AN AGENT-BASED KNOWLEDGE MANAGEMENT FRAMEWORK FOR THE E-COMMERCE ENVIRONMENT

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ABSTRACT

Knowledge Management (KM) is emerging as one of the management tools to gain competitive advantage and e-businesses are beginning to invest in KM initiatives. Though several organizations have reported successful KM projects, there are many failures due to a variety of reasons including the incongruence between strategic and KM objectives, as well as lack of a framework for supporting KM related activities. This paper presents a framework for knowledge management, which takes into account the different levels of knowledge that exist within e-businesses. The architecture of a KM system that incorporates enabling technologies such as intelligent agents and XML is also discussed.

INTRODUCTION

The e-commerce business paradigm has been well established and the number of e-businesses carrying out commercial transactions over the web has increased by leaps and bounds. At the same time, many of the traditional businesses moving into the e-business arena are not performing well partly because of inflexibility and the inability to manage their online customers and business processes (21). Organizations have to redesign their internal structure and external relationships and create knowledge networks to facilitate the creation and management of e-business knowledge that would improve back-office efficiency, greater customer intimacy, and flexible adaptation to market changes (1, 4). Thus, it is imperative that e-businesses invest in knowledge management and establish processes and infrastructure necessary to create and manage e-business knowledge.

Knowledge management (KM) not only focuses on managing the knowledge assets of an organization but also managing the processes that act upon these assets (12). Knowledge networks facilitate interactions with external stakeholders, such as suppliers, customers and business partners (19, 34). Some of the advantages of implementing a KM infrastructure are: a) providing effective and timely access to corporate knowledge at all levels so that efficiencies and competitive advantages are realized, b) transforming the diverse members of the organization into a knowledge work community, and c) enabling evidence/knowledge based decision-making to improve the quality and timeliness of the decisions made (27).

While several organizations have successfully implemented KM initiatives, there are many reported cases of unsuccessful KM projects that provide ample opportunities for analyzing and learning from those mistakes (2, 14). Some of the pitfalls of KM projects (7) are lack of: 1) congruence between strategic objectives and KM objectives, b) identification and standard representation of knowledge assets to be managed, c) routine processes to support KM life cycle, d) infrastructure and key personnel in charge of KM activities, e) access to knowledge, and f) knowledge sharing attitude and motivation. Fahey and Prusak (14) also point out that the fundamental purpose of managing knowledge is to create a shared context between individuals, which is not always achieved.

Hence, the objective of this research is to: a) develop a knowledge management framework for capturing, manipulating and disseminating e-business knowledge using enabling technologies such as intelligent-agent and XML, and b) develop an architecture for a system which implements this framework to partially automate KM activities.

The remainder of this paper is organized as follows. Following the introduction, some background material on knowledge management, intelligent agents, and XML technology is provided. The next section discusses the role of KM in e-commerce and presents a knowledge management framework that differentiates between various types of knowledge. The architecture of an agent-based system that incorporates the proposed framework is discussed next. Then, the implementation details of the proof-of-concept prototype as well as a sample session with the prototype are described, and finally the paper concludes with a summary.

BACKGROUND

This research draws from established theories from the areas of Knowledge Management (KM Life Cycle), Intelligent Agent Systems (Agency theory), and Text Representation & Rendering (markup languages). These three areas are briefly described in the following sections.

Knowledge Management

There is an increased sense of urgency in institutionalizing comprehensive knowledge management programs due to the fact that the Internet and the World Wide Web are revolutionizing the way enterprises do business. Organizations have to motivate and enable their knowledge workers to be more productive through knowledge sharing and reuse. A well designed KM infrastructure will make it easier for people to share information during problem solving that would result in reduced operating cost, improved staff productivity, cost avoidance, and soft benefits such as increasing the knowledge base and sharing expertise.

To a large extent, the design and development of a KM system depends on the type of problem to be solved and the

relevant knowledge that it has to manage. In general, business knowledge is classified based on the ability to formalize, represent and communicate. For effective use of such knowledge systems, the capability to manipulate different knowledge forms is crucial. Fowler (17) presents the following knowledge taxonomy: *declarative* (facts and assertions), *procedural* (logic and methods), *explicit* (articulatable, codeable, systematic), *tacit* (inarticulatable, interpretive, conceptual), *specific* (localized, clear, inductive), *abstract* (generalizable, obtuse, deductive), and *logic* (concept, attribute, value). Several KM frameworks have been presented (20, 24, 26, 35) that consider these different types of knowledge and the processes involved in conversion from one to the other. For example, conversion from tacit to explicit knowledge is called "externalization," whereas from explicit to tacit is called "internalization." While these frameworks characterize the strategic view of knowledge management, they do not provide a step-by-step support for operationalizing KM practices. Drawing from system development literature, several authors have proposed knowledge management life cycle models, which advocate a phased approach for knowledge management (8, 10, 25). These models provide a high level view of the activities that should be part of knowledge management. However, they fall short of incorporating the processes, tools and techniques that are necessary in each phase. This research attempts to integrate relevant enabling technologies into an environment that would support organizational knowledge creation, use, and management. Two such technologies are intelligent agents and extensible markup language (XML), which are briefly discussed in the following sections.

Intelligent Agents

Software agents are useful in automating repetitive tasks, finding and filtering information, and intelligently summarizing complex data. Just like their human counterparts, intelligent agents can have the capability to learn and even make recommendations regarding a particular course of action. In today's information age, much of the work involves one or more aspects of knowledge management. Intelligent agents can act on behalf of human users to perform laborious and routine tasks such as locating and accessing necessary information, resolving inconsistencies in the retrieved information, filtering away irrelevant and unwanted information, and integrating information from heterogeneous information sources. In order to execute tasks on behalf of a business process, computer application, or an individual, agents are designed to be goal driven, i.e., they are capable of creating an agenda of goals to be satisfied. Agents can be thought of as intelligent computerized assistants.

Several types of intelligent agents have been proposed and implemented (5, 13, 22, 34). While there is no consensus on what the architecture of an agent should be, there is some agreement on the properties of agents. Sycara et al. (32) outline the desirable characteristics of intelligent agents. They are: (a) taskable, b) net-centric, c) semiautonomous, d) persistent, e) active, f) collaborative, g) flexible, and h) adaptive. The taskable property refers to being able to take directions from human agents as well as other software agents, whereas the net-centric property relates to agents being distributed over a network but are self-organizing. Agents are semiautonomous and perform tasks on their own. They are also persistent and do not require frequent attention. Agents are active and have the ability to initiate problem-solving activities. They are collaborative, i.e., delegate tasks to other agents and work cooperatively. Agents are also flexible and adaptive in the sense that they can deal with heterogeneity of other agents and information sources as well as accommodate changing user needs and task environments.

Cooperative intelligent agent systems contain agents (intelligent computerized assistants) that are capable of acting autonomously, cooperatively, and collaboratively to achieve a collective goal (22). An agent by itself may not have sufficient information or expertise to solve an entire problem; hence mutual sharing of information and expertise is necessary to allow a group of agents to produce a solution to a problem. Cooperating agents can communicate (exchange information) and collaborate (work together on a common task or sub-task).

XML and Knowledge Management

Extensible Markup Language (XML) is emerging as a fundamental enabling technology for content management and application integration. XML is a set of rules for defining data structures and thus making it possible for key elements in a document to be characterized according to meaning. XML has several advantages. First, it is a descriptive markup language rather than a procedural markup language. Hence, it is possible to understand the semantics of the XML document. Second, it is vendor independent and therefore highly transportable between different platforms and systems while maintaining data integrity. Third, it is human legible. It is also worth noting that XML has its roots in SGML (Standard Generalized Markup Language) and adheres to many of its principles. SGML has been successful in e-commerce for many years. For example, the Electronic Component Information Exchange (ECIX) standard used for sharing component information across the EC supply chain utilizes SGML/XML technology for unambiguous exchange of electronic component information between suppliers and end users (http://www.si1.org/ecis/).

XML enables us to build a structure around the document's attributes, and RDF (Resource Description Framework) allows us to improve search mechanisms using the semantics of annotations (9). RDF uses a simple data model for representing properties of resources such as images, documents and the relationships between them. The content of documents can be described using semantic annotations, which can then be used in searching for documents with certain content. RDF provides many advantages such as: a) standard way to represent semantics, b) support human readable and machine processible vocabularies, c) standardize vocabularies within a particular community, and d) eliminate the need for a centralized registry. Thus, RDF provides an information architecture that can extend capabilities for networking resources and information retrieval.

XML makes it possible to deliver information to agents in a form that allows automatic processing after receipt and therefore distribute the processing load over a federation of agents that work cooperatively in problem solving. The set of elements, attributes, and entities that are defined within an XML document can be formally defined in a document type definition (DTD). DTDs can be embedded, or referenced within the document, using which the structure of the document can be verified. During knowledge creation, the results can be structured in a document based on a previously designated DTD. The semantics associated with the tags can be standardized, so the agents can use this meta-data in making inferences (30). This also facilitates the agents in finding the relevant information from the knowledge repository.

The eXtensible Stylesheet Language (XSL) can be used for expressing style sheets, which have document manipulation capabilities beyond styling. Thus, a document in the knowledge repository can be viewed differently and transformed into other

documents to adapt to the needs of the user, while being stored internally in a unique format (18). The ability to separate content from structure enables agents to analyze documents and derive new knowledge that can again be stored using the same uniform representation. We contend that by combining intelligent agent and XML technologies, one could envision a knowledge management environment that supports all phases of the knowledge life cycle, namely create, organize, formalize, distribute, apply, and evolve. The following section discusses the role of KM in e-commerce and presents a framework for managing KM activities within an e-business.

KNOWLEDGE MANAGEMENT AND E-COMMERCE

Electronic commerce activities include the electronic exchange (delivery or transaction) of information, goods, services, and payments over telecommunications networks, primarily the World Wide Web. But e-commerce activities also include the establishment and maintenance of *online relationships* between an organization and its suppliers, dealers, customers, strategic partners, regulators, and other agents related to (or in support of) traditional delivery channels. These activities may be business-to-consumer ("B2C" such as direct book sales to the general public by www.amazon.com), business-to-business ("B2B" such as corporate procurement or supply chain management using a secure extranet similar to www.covisint.com), consumer-to-consumer ("C2C" such as a public auction at www.ebay.com), or within a business (such as an employee intranet or an enterprise resource planning (ERP) system). This environment enables organizations to reengineer their internal and external functions, increasing both efficiency and effectiveness. Firms can automate existing processes and dramatically reduce cycle times throughout the supply chain (33). They can enhance communication, collaboration, and cooperation between knowledge teams (including virtual teams) using *intranet* technologies and between the organization and members of its external constituent organizations using *extranet* technologies.

Role of KM in E-Commerce

With the ubiquitous nature of Internet and globalization, brick-and-mortar companies are moving toward click-and-brick type of environment where they not only manage the traditional business processes, but also incorporate e-commerce activities to supplement their business offerings. Organizations are embracing e-commerce business models to take advantage of the global reach as well as the potential to react to changes in the marketplace quickly by gathering and analyzing customer data. The Internet economy is very dynamic and the traditional way of doing business is inadequate because of the reduced cycle time. For example, strategic planning in traditional organizations is a time consuming activity because of the difficulty in gathering relevant information and knowledge. To mitigate this problem, e-businesses can be proactive and incorporate KM processes to facilitate quick access to different types of knowledge (21).

In e-commerce market space, large amounts of data can be gathered easily and by analyzing this data in a timely manner, organizations can learn about their clients and generate useful knowledge for planning and decision-making. For example, in B2C market, when a customer visits a storefront, the actions of the customer can be tracked electronically and this data can be analyzed to understand customer learning and buying process and eventually determine demand for product lines. Similarly, in the B2B market, organizations can scan the environment and monitor changes in the industry and form strategic alliances or partnerships. Figure 1 shows the normal activities that take place in the traditional as well as the electronic market space. In order for these processes to be successful in both environments, appropriate knowledge is needed to execute them. Identifying and capturing different levels of knowledge through a systematic approach is the key to success.

Core knowledge management activities (Figure 1) within e-commerce firms should include: a) identification, b) creation, c) capture and codification, d) classification, e) distribution, f) utilization, and g) evolution, knowledge identification relates to determining what knowledge is needed to develop products and partnerships. Knowledge creation involves using various tools and techniques to analyze transaction data and generate new "nuggets of knowledge" that will aid in understanding market trends. Knowledge capture and codification includes gathering new knowledge and storing it in a machine-readable form. Knowledge classification organizes knowledge using appropriate dimensions, or based on prior use. Knowledge distribution is sharing relevant information with suppliers, consumers and other stakeholders through electronic networks – both public and private. Knowledge utilization involves using appropriate knowledge in problem solving, decision-making, establishing and terminating partnerships. Knowledge evolution entails updating knowledge as time progresses.

Having discussed the impact of KM on e-businesses and the various activities that should be part of the KM life cycle, we present a KM framework for e-commerce organizations.

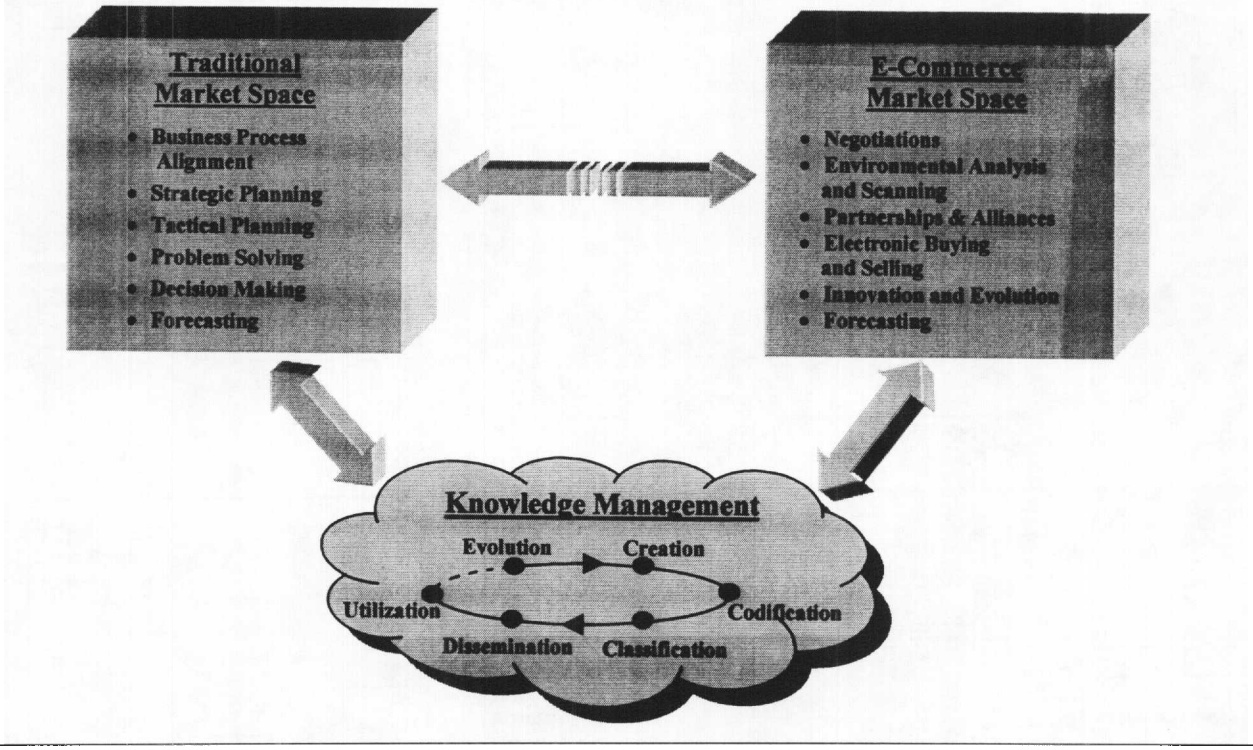
KM Framework for E-Commerce Organizations

For any knowledge management framework to be successful, its functional attributes should be aligned with the knowledge activities (23). Furthermore, it is imperative that everyone in the organization knows where to go to find the organization's knowledge, as well as use it in the context that is right for them (31). The available knowledge should also be accessible anytime, anywhere and should be current. Thus, a knowledge management framework should efficiently support the organization's knowledge flow while meeting the basic usability requirements (16). For example, within an e-commerce organization, the different stakeholders should be able to view and use relevant knowledge in support of their activities, be it product development, relationship management, or market analysis.

Various units within an e-business gather, generate, and utilize different types of knowledge with varying degrees of granularity depending upon the tasks they perform (6, 28). In order for that organization to successfully implement a KM program, it should take an interdisciplinary approach and provide a broad range of processes and tools for modeling and manipulating relevant knowledge (11, 29). In this vein, we propose a framework (Figure 2) that encompasses the overall processes necessary for implementing knowledge management initiatives within an e-business. This framework distinguishes between three levels of knowledge: product, process, and domain knowledge. The product knowledge relates to characteristics of different types of products that are currently available in that domain. Process knowledge (procedural) deals with initiating, planning and executing generic processes that are carried out by the stakeholders within an e-business. For example, in the B2B environment, the process knowledge may relate to establishing partnerships as well as generating performance indices to evaluate the strength of the relationship over a period of time (33). Based on the partnership requirements and the type of collaboration, the salient

characteristics of the partnerships can be abstracted out and classified for evaluation and future utilization. The domain knowledge relates to generic knowledge that could be utilized by all the stakeholders in a particular domain. This knowledge could be acquired from both internal and external sources. For example, in B2B logistics domain, regulatory requirements may impact certain aspects of procurement. Thus, partners collaborating in the context of e-procurement or e-auction need to be aware of the changes in regulations. Overall, the proposed framework emphasizes easy access to different levels of knowledge and feedback between knowledge processes.

FIGURE 1
Knowledge Intensive Activities Within E-business Organizations



Our KM framework (shown in Figure 2) consists of the following four major processes: a) *develop* – identification & creation, b) *denote* – codification & storage, c) *disseminate* – distribution, and d) *deploy* – utilization and providing feedback. The knowledge development process includes identification and creation of new knowledge. It focuses on determining the relevant product, process and domain knowledge needed to successfully carry out e-commerce activities and acquiring or generating this knowledge by monitoring the activities and information exchanges between stakeholders. For example, in the B2C market, the past history of customer purchases from the online store can be analyzed to create a profile of the customer, which may include his or her buying habits, attributes of products purchased, general areas of interests, etc. This knowledge can be used to recommend similar products as well as cross-sell related products. Domain and process knowledge become critical in the B2B market because it helps in forming strategic partnerships, and when changes in the environment cause them to be less productive, then the organization must realign its partnerships.

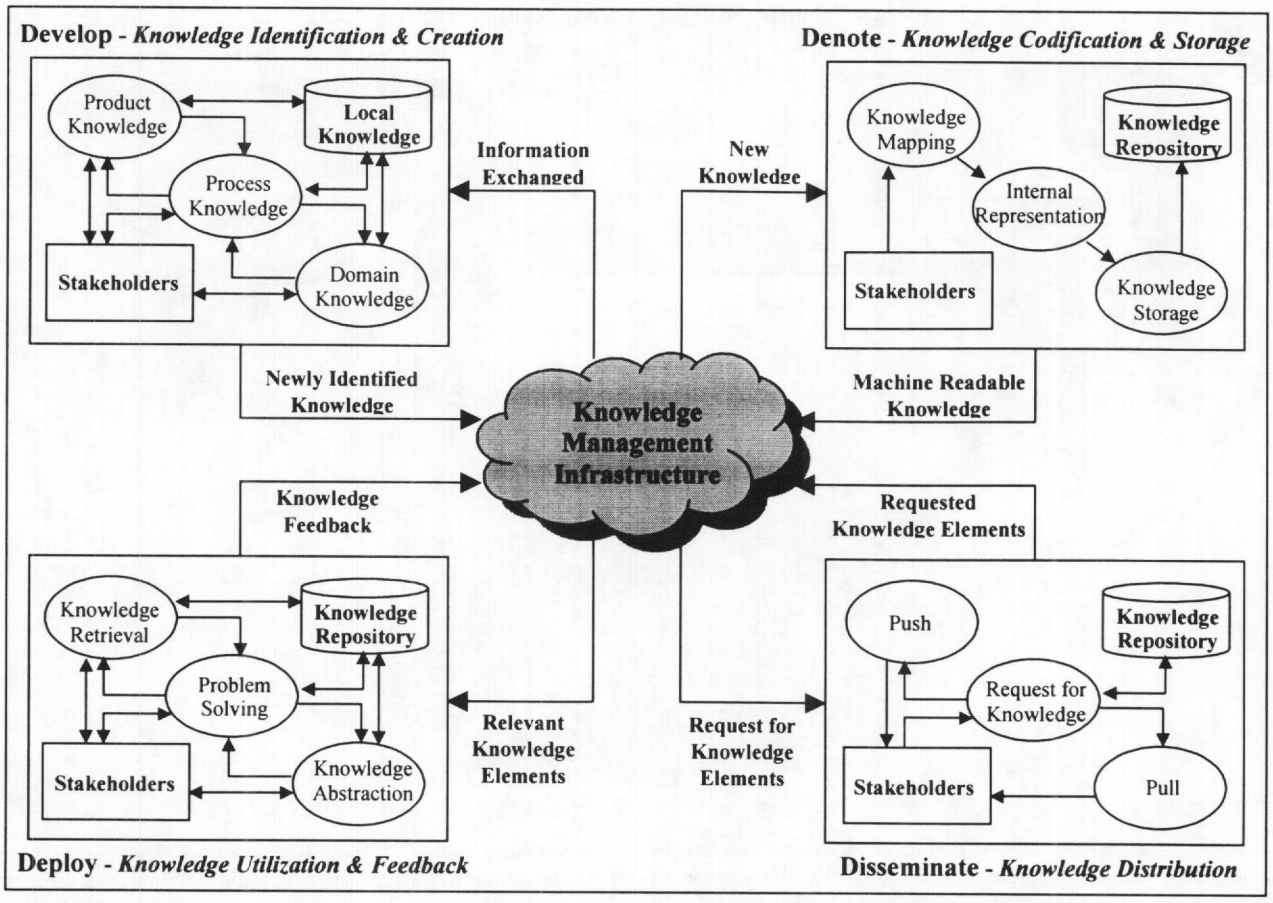
The denotation process involves knowledge codification and storage. It deals with archiving the new knowledge by adding it to the persistent knowledge repository that can be used by all the stakeholders. This process consists of mapping the knowledge to appropriate formalisms, converting it to the internal representation and storing it in the knowledge repository. Current technologies such as XML and Universal Description, Discovery and Integration (UDDI) can be used for internal representation and storage. It facilitates easy search and retrieval of relevant knowledge from the repositories and enables the stakeholders to apply this knowledge in decision-making.

The knowledge dissemination process relates to handling requests for knowledge that could be used in evaluating a specific problem scenario. Knowledge dissemination can employ several technologies such as "push" and "pull" technologies depending upon the organization's culture and infrastructure. Push technologies allow an organization to be proactive and disseminate knowledge as it becomes available to interested parties, whereas pull technologies make that knowledge available to stakeholders only on demand so that they are not constantly inundated with unsolicited information.

The knowledge deployment process comprises of knowledge utilization and providing feedback. This process facilitates the stakeholders to specify various knowledge elements that they may need in order to solve a particular problem and retrieve that knowledge. Utilization of this knowledge in the context of a particular problem may result in additional knowledge, which can be abstracted out and stored in the knowledge repository for future use. Stakeholders can provide feedback regarding quality of knowledge stored in the repository as well as how easy or difficult it is to search for

relevant knowledge. They can also identify new types of knowledge that need to be gathered based on strategic objectives and the changes that are taking place within the environment. For example, in B2B market space, unexpected economic activities may cause a major shift in a particular industry and having knowledge about its impact would be crucial for planners and decision-makers.

FIGURE 2
Knowledge Management Framework for an E-Commerce Organization



ARCHITECTURE OF AN AGENT-BASED KNOWLEDGE MAANGEMENT ENVIRONMENT

While several approaches have been explored for supporting the knowledge activities of an organization, corporate portals are increasingly becoming popular (4, 15). Portals provide a single point of entry to the distributed sources of knowledge within an organization. Portals also facilitate easy gathering of knowledge by providing uniform interface, and are accessible anytime anywhere. In this research, we adopt a portal-based approach for designing our system. The architecture of the proposed knowledge management environment is shown in Figure 3. This architecture follows the traditional three-tier client-server architecture consisting of HTML clients, a web server, and various knowledge repositories connected through Internet or the corporate intranet (18, 30). In addition, the server side is augmented with intelligent agents to support the various activities of the stakeholders including knowledge creation, storage and dissemination.

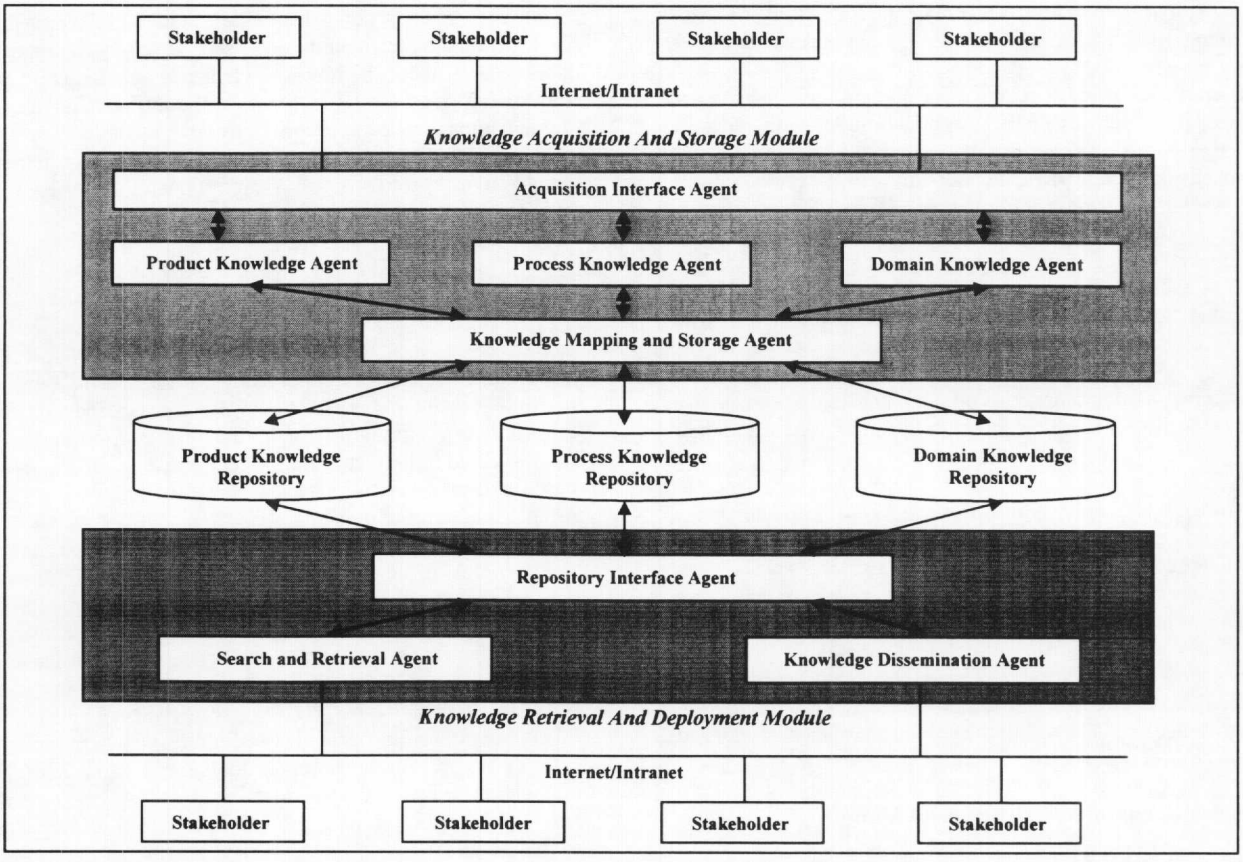
The client is a basic web browser that the stakeholders use to carry out different tasks. For example, employees can use the portal to create and store product related artifacts or retrieve relevant domain knowledge that could be used in problem solving; customers can use the portal to scan the environment and learn about various product offerings, as well as send and receive information related to product requirements and shipments. The knowledge server contains the following two high-level modules: a) knowledge acquisition and storage module, and b) knowledge retrieval and deployment module.

The knowledge acquisition and storage module is responsible for the early phases of the knowledge management life cycle, which involves identifying, acquiring and storing new knowledge that would be useful in decision making. This module contains the following agents: a) acquisition interface agent, b) product knowledge agent, c) process knowledge agent, d) domain knowledge agent, and e) knowledge mapping and storage agent.

The knowledge retrieval and deployment module is responsible for the later phases of the KM life cycle, in particular, activities related to searching and retrieving relevant knowledge, as well as sharing this knowledge with the stakeholders so that it can be utilized in different scenarios. The

knowledge retrieval and utilized module consists of the following three agents: a) repository interface agent, b) search and retrieval agent, and c) knowledge dissemination agent. The two modules of this architecture along with their constituent agents are briefly described in the following section.

FIGURE 3
Architecture of Knowledge Management Environment



Knowledge Acquisition and Storage Module

The knowledge acquisition and storage module consists of several agents that assist the stakeholders in creating and storing product, process, and domain knowledge. Based on their day-to-day activities, stakeholders may either identify new knowledge that needs to be gathered or create knowledge that could be used by others within the organization. Any knowledge that is generated needs to be represented and stored in such a manner that it is readily accessible and usable by others. For example, Daimler Chrysler maintains an "Engineering Book of Knowledge," which is a centralized repository that contains wealth of knowledge about vehicle designs and design changes. The repository is consulted when embarking on a new design and is also updated on a continual basis by design engineers. Thus, the knowledge acquisition and storage module aims to facilitate this knowledge creation and acquisition process through the use of agents and make it seamless so that it becomes part of the daily routine. The agents that are part of this module are briefly described below.

Acquisition Interface Agent. The acquisition interface agent provides facilities for different stakeholders to browse the various knowledge repositories that exist within the organization, as well as interact with other knowledge agents in identifying and creating new knowledge. It also keeps track of the user profiles, preferences and prior activities. The interface agent is responsible for gathering the input from the user, passing it on to other knowledge agents, and sending the results back to the user. It creates dynamic HTML documents containing the results of the browsing activity and serves them to the client-side.

Product Knowledge Agent. The product knowledge agent enables the stakeholders to create and modify product related knowledge artifacts. For example, it supports the stakeholders to define product requirements and create specifications, document product characteristics and how to use them, obtain feedback and testimonials from the customers, and assist in customer support inquiries. These knowledge artifacts are stored in the "Product Knowledge Repository," which can be searched to learn more about current products or determine how well a particular product is performing.

Process Knowledge Agent. The process knowledge agent assists stakeholders in creating process knowledge as well as executing them. It checks whether the prerequisite conditions exist for a particular task to be carried out. The process

knowledge agent also monitors the activities and transactions that are taking place within the environment and inform appropriate stakeholders about critical events. For example, in the B2B environment, process knowledge agents monitor partnership activities and extract meta-knowledge about the existing relationship in terms of its characteristics such as product/service type, application domain, partner attributes, technology used, deliverable types, etc. This meta-knowledge, which is stored in the "Process Knowledge Repository," is used in planning, establishing and evaluating other partnerships.

Domain Knowledge Agent. The domain knowledge agent is responsible for extracting application domain specific knowledge based on the products and the collaborations that have taken place in a particular domain over a period of time. For example, if there are a number of partners for a particular type of product or service, based on the similarities and variations in these partnerships, specific "nuggets of knowledge" related to factors that impact the success or failure of these partnerships and the market conditions that foster their growth can be derived. This domain knowledge is stored in the "Domain Knowledge Repository," and can be generalized to similar types of domains. The domain knowledge agent also informs stakeholders about changes in the environment and their impact on the business processes.

Knowledge Mapping and Storage Agent. The knowledge mapping and storage assistant is responsible for generating the internal representation of the knowledge artifacts so that they can be stored, organized, disseminated and used by other stakeholders and applications. It maps the product, process, and domain knowledge to corresponding templates and stores them in the appropriate repository. Users can select a particular template that already exists or define a new template on the fly. The knowledge artifacts within the repositories can be organized based on subject or a specific taxonomy.

Knowledge Retrieval and Deployment Module

The knowledge retrieval and deployment module acts as the interface to knowledge repositories. It enables stakeholders to search these repositories for specific information related to the problem they are solving. This module is also responsible for content delivery (knowledge that may be of interest to certain groups) on a periodic basis. The following paragraphs briefly describe the agents that are part of this module.

Search and Retrieval Agent: The search and retrieval agent assists the user in specifying the type of knowledge that he or she is interested in. The interface is a web browser in which users can type natural language sentences indicating the general area of interest and the type of knowledge elements they are seeking. Simple natural language processing techniques translate the user's query into structured query language and an initial query is constructed. Additional user input is sought if some terms need further clarification. The initial query is then passed on to the repository interface agent.

Repository Interface Agent: The repository interface agent maintains a global knowledge schema, which keeps track of what knowledge elements are stored in which repositories. This agent also provides mechanisms for accessing and querying these repositories for specific knowledge artifacts. Specifically, this agent refines the initial query generated by the search and retrieval agent based on the meta-data related to the knowledge repositories. The refined query is then executed against the appropriate knowledge repository and the result is passed on to the knowledge dissemination agent.

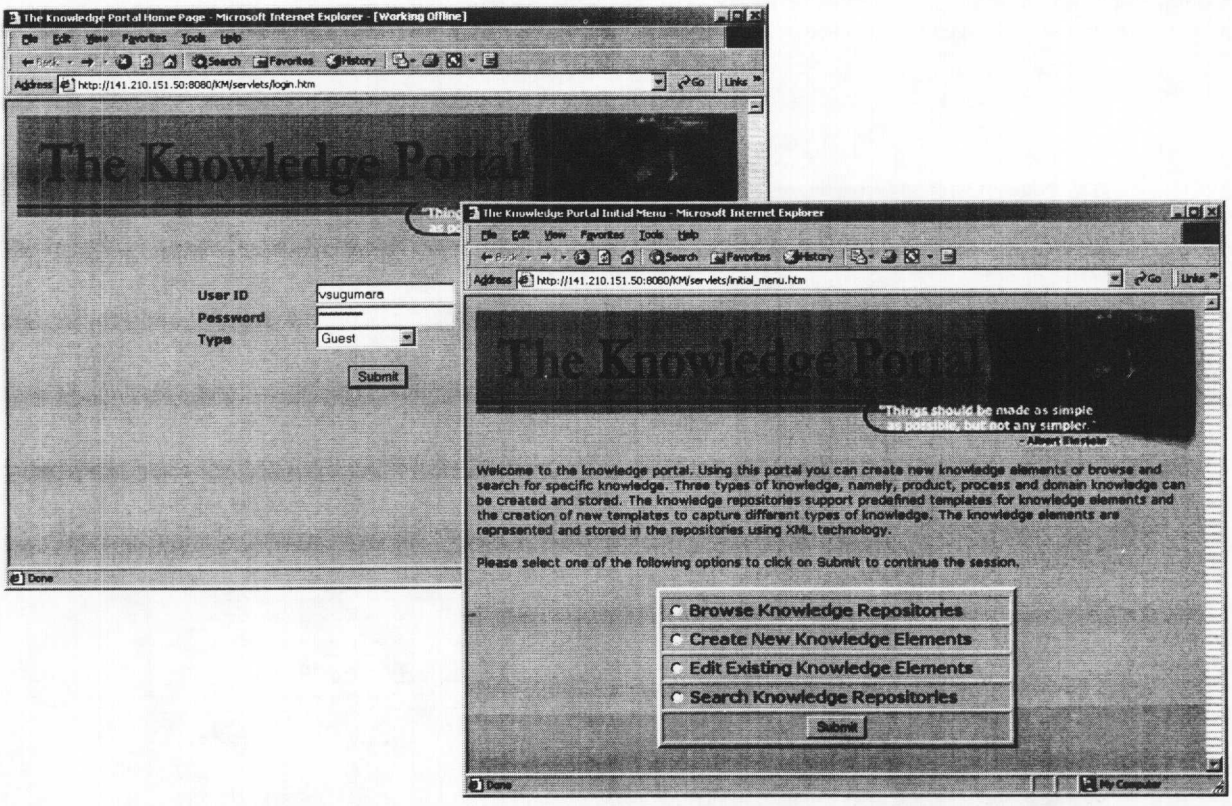
Knowledge Dissemination Agent. The knowledge dissemination agent is responsible for content delivery. It formats the results from query execution and presents the information to the stakeholders using web technologies. The knowledge dissemination agent can be configured to deliver content on a continual basis or to deliver content on demand. For example, whenever new knowledge is added to the repositories, push technologies could be used to inform appropriate stakeholders about the new knowledge or automatically deliver this content via the Web. Of course, the intrusive nature of this approach may not be appropriate for all stakeholders and hence this agent allows users to set their preferences as to whether they would like to receive knowledge updates as they become available or only on demand.

PROTOTYPE IMPLEMENTATION

A proof-of-concept prototype has been developed. The agents have been implemented using JADE (Java Agent Development Framework) (3) from CSELT, Turin, Italy. JADE is a middle-ware that is used to develop agent-based applications that are in compliance with the FIPA specifications for interoperable intelligent multi-agent systems. JADE is Java-based and provides the infrastructure for agent communication in distributed environments, based on FIPA standards. The reasoning capability of the agents has been implemented through JESS, which is an expert system shell written in Java. The product and the process knowledge, as well as the application domain knowledge are stored in native XML databases with appropriate DTDs. The knowledge repositories have been implemented as XML databases, created using the Tamino software (from Software AG – **www.softwareag.com)**. Among other things, Tamino provides X-Studio, which is a complete suite of application development tools for creating XML-based applications. Tamino XML databases store data directly in native XML format and provide facilities for fast storage, exchange and retrieval of XML documents. In designing this KM application, we have developed the DTD and RDF for various knowledge elements, and they are used as templates in creating these knowledge elements. New templates can also be defined and the corresponding DTDs can be generated. The following paragraphs describe a brief sample session that provides a glimpse of some of the functionalities of the prototype.

When the user accesses the knowledge portal, a login screen (shown in Figure 4) is presented where the user can type in the userid, password and the user type. Users are provided different levels of access to control the evolution of the knowledge repositories. For example, guest users cannot create new knowledge elements and store them in the repository. There are several issues related to repository management, which are beyond the scope of this paper and are not discussed here. Once the user is authenticated, depending upon the type of the user, appropriate menus are presented. For example, if the user type is "knowledge engineer," he/she can create new knowledge elements and submit them to the repository. For such users, menus with create/edit options (Figure 4) are presented. From this initial menu, the user can browse, create or edit knowledge elements, and search the repositories for specific types of knowledge elements. The acquisition interface agent handles user authentication as well as providing appropriate menus for different types of users.

FIGURE 4
Login and Initial Menu from the KM Prototype



Assume that the user selects the browse knowledge repositories option (Figure 4). Then the interface agent presents another menu from which the user can select one or more of the product, process and domain knowledge repositories to browse. The interface agent then establishes a session with the selected repositories (Tamino XML database) through the X-Bridge API. The user can navigate the repository through the interface shown in Figure 5. The tree structure presented in the left window of Figure 5 shows the knowledge repositories that are currently open and the user can highlight any one of them to view its content. As indicated in Figure 5, currently the Process Knowledge repository has been selected and the right side window displays the process information. The default process template has been used to display process knowledge, which contains properties such as process ID, process name, pre-conditions, post-conditions, etc. (see Figure 5). For each property, the corresponding values are also shown and the user can cycle through the processes and properties by clicking on the up or down arrow.

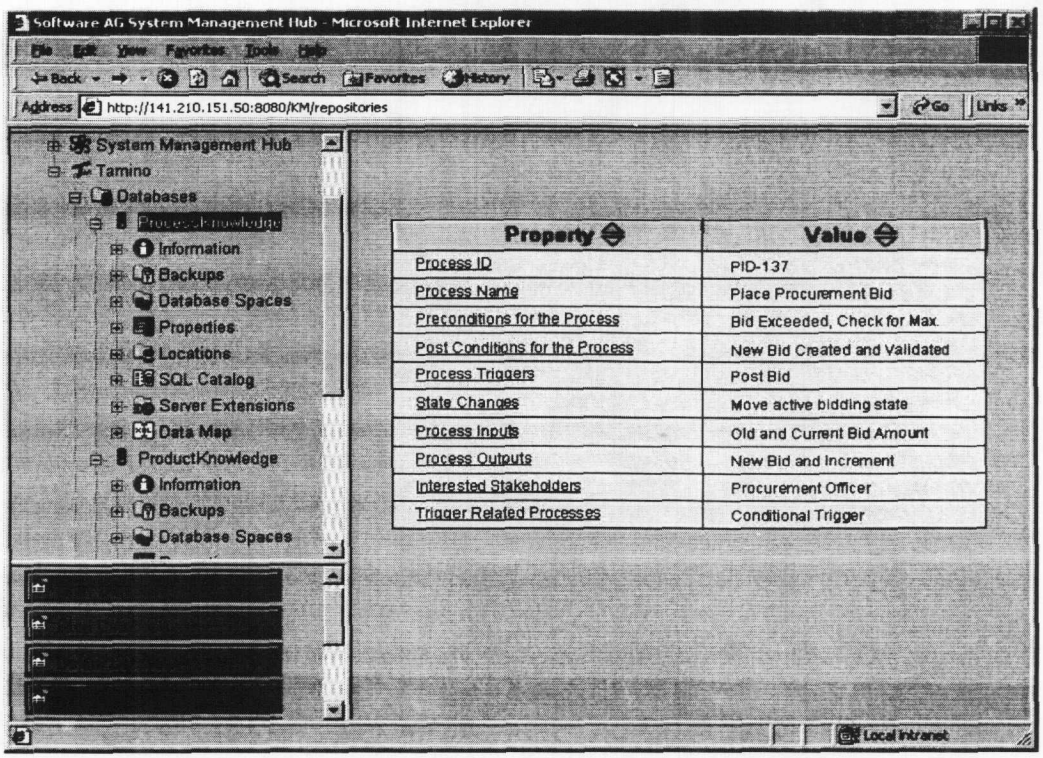
From the initial menu (Figure 4), the user can also create new knowledge elements. When the user selects this option, the interface agent presents another menu from which the user can indicate the type of knowledge element to be created, and the appropriate knowledge agent is activated. For example, if the user wants to input process knowledge, the Process Knowledge Agent facilitates the creation of this knowledge. The user can define a new process template or use an existing one. Figure 6 shows the default template and the user can fill in the values for all the attributes of a process. The process knowledge agent gathers this input and passes it on to the knowledge mapping and storage agent, which verifies this information against the DTD and creates the XML document and stores it in the process repository.

The user can also search the knowledge repositories. The search and retrieval agent provides a rudimentary natural language interface (Figure 7) for specifying the search criteria. The user can type in a sentence describing what he/she is looking for and the agent can identify keywords in this sentence and generate the appropriate query. This initial query is then passed on to the repository interface agent, which then further refines it based on the meta-knowledge about the repositories and executes it to retrieve complete and partial matches. The result is passed on to the knowledge dissemination agent, which formats the results and dynamically creates an HTML document to be displayed to the user.

The current prototype has been evaluated by five systems analysts, which are involved in KM initiatives. The objective of this informal validation is to get feedback regarding face validity, visual interaction, content validity, and construct validity. The subjects were asked to interact with the system and create various knowledge artifacts (e.g. product and process knowledge) using predefined templates and populate the repositories. They were able to browse these knowledge elements or the content of other repositories. The subjects were then required to perform a simple decision-making task, which required them to retrieve relevant knowledge and use it to analyze the problem and make a recommendation. At the end of the session, subjects were asked to provide written comments on the ease of use of the system and their impression of how well the system would assist them in problem solving and decision-

making. The initial feedback is very positive and substantiates the viability of the proposed KM system. For example, one of the subjects commented: "The system provides a systematic way to capture knowledge about a particular domain and could be used by a novice user in understanding and solving problems in that domain." While the early feedback is encouraging, much work is yet to be done. Some of the future work includes enhancing the functionality of the agents, creating a fully operational and scaleable system, developing tools for repository management, improving the search and retrieval mechanisms, and a formal evaluation of the system.

FIGURE 5
Browsing the Process Knowledge Elements



SUMMARY

Organizations are investing heavily in creating centralized knowledge repositories to improve business processes, promote knowledge sharing, and retain expertise even after employees leave the organization. This paper has presented a framework and architecture for supporting knowledge management activities within e-commerce organizations. The unique contributions of this research are: a) the knowledge management framework that takes into account different levels of knowledge that exist within an organization, b) client-server based architecture for implementing a system that supports various phases of the knowledge management life cycle, and c) integrating enabling technologies such as intelligent-agents and XML to create an environment that fosters cooperative knowledge work.

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FIGURE 6
A Template for Specifying Process Knowledge

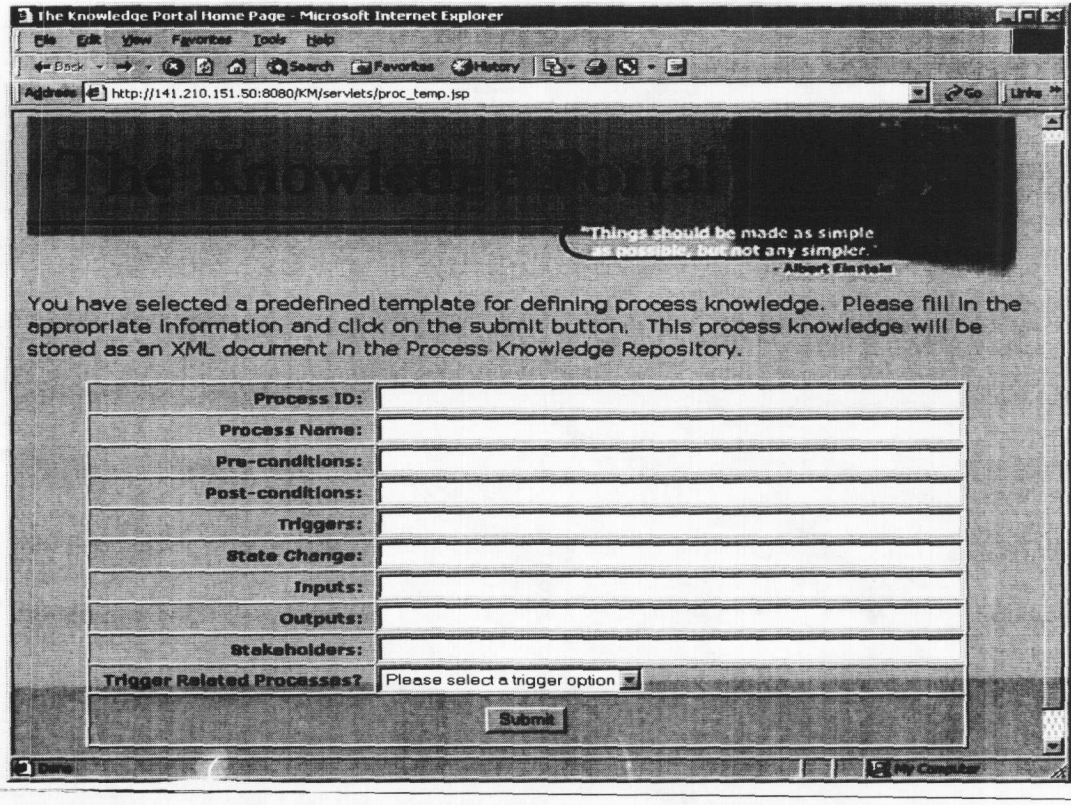
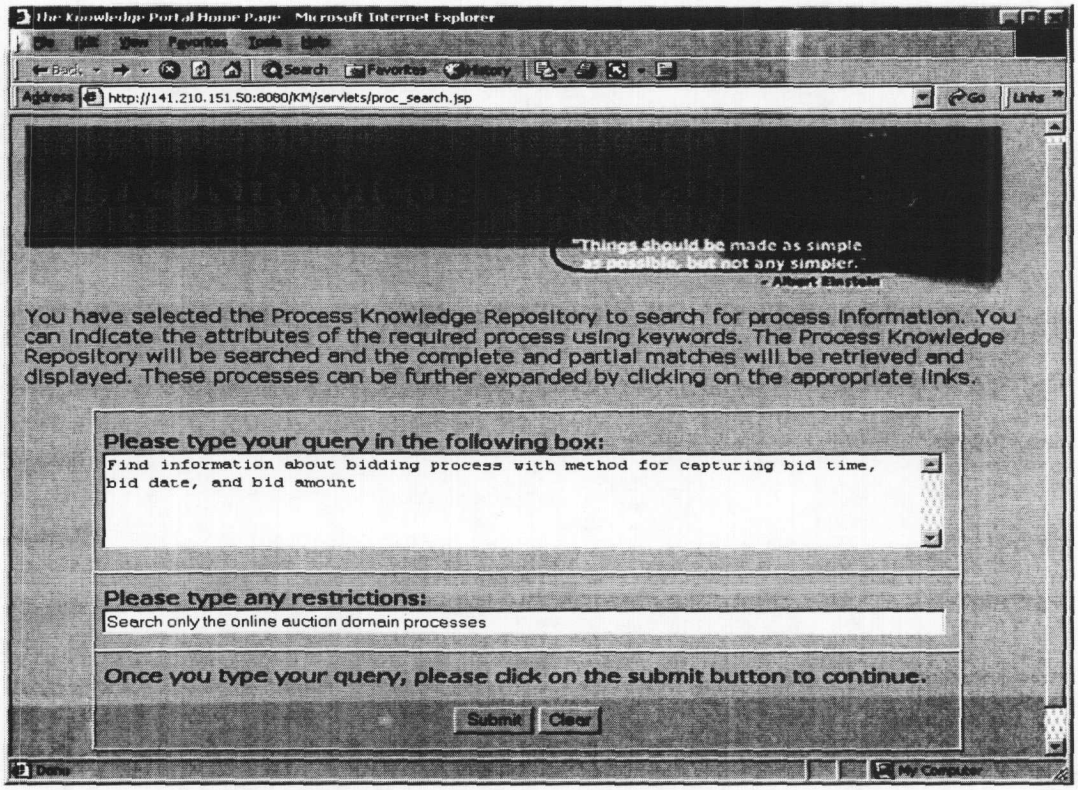


FIGURE 7
Searching for Process Knowledge



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