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INFORMATION SHARING AND REUSE IN E-KM USING THE SEMANTIC WEB TECHNOLOGY

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ABSTRACT

e-KM is the electronic knowledge management system that enables sharing of corporate knowledge in an organization. Due to globalization, organization often faces with sharing of corporate knowledge in different locations. It is not an easy task to maintain and update distributed knowledge in a timely manner in a rapidly changing environment. This paper proposes the application of the Semantic Web technology, in particular the use of ontology, as a means for knowledge representation that allows standardization of concepts and terms used by community of users in the e-KM environment. This way human users as well as software agents can communicate with each other based on a standardized list of vocabularies.

Index Terms— e-KM, Semantic Web, Ontology

1. INTRODUCTION

The purpose of building electronic knowledge management system (e-KM) is to share corporate knowledge in the organization with the aim of providing support for knowledge sharing within communities-of-practice. In general, successful use of e-KM can result in leverage for sharing knowledge within an organization. However, it is difficult to keep distributed knowledge up-to-date and to maintain the sharing of knowledge in the current rapid changing environment. Globalization of organizations also means there is a need for knowledge to be shared in different locations. Knowledge sharing within an organization is often focused on skills and facts that can be written down and taught to others. This type of knowledge is often classified as explicit knowledge. On the other hand, tacit knowledge is knowledge and skill that is hard to describe such as experience or native talent in people. In general, it is difficult to code tacit knowledge.

Knowledge acquisition is generally considered to be one of the most important steps in knowledge management development. Knowledge acquisition method is designed to construct explicit knowledge from implicit or tacit knowledge. This is often performed using manual methods such as interviewing, tracking the reasoning process, and observing documented and undocumented knowledge. The aim of this process is to find what information or knowledge is being used and how it is being used. Another difficulty that has been identified is the need in sharing and reuse knowledge in e-KM. Inefficient knowledge representation can result difficulty to change and update knowledge stored in e-KM, in particular if one wishes to extend or revise knowledge gained through new processes or new learning.

2. LITERATURE REVIEW

2.1. Knowledge Management System (e-KM)

To clarify ambiguous definitions used in many fields of studies, we begin this section by defining the terms used in this paper: data, information and knowledge. Data are the raw inputs of individual facts or items of information. Information is processed and value-added data. Knowledge is the understanding of what information implies. For example, the raw input value of 0.15 means nothing until it is linked to another fact such as the stock price, and a company called Apple, Ltd. Now, the value of 0.15 is processed as an increment value for the stock price of the company Apple. In addition, we learn that this stock price has increased by 0.15% for the company Apple overnight. In other words, as far as we understand, the company Apple has earned 0.15% of its stock value that makes it financially stronger today. We say that we gained knowledge about Apple's current financial value. Knowledge can be further classified as tacit and explicit knowledge [17]. Tacit knowledge is knowledge that cannot be easily described such as skills, experience or native talent. Explicit knowledge is skills and facts that can be written down, expressed in a procedural manner and taught to others such as financial analysis documents.

Since the mid-1970s, knowledge began to play an important role in organizational strategies. By the 1980s, the importance of organizational knowledge is increasingly recognized. Organizations have focused on processes and strategies to manage innovation and to build knowledge [10]. As a result, a system is developed to provide a technological base for managing knowledge. The term knowledge management can be viewed as management of knowledge-related activities. These activities include broad, multi-dimensional and cover most aspect of activities in an enterprise [16]. For example, MediaOne knowledge management project is initiated in 1998 to support shared corporate resources and individual experiences across the enterprise [12].

There are different approaches in which knowledge management is used in the organizations. The first approach is that of repository model. For example, the use of web sites as a disclosure platform for corporate performance has been shown to be beneficial [6]. It focuses on managing information and reusing knowledge in tangible formats. Knowledge management is also considered to be an organizational intellectual asset [2]. This approach is viewed from the legal perspective. It involves intellectual capital, copyright, patents and trademarks. Knowledge management can also be regarded as business intelligence. It is a process to produce valuable up-to-date information for operative and strategic decision-making [8]. One of the important factors for this process is supported by financial analysis. One practical example in finance is the use of XBRL (eXensible Business Reporting Language) to standardize protocols for transmission of accounting information in the Internet [4]. With the help of business intelligence, organizations achieve competitive advantages in a rapidly changing business environment by utilizing intelligence to the relevant knowledge gained. Other approaches include the cognitive and continuous learning approach which is the ability to learn. It involves an individual ability's to acquire continuous and ongoing renewal of organizational information and reuse it for problem solving and decision-making. In addition, cognitive approach of knowledge management focuses on learning within groups as well as individual's learning level.

Thus, it can be seen that a lot of organizations have begun to recognize knowledge as the most valuable asset in their organizations. These valuable assets include personal skills and experience as well as any stored information within the organizations. In general, e-KM refers to a system that designs specifically to provide the sharing and integration of knowledge [1]. It allows corporate knowledge to be shared effectively and efficiently [15]. According to Thierauf [14], e-KM is a system that can provide competitive advantage by giving decision makers necessary insight into patterns and trends that affect the problem domain. Using e-KM one is able to make comparisons, trends analysis, historical and current knowledge presentations to assist in decision planning and decision making by analyzing and understanding the patterns quickly and identifying the most significant trends.

2.2. The Semantic Web

The Semantic Web is described as an extension of the current Web in which information is given well-defined meaning (known as ontology), and enabling computers (in particular software agents that behave like personal assistant) and people to work in a cooperative manner [3]. The term ontology is defined as "a formal explicit specification of a shared conceptualization" [7, p.2], or "a formal specification of a shared conceptualization" [5, p.28]. Basically, ontology works like a standardized list of vocabularies, that is, everyone communicates with each other in the same language [7]. For example, *a/c* stands for an account, and it is a terminology well-known to everyone in the accounting and finance discipline. There are other names that can be associated with *a/c* such as bank account or financial credit. In this case *a/c* has a similar meaning it associated with, this is known as synonym. Thus ontology seeks to demonstrate a clear understanding of the domain of interest for well structured Web resources in the Semantic Web.

However, current web resources, such as web-based financial documents, in the current Web do not normally contain data about data (metadata); which refers to their relationships to other web resources. This kind of web-based metadata is referred as ontological information. We call this type of web resource as a "not well-structured web resource". Figure 1 shows an example of how information is represented in the current Web using hyperlinks. A web resource is linked to each other using a hypertext reference (*href*) in HyperText Markup Language (HTML). This type of information does not provide adequate information on the kinds of relationships between the resources. In Figure 1, we know that there are four web resources that are linked to one another and we can browse these documents by clicking the link on the Web browser. However we do not know what kind of relationship exists between these resources.

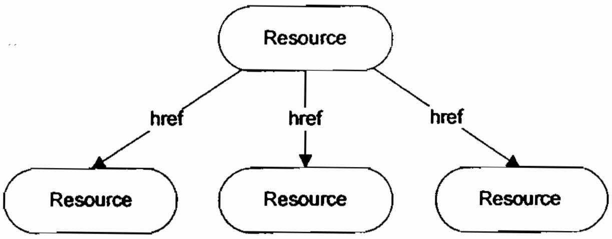

Figure 1 Example of information on the current World Wide Web.

Figure 2 shows another example of web resource with ontological information, where the node is shown as ellipse, the resource is represented as rectangle, and the link as arrow [18]. Figure 2 shows more informative relationship. In this example, the links *relatedTo*, *hasMission* and *knownAs* are more informative than simply a link of *href*. In Figure 2, the web resource of the Stock Exchange of Thailand (SET) is identified by the Uniform Resource Identifier (URI): *http://www.set.or.th/SET*. This resource has properties such as name (*knownAs*) and mission (*hasMission*). The link *relatedTo* describes a university name: The University of the Thai Chamber of Commerce identified by URI *http://www.utcc.co.th*. Thus we can say that URI *http://www.set.or.th/SET* can be read as The Stock Exchange of Thailand that is related to The University of the Thai Chamber of Commerce.

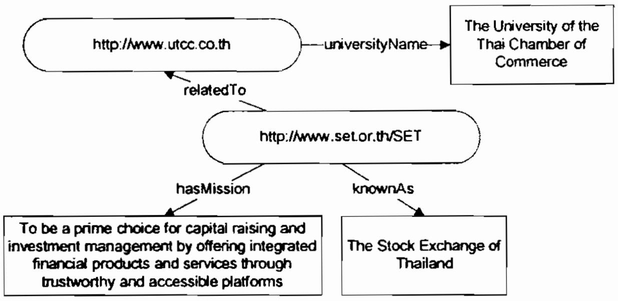

Figure 2 An example of partial ontological information for SET.

To illustrate an SET ontology, we use Protégé editor which is a tool used to build the ontology. Figure 3 shows a graphical representation of the SET ontology that specifies the concepts of the SET related information, services and products for decision support in financial practices, and sharing of accounting data within the organization.

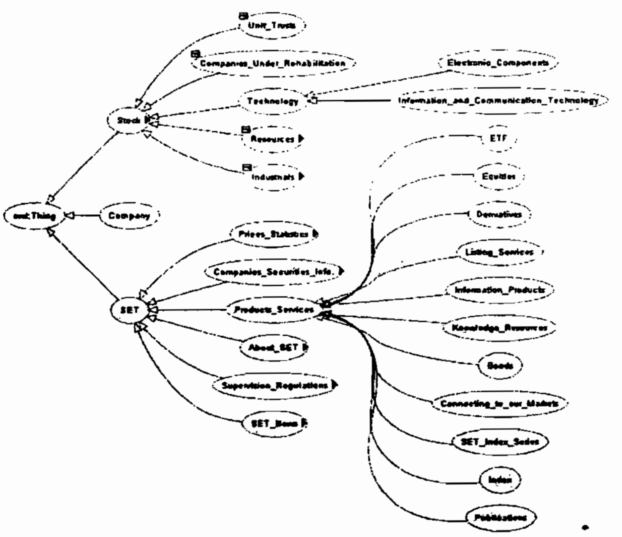

Figure 3 Example of SET ontology with partial information.

There are over 85 defined concepts (known as classes) of the SET ontology. For instance, the concept of Stock has 11 sub-concepts. Due to space constraints, only five of these sub-concepts are shown in Figure 3. According to SET, each sub-concept of Stock is disjoint. This means it must belong to an industry only. For example, company *A* that is classified as the *technology industry* cannot be classified as a *resource industry* at the same time.

In relation to the Semantic Web and ontologies, James Hendler [9] forecasts a vision of the Semantic Web Ontologies, as shown in Figure 4. The first step of its use is to create web pages with ontological information. This means knowledge experts and individuals can develop decentralized small-sized ontologies. Overtime, one or more ontologies can be linked to other ontologies to allow sharing of repositories. The second vision of the Semantic Web Ontology is the definition of services in a machine-readable form. This means ontologies can be used to agree on terms and constraints for web services. For example, e-commerce programs can share and reuse information based on machine-readable ontologies. The final vision of the Semantic Web Ontology is the use of logics and software agents. Logics and rules are being used to improve description of software agents' services. Intelligent software agents are communicating with other agents using the terms represented in ontologies, exchanging portion of other agents' ontologies, as well as merging other agents' ontologies as.

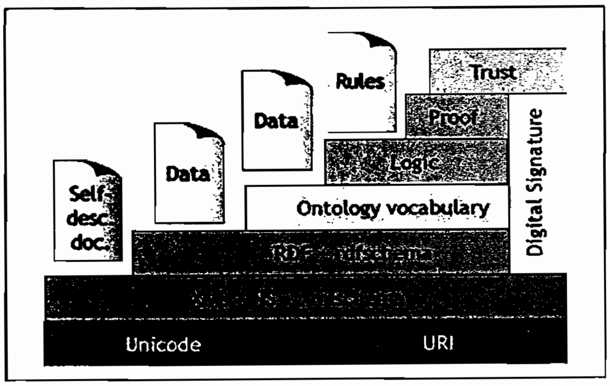

Figure 4 The Semantic Web as a layer cake. (Source: Berners-Lee et al. 2001b, p. 30)

One of the challenges in the development of e-KM is the difficulty in accurately representing knowledge explicitly, particularly in the domain of interest. A domain expert often finds that it is not possible to expressively describe his or her knowledge to the system engineer. Thus the need for building better and more interoperable interpretation approach is essential to solve the ambiguity problem in knowledge representation. There is also a need to share meaning of terms or a set of names as those used in a given domain by an individual or the community. In order to effectively deploy a shared term or name, a clear understanding of the particular domain has to be agreed by the community of practice. In other words, a way to conceptualize the given domain by the community has to be published and broadly agreed among the interest groups. This approach ensures situations where misunderstanding and misinterpretation of conceptual modeling in terms of taxonomy not likely to occur. Thus an ontological approach not only provides a clear understanding of terms but also for unambiguous definitions of complex concepts and classifications.

3. SYSTEM DEVELOPMENT

e-KM is an a kind of information systems, thus it is essential to follow a system development methodology to develop an e-KM. This paper follows the systems development life cycle approach (SDLC) which consists of the following stages: 1) system planning, 2) system analysis, 3) system design, and 4) system implementation.

3.1. System Planning

The system planning phase identifies the need for a new or enhanced system. We have selected the Stock Exchange of Thailand (SET) as a case study in this paper in order to investigate possible ways to deal with knowledge sharing and reuse in e-KM. The proposed system incorporates new functionalities into users' daily work rather than developing a new system from scratch. We will investigate the scenarios in which both human and software agents use a specific domain that deals with a specific ontology; that is the domain knowledge of the SET. The software agent accesses information available on a corporate server using its own ontology that has a common semantic source. The semantic source maps the concepts and their relationships to the SET server. Thus both human and software agents are able to use the same domain knowledge to answer query. This is known as reasoning. We use the Semantic Web technology which has the capacity of reasoning to customize the user queries in a form of frequently asked questions (FAQ).

3.2. System Analysis

During the systems analysis phase, we consider tasks associated with information retrieval and knowledge representation. In the current business world, which is characterized by globalization and rapid changing demands, a comprehensive view of knowledge management approach is on demand to support emerging global economy. This results in knowledge representation becoming more complicated which requires a more systematic approach to analysis. When a well-defined and agreed terminology is adopted within the community of practice, challenges associated with knowledge representation can be minimized. As discussed, this can be achieved using ontology. Ontology not only provides a better support for standardization of terminologies, it also provides an opportunity for better knowledge sharing and reuse [11].

Ironically, financial web resources in the existing Web environment are mainly published for mass media. This is generally not a context-sensitive approach. For example, when a researcher uses keywords to search in an online financial database (generally the keywords are considered to be "valid" keyword in the domain of search), the results of the query often do not match as intended. The current Web contains vast amount of financial information resources, such as financial reports, statistics, stock prices and information of listed companies. Making these resources available in a more structured way is one of the goals of our long term project efforts. Using an ontological approach enables a well-defined financial sector conceptual model to be developed. With the well-formed conceptual model of the financial data, we can produce a reliable query processing module which can be integrated into, a Web service through simple client application. The end-user query can be widened or narrow- downed to specific concepts such as a list of newly listed companies that only worked for a particular industry. The former information is already available in the SET and the latter is also available within companies that maintain details of their partner companies. Thus both data can be easily shared over a query. This is an example of advantages of sharing ontological information over the Web. In this paper, we start with a small-scale, but practical example of ontology for the Stock Exchange of Thailand (SET). Potential use cases of this ontology are for decision support in financial practices, and sharing of financial data within an organization. In this way, frequently asked questions for the SET can be answered systematically.

Demand	Supply
Business	Market trends, patterns, effects
Learning	Knowledge reuse and share, personal skills development
Legal	Intelligent property, copyrights, patents
Strategy	Value-added, decision marking, business intelligent

Table 1 Knowledge management system on business needs on demand and supply.

3.3. System Design

In the system design phase, both logical and physical design is transformed into a technology-specific system. Our investigation shows that the SET has six categories on its website: *About SET, Companies / Securities Info., Prices & Statistics, Products & Services, SET News* and *Supervision & Regulations*. Each category has several subcategories. For example, *About SET* has *Mission & Vision, SET Overview, Corporate Reports, SET Holidays, Job Opportunities* and *Map to SET*. For the purpose of demonstration, this paper focuses on an application of corporate governance based on information from the SET. We constructed concepts started from categorizing the different terms according to their relations in the ontology. A key idea of constructing such an ontology is to share common understating of domain knowledge: the SET. Figure 5 shows an example of the SET ontology constructed for this research.

Figure 5 Example of the SET ontology

In Figure 6, the client-server architecture provides a simplified web service whenever the client requests for information service. For examples, client 1 requests a list of the SET listed companies that is only available as a form of EXCEL file on the SET server. It does not include details of those listed companies such as a contact phone number and business address (although recently it includes the website addresses). We use an ontology on the top of the current system as an extension module to reuse company information already available online, and share among the clients (for example, CG client 1 and Software Agent 1 in Figure 6). In this way, an introduction of new functionality minimizes conflicts with existing systems' functionalities. The purpose of supporting machine understandable format meets the requirement of ontological design concept as it can improve knowledge acquisition process using intelligent software agents. Sometimes, the software agents need to compare or merge information of two or more terms to check whether it refers to the same concept. This happens when logical expressions, such as AND or OR, are used by the software agents.

Thus both normal client applications and the software agents can access to Corp. A server by using web service or built-in ontology-based query.

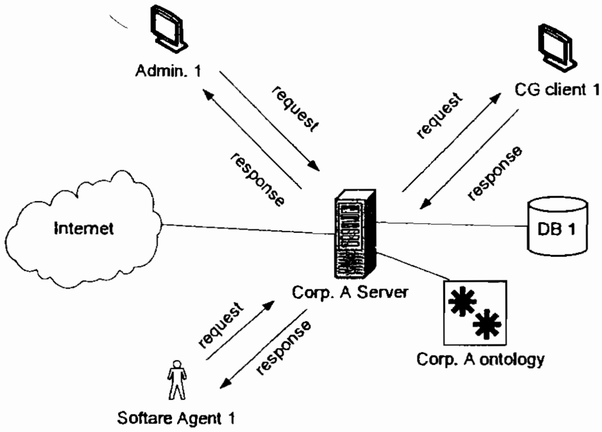

Figure 6 e-KM application on the Semantic Web environment.

3.4 System Implementation

In the final system implementation phase, systems specifications are turned into a working system. In addition, our current approach to the systems development also focuses on a self-adaptive development process. It is known as agile methodologies. The reason is that the system has dynamic requirements and continual user involvement. Using prototype, we illustrate how the system works over the Semantic Web. The SET provides information to build a possible ontology for its domain. Some of the questions we want to answer are: Which is the list of the SET listed companies, and what is their contact information? Which are the delisted companies of the SET?

Once we have an idea of what we want to know, we start to list some of the important terms we need. These include basic concepts, properties (characteristics of a concept) and relationships. We add the terms used on the SET. Furthermore, we have also added our own concept of 'company'. Each company has a name, contact information that may or may not be a listed or delisted company of the SET. For example, we want to know the delisted company's name, and an office phone number. As we continue to build our terms up, we are implicitly defining the scope of our ontology. For instance, in our initial examination, we had not considered the term 'company' as it is not a part of the SET. However, we have to define it in our ontology to allow contact details to be focused on, which are not available from the SET. Therefore, we decide to include company as a term of interest as well as properties associated with company's contact details. In general, it is a repeated process when there is inconsistency, duplication or missing concept.

We will illustrate how to locate the company's records in the knowledge base (known as instances) using the Protégé editor. First, the user inputs "Company" in the form window in Figure 7a. The company records are then displayed in Figure 7b. In practice, it should include all companies listed on the SET with all comprehensive information.

Figure 7a An example of listed companies from the SET.

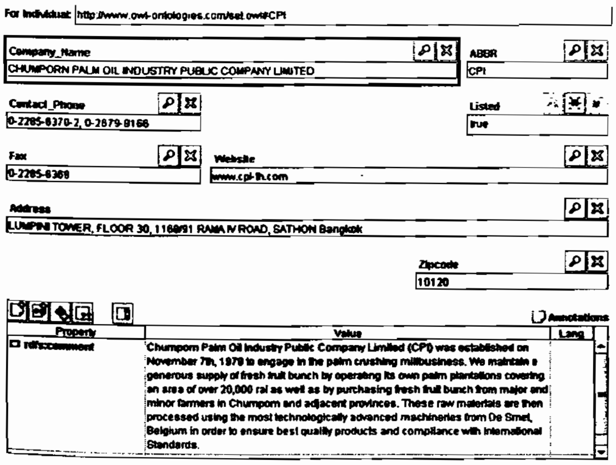

Figure 7b An example of listed companies' contact details.

Suppose we are interested in locating all listed companies of the SET and their contact information. Using Protégé editor, we can build and locate all companies that match the criteria we have specified. To create a query, we selected one class (Company), and one slot (Listed) within that class. We set 'Listed' slot as a 'true' value to retrieve the listed companies (as shown in Figure 8). In this way, the query can be tailored to the need of the users.

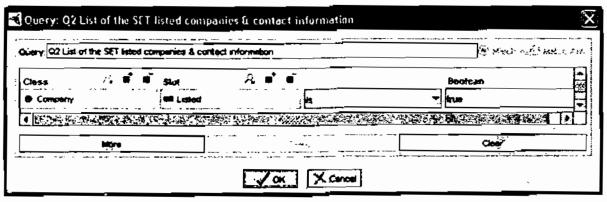

Figure 8 An example query on 'listed companies and contact information of the SET'.

As can be seen from Figure 8, when the user locates companies that they are interested in, they can browse the company list for a specified list; for example of listed or delisted companies. Figure 9 shows the result of the listed companies. For each concept 'company' in the ontology, it returns with a contained data. For example, the first record shows a company name 'CPI': CHUMPORN PALM OIL INDUSTRY PUBLIC COMPANY LIMITED. For demonstration purposes, there are 19 limited companies on the figure. In reality there are 496 companies in 2009 [13].

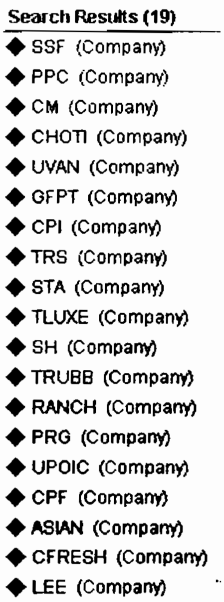

Figure 9 Results of lists of the SET listed companies and contact information.

As shown in Figure 10, the web application makes it possible to browse the knowledge form associated with the SET ontology on the Web. For demonstration, a simple SPARQL query is implemented to return the result in the browser window. SPARQL is the query language for RDF (Resource Description Framework) as well as OWL (Web Ontology Language) [19]. The following code shows how to find the company information from the given data graph with the main building blocks of the SPARQL query. The query consists of two parts: the SELECT clause identifies the variables to appear in the query results, and the WHERE clause provides the basic graph pattern to match against the data graph.

```
PREFIX set: <http://www.owl-
ontologies.com/set.owl>

SELCET ?companyName ?aBBR ?contactPhone
?fax ?website ?address ?zipcode
WHERE
{
   ?x set:isListed "true"
   ?x set:Company_Name ?companyName
   ?x set:ABBR ?aBBR
   ?x set:Contact_Phone ?contactPhone
   ?x set:Fax ?fax
   ?x set:Website ?website
   ?x set:Address ?address
   ?x set:Zipcode ?zipcode
}
```

An advantage of this approach is that the SPARQL query provides a means of sophisticated integration over distributed source of information. A disadvantage is the implementation of the query engine is directly dependent on the repository being used. In this case when multiple ontologies are stored in using file-based systems, it may cause computation limitation. Thus the design decision on how queries are to be translated should be based on optimization techniques.

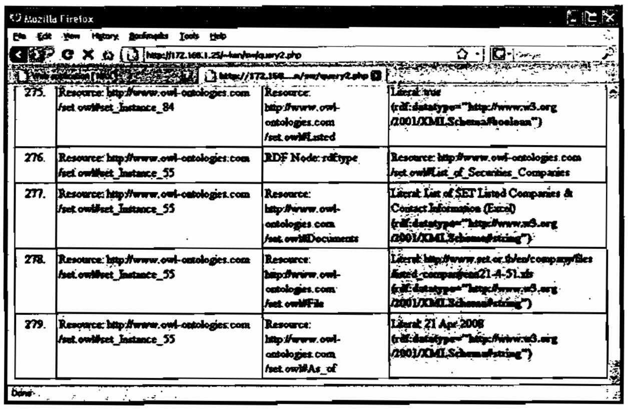

Figure 10 An example of web application using the SET ontology.

In this section, we discuss an alternative approach for our e-KM in the client-server architecture. While the above approach shown in Figure 10 may provide some possibilities, it is not intuitive for normal users. We aim to demonstrate the potential of Semantic Web technology for developing ontology-driven e-KM in the client-server mode which can be viewed as management of knowledge-related activities that includes the use of web sites as a disclosure platform for corporate performance and trends analysis of historical and current knowledge presentations. Figure 11 illustrates the following: the CG client 1 (See Figure 6) browses the company's data using the Protégé user interface. In this way, the CG client can be familiar with information provided for the e-KM application, which is a knowledge domain of the SET. It is important to note that the Protégé's client-server mode is capable of allowing multiple clients to simultaneously edit a shared ontology stored on a Protégé server, however we limited the CG clients only to browse information. Once the necessary content and ontologies are published on the Web, an important trade-off is that it provides the ability to use knowledge. That is, it draws inference from the information that has been explicitly stored on the server. In contrast, it seems impractical to incorporate any modification of the existing ontologies via the CG client. It has no substantial advantage of providing such features to the CG client due to security concern, which may result in removing important portions of the ontologies.

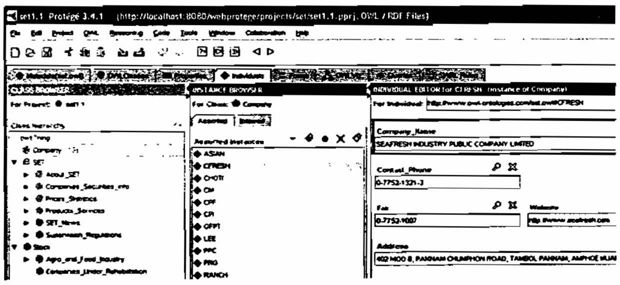

Figure 11 Illustration of ontology-driven e-KM in the client-server mode.

Since most of the CG clients in general populations do not have advanced IT skills, it is unrealistic to expect that they will adapt to the advanced interface such as through the use of configurable software agents. In view of this, we adapted that most of the input and output interfaces supported by Protégé initially. As this research is currently in progress, we have not yet deployed software agents in our system. However, it is our goal that the e-KM will provide the user an assistant agent monitoring the information. As the system requires flexible and autonomous software agents to assist human agents (the CG clients, See Figure 6), the assistant agent will gather the information provided by the corporate server (Corp. A Server, See Figure 6) and then it performs the task given by the human agent.

4. CONCLUSION

It is essential to maintain distributed knowledge to ensure it is current, up to date and be able to make rapid growing data continuously available in a changing world. E-KM enables sharing and reusing of corporate knowledge. One of the main differences between the conventional knowledge management system and the e-KM proposed here is the use of ontology. The proposed e-KM enables us to find information, share and reuse for both human and machine users on the Semantic Web environment. With ontology, a standardized list of vocabularies can be developed so that everyone in the community can communicates with each other with the same language. This leads to minimizing asymmetric information problems.

In the next stage of the study, we will investigate the development of an ontological-based e-KM of corporate governance (CG) client based on information from the SET. In this scenario, we consider CG as a way to direct business to its strategy and information disclosure, and as a mechanism to monitor fraud in the business. In this aspect, software agents can be developed to detect conformance of corporate governance using ontology-based e-KM. The system provides corporate governance policy to be shared and reused by financial users as well as software agents. Any change to the corporate governance policy can be updated and distributed accordingly by the e-KM.

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