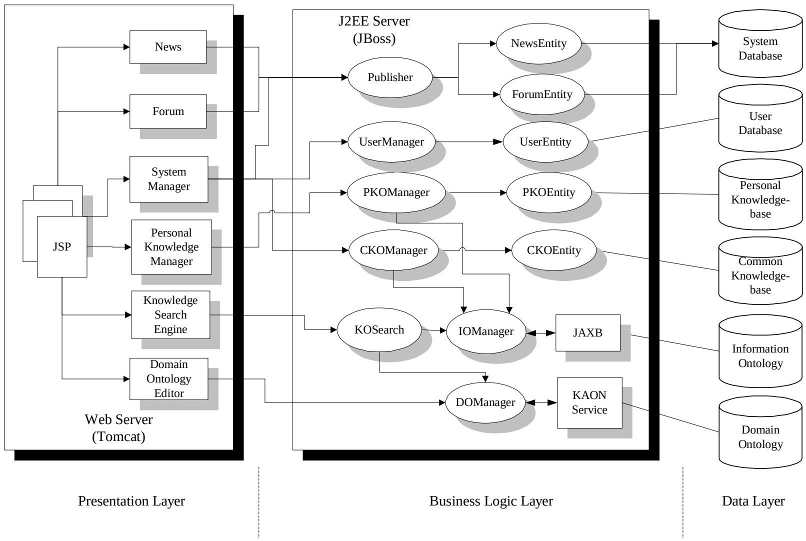

Figure 3: The architecture of an ontology-based knowledge management system

The development of a new KMS is also a time-consuming and laborious task. Furthermore, the lack of generic KMS and the different characteristics of domain knowledge make it difficult to apply existing KMS to other industries. To remedy such limitations, we follow the design philosophy of component reusbility in developing the proposed KMS. In particular, we propse a scheme based on XML/Java technologies which can automatically generate the KO management (KOM) components so that one may reengine the system to accommondate with different requirements of other domains.

Figure 4 shows the conceptual architecture of the proposed scheme. System developer defines a meta-schema description (MSD) for describing the format of the information ontology. MSD Parser reads the description of meta-schema, and then invokes the JBGenerator and the JSPGenerator according to the description. JBGenerator is responsible for reading JavaBean Template base and generating java beans that are in charge of the management of knowledge object base. The knowledge object base, KOBase, is a repository whose contents are adherent to the XML format. The KOBase Manager manages the KOBase via the Information Ontology Maintainer component. The Information Ontology Maintainer is constructed by applying JAXB [Jaxb, 03], a Java XML binding technology, which automatically generates java components for processing XML files via defining an XML schema. The KOBase Manager and Information Ontology Maintainer are compiled into a java package, named KOM Java Package which is to be deployed in the business logic layer mentioned in Figure 3. On the other hand, JSPGenerator is responsible for generating java server pages that is user interface in the presentation layer of Figure 3 according to the JSP Template base.

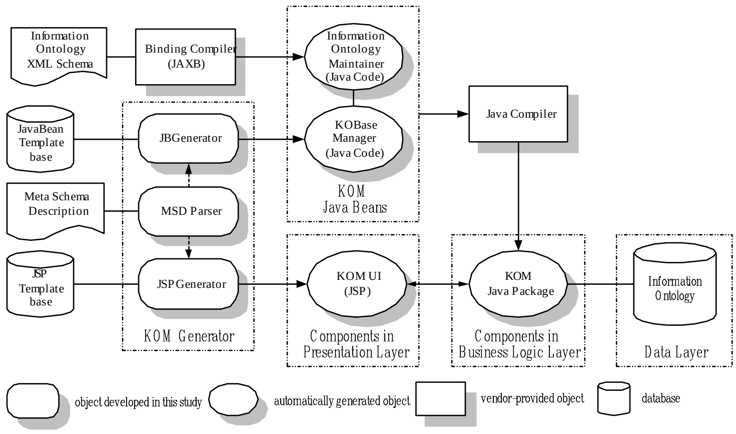

Figure 4: A scheme for automatic component generation

4 System Demonstration

Currently, a prototype of the ontology-based KMS has been developed and under test at MIRDC. This system provides three classes of functionality, system administration (for example, membership privileges, accounts, and ontology editing), management of knowledge objects (including create, edit, browse and search), and community of practice (such as forums). We only discuss the knowledge search functionality due to space limitation. As mentioned in Section 3, the system provides two search models. When a knowledge worker wants to search knowledge objects whose keywords in the information ontology contain ‘DieComponent’, he will get nothing if the choice of “Enable domain ontology” is disabled since there are no knowledge objects contains the ‘DieComponent’ keyword in the information ontology. On the contrary, more semantically matched knowledge objects will be returned if the choice is enabled (see Figure 5).

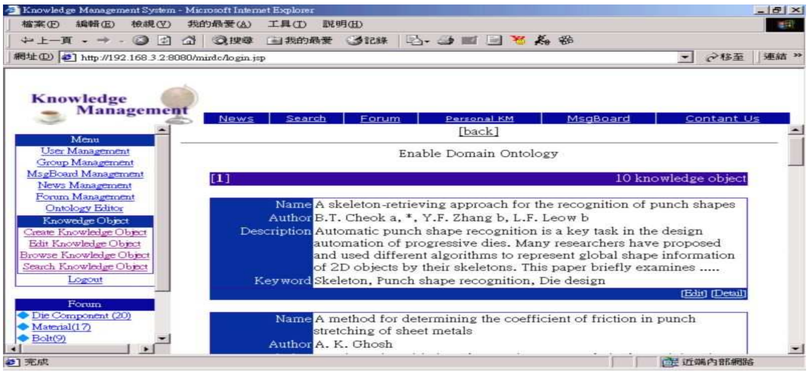

Figure 5: Result of searching a knowledge object

5 Discussions and Conclusions

We propose the framework of an ontology-based KMS and develop a prototype for supporting the KM in a real case study of MIRDC in Taiwan's metal industry. During developing the proposed system, establishing a definite and consistent ontology is the most challenge task. The major hurdle is the communication between domain experts and knowledge engineers. It has been taken most time and efforts to reach consensus for 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, or knowledge we need. In this study, we established common consensus and defined the initial domain ontology in the metal industry. The resulting ontology is classified into the information ontology and the domain ontology so that the semantic match of knowledge search can be realized. The ontology-based system is built upon the KAON suite for the sakes of flexibility and robustness, and utilized the KAON API to communicate with KAON services for maintaining the information ontology and the domain ontology. Furthermore, we propose a scheme on the basis of Java/XML technologies to reduce the overhead in developing this KMS and increase its applicability to other domains. At present, the system focuses on the issue of knowledge sharing and provides a simple way for knowledge searching. In the future work, the inference of the domain ontology will be incorporated into knowledge searching to support more precise and effective knowledge sharing. The other important issue of knowledge searching is the design of a knowledge map, which allows engineers to be aware that how knowledge objects they can retrieve, and prompt engineers what knowledge they need in the next step.

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