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Rahul Singh
University of North Carolina, Greensboro

Lakshmi Iyer
University of North Carolina, Greensboro

A. Salam
University of North Carolina, Greensboro

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Rahul Singh
Bryan School of Business and Economics
University of North Carolina, Greensboro
rahul@uncg.edu

Lakshmi Iyer
Bryan School of Business and Economics
University of North Carolina, Greensboro
lsiyer@uncg.edu

A. F. Salam
Bryan School of Business and Economics
University of North Carolina, Greensboro
amsalam@uncg.edu

Abstract

A common strategic initiative of organizations engaged in electronic commerce (EC) is the development of synergistic relations with collaborating partners in their value chains to deliver value proposition to their customers. This requires the transparent flow of problem specific knowledge to partner organizations over systems that exhibit high levels of integration. The unambiguously interpretable flow of knowledge to inform online business processes is a challenging task with significant competitive benefits for organizations that exhibit technical initiative. The challenge for EC research is to develop ways to deliver the promise of technical advancements in the computer and engineering sciences to benefit businesses and consumers. This research presents a framework applying fundamental work done in domain ontologies, web services, and multi-agent systems to develop a mechanism to deliver context specific domain knowledge to partner organizations. We demonstrate the development of Knowledge Services for EC as domain specific knowledge available over heterogeneous information platforms through web services technology using a multi-agent systems framework. We illustrate the potential of knowledge services through a model that enables online processes in electronic marketplaces using ontologies, web services, and a mutli-agent architecture.

Keywords: Web service, knowledge management, intelligent agent, ontology, electronic marketplace

Introduction

Competitive forces in the digital economy require organizations to continually seek innovative solutions that streamline business operations. Strategies such as supply chain management, collaborative product development, infomediary based electronic marketplaces (eMarketplaces), and enterprise resource planning (ERP) have been strategically employed in the past decade. These support the development of synergistic relations with collaborating partners in organizations' value chains in delivering the organizations' value proposition to customers. Invariably, such strategies call for the transparent flow of information and context specific knowledge across partner organizations over systems that exhibit high levels of integration. The unambiguously interpretable flow of knowledge to inform online business processes is a challenging task with significant potential competitive benefits for organizations that exhibit technical leadership.

The past decade has seen significant advances in web based technologies as the means to achieve the integration of heterogeneous systems across organizations. Such integrations are required to serve a variety of business needs including collaborative product design, multi-party business transactions, and outsourcing of business functions. Transparency in the flow of information between information systems of partner organizations goes beyond simple integration of hardware and software systems with web-based components (Stal, 2002). It requires a common language to express specific constructs important to the system context and relevant business rules that can be applied to assist autonomous system entities and decision makers in solving specific business problems. These requirements are in addition to the platform and technical implementation independence currently delivered by selected web based technologies. Disparate technical systems need the ability to share data, information, and knowledge among multiple on-line processes that arise from the need for collaboration among organizations. In addition, ad-hoc problem solving by decision makers must be supported using interfaces and entities that reduce cognitive load on humans. These are necessary in order to realize the potential of web services as enablers of collaborations in the online processes for companies engaged in EC.

This research presents a knowledge services architecture, founded on a web services framework, to enable the transparent exchange of knowledge between agents that manage online processes of organizations engaged in EC. We illustrate the development of a *knowledge context* unit using a simple knowledge representation scheme. A knowledge context unit contains domain ontologies and business rules and represents knowledge for a specific problem domain in standard eXtensible Markup Language (XML) format. This representation is easily managed in a modern DBMS that can store and retrieve XML-based information. A collection of knowledge contexts comprises the knowledge contained in a knowledge repository. The knowledge repository can service requests for knowledge services through a Knowledge Agent. Knowledge services are provided by delivering the XML representations of the domain ontology and business rules, encapsulated in standard Simple Object Access Protocol (SOAP – **http://www.soap.org**) headers. This architecture provides knowledge services by sharing the contents of a specific knowledge context through the web services architecture and makes them available to EC online processes. An overall schematic of the architecture is shown in Figure 1.

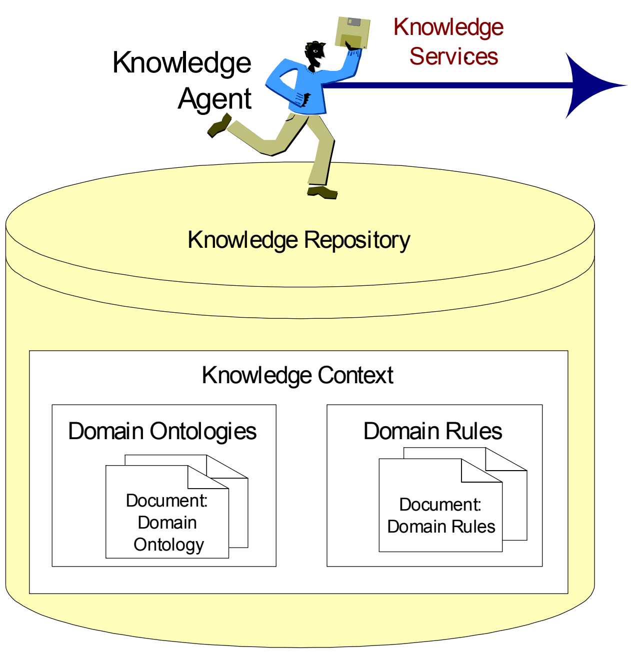


Figure 1. Overall Schematic of Knowledge Services Architecture

A key component of the Knowledge Services architecture presented in this paper is the autonomous processing of knowledge contexts using a Knowledge Agent. The Knowledge Agent manages the distribution of knowledge services and interacts with user agents. We illustrate the knowledge services architecture and demonstrate its utility in providing domain specific knowledge, including ontologies and business rules, in a manner that is interpretable by agent and human decision makers. In addition, we show the use of the Knowledge Services framework to enable knowledge exchange and intelligent support to enhance online processes in an eMarketplace.

Developments in web-services continue to overcome technical hurdles and mature to deliver their potential of an integrated platform where application programs can share information over heterogeneous platforms using standardized formats. The onus and challenge for EC research is developing ways in which the promise of technical advancements in the computer and engineering sciences can be beneficial to business and consumers. This research demonstrates a framework applying the fundamental work done in ontologies, web services and multi-agent systems to develop a system model to enable collaborative business process; thereby delivering the potential of web services enabled collaborations to online processes of EC.

Requirements for Knowledge Services

The requirements for knowledge services in eMarketplaces can be broadly identified based on the need for businesses to exchange knowledge. This knowledge exchange is only possible through the use of a vocabulary that represents shared understanding of conceptualizations pertaining to the domain of interest. In other words, a set of ontologies need to be developed and accepted by participating firms as a first requirement towards automating the process of knowledge sharing among interested parties in the eMarketplace. In addition to the agreed upon ontologies, there is also a need to represent the rules for processing and making sense of the transactions to be built upon the agreed upon ontologies. These rules form the heart of the inference mechanism. The third requirement is to develop a method for representing the ontologies and rules that allows for interpretation by both intelligent agents and human decision makers. These three requirements will then define the systems components needed for representing, storing, managing, and using ontologies and corresponding rules for knowledge exchange among participating firms.

Knowledge Services Components

Knowledge is defined as the highest order in the continuum of data and information, as having utility and specificity in its context domain. Functionally, and in systems, the lines between useful information and knowledge are blurred (Grover and Davenport, 2001). We take a pragmatic approach to defining knowledge for EC as *information in the context of a specific problem domain, upon which action can be advised or taken*. This view is consistent with the knowledge content of ontologies for knowledge processes described in detail in Staab, et. al., (2001).

Knowledge representation is given operational form in the knowledge services architecture through two components that contain ontological information about the problem domain, referred to herein as the *domain document*, and business rules, referred to herein as the *rules document*. Together, these documents comprise information about entities in the problem domain through an explication of its attributes; and information that can advise actions to be performed in the context of the problem domain. In other words, these documents represent the available knowledge about a problem domain. Additionally, context specific knowledge contained in the domain and rules documents must be actively managed to allow multiple representations and specific information to be made available to users of the knowledge. In this research, a knowledge context includes domain ontology and rules in addition to functions that manage, present, and use the ontology and rules. Management of knowledge is achieved through a knowledge context object responsible for providing the information contained in the domain and rules documents, as shown in Figure 2.

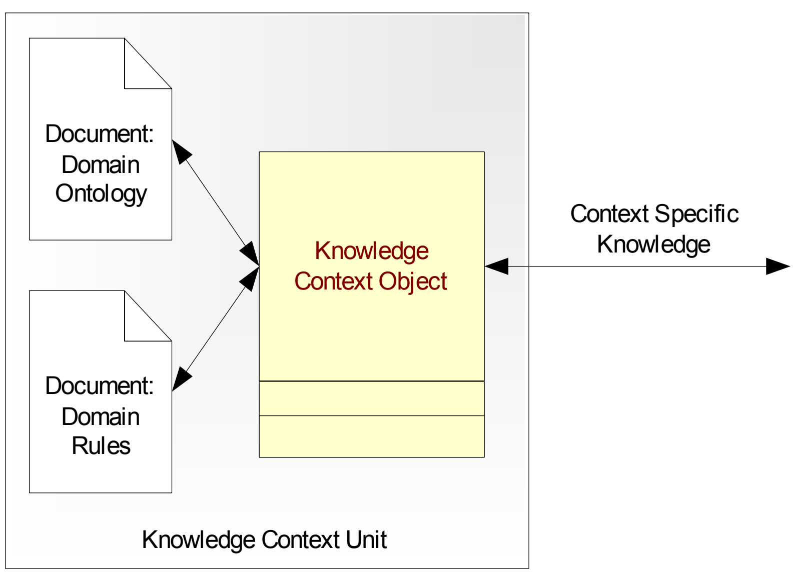


Figure 2. A Knowledge Context Unit

Knowledge services use knowledge contexts to provide agent enabled online processes of partner organizations with descriptions of the problem domain and usable forms of the rules employed in making decisions regarding the business context. Knowledge Services are delivered by the Knowledge Agent to User Agents using Web Services to collect and provide domain specific knowledge. Thus, we define *Knowledge Services as domain specific knowledge, including domain entity ontologies and business rules, provided by the knowledge agent to users, through their agents, over heterogeneous information platforms via web services technology*.

Knowledge specification of an online process using ontologies includes the description of the shared context, with descriptions of the various attributes of the item being bought or sold, descriptions of the organization entities engaged in the sale and descriptions of the various terms used to describe the entities. Additionally, the ontological representation contains knowledge regarding the knowledge process including purchase preferences of the buyer, selling preferences of the seller and descriptions of the terms used to describe these preferences. For example, in an infomediary enabled eMarketplace, buyers and suppliers provide representations of their need for products or services in the form of their respective demand and supply functions. These exchanges require the sharing of both attributes pertaining to the demand or supply and business domain rules (transaction contracts) for accepting a transaction. The infomediary performs a vital function in the e-marketplace as an enabler of transactions and a repository of knowledge about buyers, suppliers and the nature of exchange between them (Grover and Teng, 2001). The knowledge required to automate online processes requires complete ontologies of the data used to describe the exchange in addition to the explication of business rules that can be applied to express preferences of buyers and sellers engaged in the EC online process. In section 4, we provide an illustrative example of the application of the knowledge services architecture to "buy-don't buy" decisions typical of an eMarketplace. The following section takes a bottom-up approach in constructing the proposed knowledge services architecture.

Knowledge Services Architecture

Knowledge Representation and Ontologies

The technical realization of on-demand, context-specific, and useful exchange of knowledge between collaborating organizations is a challenging task. It requires the explication of a common and shared attributes to describe context specific entities important to the system. It also requires information about the interpretation and action implication for the entities is required for the knowledge to be useful to decision makers in organizations. A system managing available knowledge most comprise facilities for creation, exchange, storage and retrieval of knowledge in an exchangeable and usable format, and facilities to use the knowledge in a business activity (O'Leary 1998; Alavi and Leidner, 1999). In recent years, advances in systems support for decision making to solve business problems have seen increased use of artificial intelligence based techniques for knowledge representation. Intelligent systems incorporate intelligence in the form of knowledge about the problem domain, with problem representation and decision analytical aids to inform the decision process, provide problem domain representation, and reduce the decision maker's cognitive load.

Ontologies represent an advance, developed in the area of artificial intelligence, to further the sharing and use of a common understanding of a specific problem. They provide a shared and common understanding of specific domain that can be communicated between disparate application systems, and therein, provide a means to integrate the knowledge used by online processes employed by EC organizations (Klein, et. al., 2001). Ontology for this purpose describes the semantics of the constructs that are common to the online processes, including descriptions of the data semantics that are common descriptors of the domain context. Staab, et. al., (2001) describe an approach for ontology based knowledge management through the concept of knowledge metadata that contains two distinct forms of ontologies which describe the structure of the data itself and describes the issues related to the content of data.

Modeling techniques used to explicate preferences, while retaining enough formality of expression to allow for the unambiguous interpretation by software entities, can be employed for this problem. The performance of a particular method in modeling human decisions depends on the conformance of the method with the decision makers' mental model of the decision problem (Sung, et. al, 1999). Decision Trees are a popular decision modeling technique with wide applicability to a variety of business problems. Their utility derives from the ability to offer a high level of interpretability unique to symbolic models. Decision trees allow for easy generation of decision rules, making them ideal for providing insights and explanations to non-technical users. Decision trees are especially suitable for decision problems that require the generation of human understandable decision rules based on a mix of classification of categorical and continuous data (Sung, et. al., 1999). They clearly indicate the importance of individual data to the decision problem, and are therefore useful in reducing the cognitive burden for the decision maker. It is the task of the systems designer to select the modeling methodology and knowledge representation mechanism based upon the nature of the problem and the characteristics of the decision makers.

The knowledge services architecture presented here employs ontological descriptions of the problem domain, including the domain descriptions that describe the entities that are important to the context of the online process; and description of the rules that are employed in making decisions regarding the business context. The latter employs a decision tree representation of rules to represent knowledge about the problem domain.

XML and Web Services for Knowledge Representation and Exchange

The popularity of the World Wide Web is partially attributable to the simplicity of HTML in usage and content presentation. However, HTML has limited extensibility for data description and this severe constraint limits its use for content sharing by application software in distributed environments. The use of XML and the related set of standards developed by the W3C (**http://www.w3c.org**) overcome these limitations through the creation of extensible custom tags to describe domain specific entities and their attributes. XML Schema (**http://www.w3c.org**) allow for unambiguous description of the structure of XML documents (meta-data) and their contents (data). Initiatives to develop technologies for the "Semantic Web" (Berners-Lee, et. al., 2001) make the content of the web unambiguously computer-interpretable, thus making it amenable to agent interoperability and automated reasoning techniques (McIlraith, et. al., 2001). Recently, there have been several efforts to build on Resource Description Framework (RDF) with more AI-inspired knowledge representation languages (Fensel, 2000). These initiatives are extremely promising for automating online processes through various means including agent interoperability and automated reasoning.; however, they are in early stages of development.

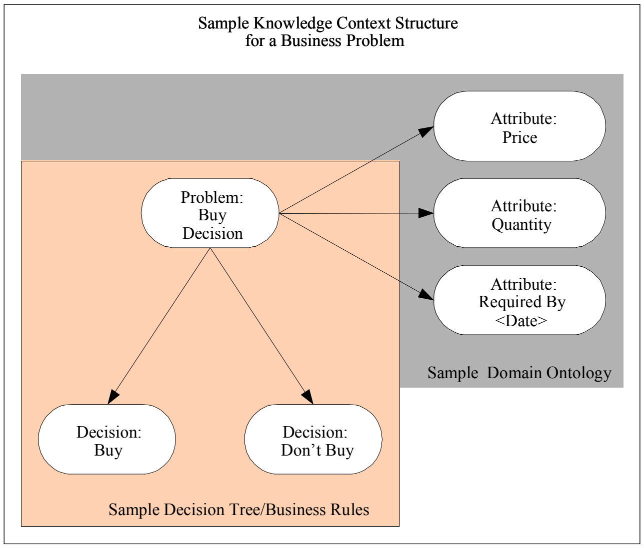
Web Services technology consists of components to which applications send requests for processing and data services. This defines the envelope and transport mechanism for information exchange between two entities. A SOAP message essentially contains an XML document which provides the foundation for web services. Web Services framework consists of the Web Services Definition Language (WSDL – **http://www.wsdl.org**) describing web services in XML format and providing a basis for tools to create appropriate SOAP messages. The Universal Discovery Description and Integration (UDDI – **http://www.uddi.org**) allows for the creation of repositories of web services that can be dynamically discovered over the internet. This vision of the web consists of services, information and processing, which can be dynamically discovered and used by human and software agents seeking specific information and processing capabilities.

Potentially, these technologies allow for software programs to be accessed through the web, to provide information, automated program communication and the discovery of services. For organizations engaged in EC, they present the potential for the automatic discovery of, and collaborations with, partners through which business relationships can be developed dynamically. This is particularly useful in business models where buyers and suppliers must dynamically find each other and transact commercially, such as the information-based eMarketplaces (infomediaries) and e-supply chain relationships. As mentioned earlier, the realization of the potential of web services requires a common and shared understanding of the problem domain; and clear knowledge of actions to be performed by the services. This is required to facilitate the adoption of these technologies by organizations and realize their potential.

Knowledge Context

Operationally, we represent knowledge using the domain document that contains ontological information about the problem domain and the rules document that contains business rules relevant to the specific business context. The domain document contains attributes relevant to the business domain problem under consideration. The rules document contains business rules that suggest and explain user actions and decision paths. In this context, users can be software agents acting autonomously on behalf of users or directly in conjunction with human users to fulfill their information requirements.

For example, a purchase decision would require information about the various attributes that describe the purchase decision, including price, quantity, and the item required by date. The problem domain also contains business rules that decide whether the purchase decision is *buy* or *don't buy*. This decision is made based upon values of these attributes for a specific instance of the decision problem. This represents contextual information about a business domain for which domain ontology and a set of business rules can be developed to model the buy-don't buy decision. Such decisions are integral to and representative of frequently occurring decision problems in eMarketplaces. The ontology representation and decision tree shown diagrammatically can be represented in XML format as shown in the XML documents in Figure 3. Thus information regarding a business entity is represented in its attribute ontology and those attribute description are used to develop business rules that represent decisions in the given business context.



Rules: Buy
if the price is less than or equal to USD $19.99
AND
the item can be delivered on the date it is required;
OR
if the price offered is less than 10% of USD $19.99,
then
the user would display flexibility in the required by date of less than or equal to a one week

```
<Rules
  KnowledgeContext = “Buy Decision”
  ID       = “BD_110011”
  ItemID= “ITWIDG011” >
  <Rule>
    <Condition
      Preference = “Less OR Equal”>
      Price
      <Value> 19.99 </Value>
    </Condition>
    <Condition>
      Preference = “Less OR Equal”>
      RequiredBy
      !-- Value from User --!
      <Value>#12/25/02#</Value>
    </Condition>
    <Decision> Buy</Decision>
  /Rule>

  <Rule>
    <Condition
      Preference = “Less than 10%”>
      Price<Value> 19.99 </Value>
    </Condition>
    <Condition>
      Preference = “Add 1 week”>
      RequiredBy
      !-- Value from User --!
      <Value>#12/25/02#</Value>
    </Condition>
    <Decision>Buy</Decision>
  /Rule>
  ...

</Rules>
```

Sample Rules

```
<Domain
  KnowledgeContext = “Decision Context”
  ID          = “Specific Buyer ID”
  Description = “Domain Description”
  ItemID      = “Specific Item ID” >
    <Attribute> Price</Attribute>
    <Attribute> Currency</Attribute>
    <Attribute> Quantity <Attribute>
    <Attribute> Required By<Attribute>

    ...    Other Attributes
</Domain>
```

Defining Domain Ontology

```
<Domain
  KnowledgeContext = “Buy Decision”
  ID       = “BD_110011”
  ItemID= “ITWIDG011” >
  <Price> 19.99 </Price>
  <Currency> USD </Currency>
  <Quantity> 2000 </Quantity>
  <RequiredBy>#12/25/02#</RequiredBy>
    ...

</Domain>
```

Sample Domain Attributes

Figure 3. Domain Ontology, Business Rule, and Knowledge Context for a Business Entity

These representations form the basis for the development of the structure of a Knowledge Context unit, consisting of domain ontology and rules that explicate advisable actions in terms of the attributes described in the domain ontology. The schematic in Figure 4 below illustrates the structure of a Knowledge Context.

The Knowledge Context is actively managed through a wrapper Knowledge Context object that extends a Java Bean. Public methods of the Knowledge context are presented as web services to the knowledge agent, which manages their delivery to users and user agents. The Knowledge Context object, with its methods and contents and the interaction between the Knowledge context object and the domain and rules documents is shown in Figure 4. The methods exposed by the Knowledge Context object for a given domain entity define the basis for the set of web services that are available for a specific entity about which the knowledge repository is able to provide information. A Knowledge Context object is a Java Bean that wraps and allows programmatic access to the information contained in the domain and rules documents with public methods to show the domain entity ontology and the business rules that are pertinent to the given business domain. The Knowledge Context provides a list of the various attributes that make up the business domain in order to inform the user, or user agent, of a common description of the various attributes that are pertinent to this business entity. With access to this domain ontology, provided by the Knowledge Context, the user application can share terminology to unambiguously refer to concepts and constructs that define the business domain under consideration. The Knowledge Context utilizes an internal representation of attributes and rules that allow the object to make decisions, with information about a particular set of circumstances described in terms of specific attribute values.

For example, as shown in Figure 3, a domain state can be represented through a set of specific values of the domain attributes. The Knowledge Context performs a simple matching function to match these provided attributes to the known set of rules and a rule is fired from the rule document. This results in the generation of a buy or don't-buy decision which can be explained through the set of attributes that comprise the rule. In the example shown in Figure 3, the user would be advised to buy the item "ITWIDG011" *if the price is less than or equal to USD $19.99 AND the item can be delivered on the required date; OR if the price offered is less than 10% of USD $19.99, then the user would display flexibility in the required by date of less than or equal to a one week*. Such Knowledge of consumer preferences can be easily collected and codified and would provided valuable information to suppliers in developing their tactical positions in the eMarketplace. A parallel set of domain ontology and rules can be developed for suppliers seeking buyers for their goods.

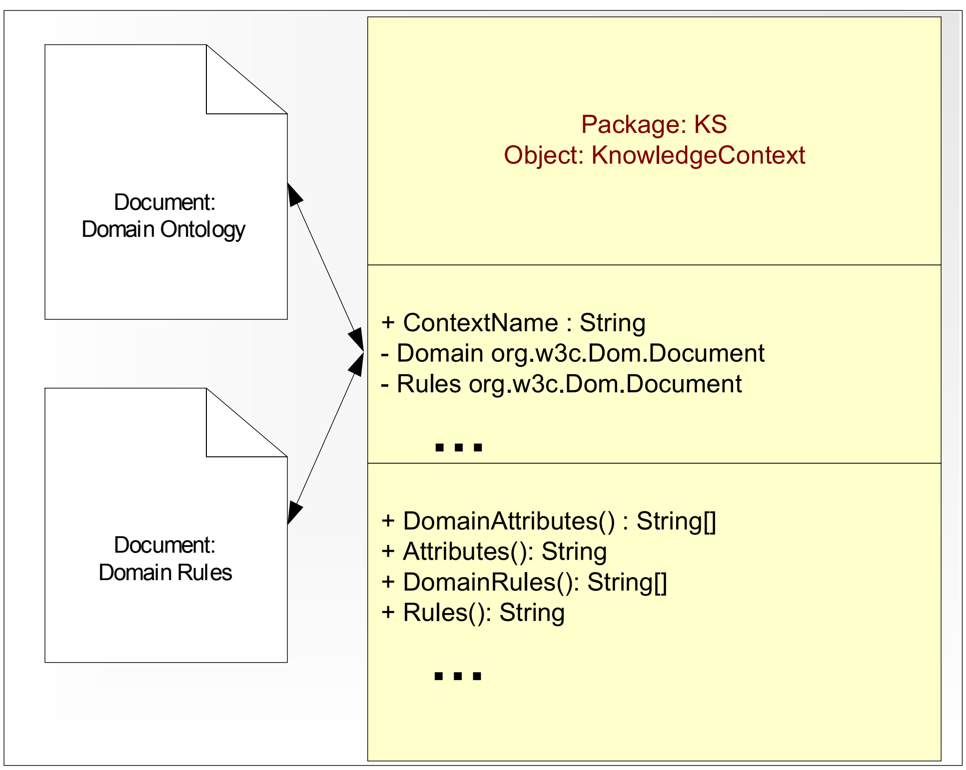


Figure 4. Modular Knowledge Context

As mentioned earlier, the Knowledge Context object is created as a wrapper class and contains methods to share XML nodes containing a set of attributes for a domain and the rules or preference criteria for a user, wrapped in SOAP envelopes through web services. This knowledge architecture is extensible to multiple buyers for the same item since the buyers are essentially represented through their expressed preferences, or rules, in the context of the application.

Knowledge Services

Knowledge Services are domain specific knowledge provided by the knowledge agent to users, through their agents, over heterogeneous information platforms using web services as a foundation. Knowledge services are delivered through the Knowledge Agent to share domain specific knowledge by presenting the returned parameters of the knowledge context object's methods to distribute domain context information and business rules as knowledge services. The knowledge agent performs the role of the manager for all services through the knowledge repository. It actively manages the information that is made available through the repository by managing the UDDI of service provided by the Knowledge Context objects. The Knowledge Agent represents the external interface through which users and user agents make requests for knowledge services provided by the knowledge repository. Figure 5 below shows a schematic for the presentation of knowledge services to the user agents.

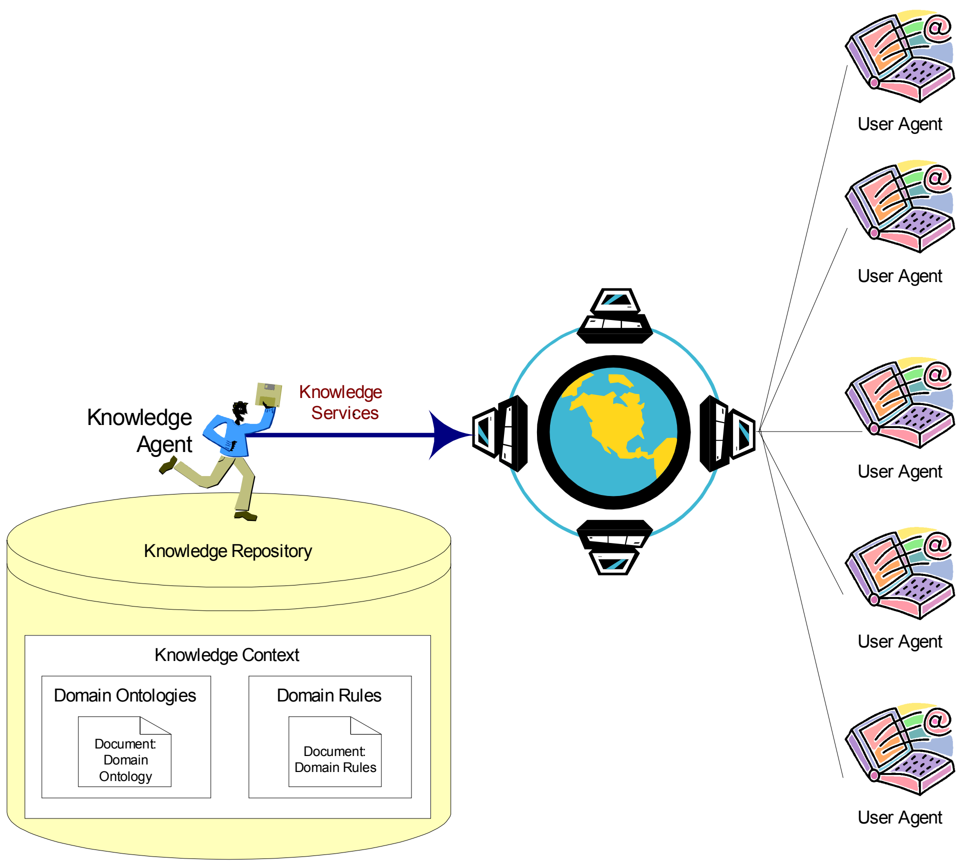


Figure 5. Knowledge Services Are Delivered by the Knowledge Agent to User Agent through Web Services to Collect and Provide Domain Specific Knowledge

The requirement of unambiguous interpretation of content places requirements of uniformity of content on the structure and nature of requests. This implies that all information exchanges between the Knowledge Agent and the User Agent must conform to formats agreed upon *apriori* to their actual exchange. This is a principal contribution of common ontologies and namespaces to the ability of web services to deliver standardized content. Demand requirements of buyers and the supply capabilities of suppliers are made known to the knowledge repository, uniquely identified through the common item that they wish to purchase or provide. The buyers and suppliers are identified in the repository using unique identifiers that are assigned to them when they register their details with the repository. At this time, the repository interface requires the registrant to identify the product of interest to them, and makes the meta-data and ontology for that item available to them. This provides a basis for a standard format for the exchange of information regarding a common item. The following section further develops the above example with an example for the development of eMarketplaces to enable knowledge infused on-line processes using agents and Knowledge Services.

Electronic Marketplaces: An Illustrative Example

Electronic marketplaces match buyers and sellers, facilitates transactions, and provides institutional infrastructure for transactions to place (Bakos, 1998). Processes in typical link of a supply chain include the explication of buyer requirements, which triggers a systemic search to identify suppliers who are able to meet these needs. This culminates in a set of suppliers who match the needs of the buyer. The buyer then selects a supplier from the set of identified suppliers who can fulfill the buyer's demand. Such binary collaboration represents the core process involved in the economic marketplace and provides the fundamental interaction unit, supported by most eMarketplaces with varying degrees of automation. The eMarketplace adds value to buyers and suppliers by providing assistance in matching buyers' needs with suppliers' products and services and deciphering complex product information for both suppliers and buyers. This critical role of the eMarketplace forms the basis for the development of the infomediary business model, as a direct response to the overwhelming volumes of information available in eMarketplaces. Grover and Teng (2001) provide a detailed description of the value-added activities provided by infomediaries in the eMarketplace.

An analysis of the infomediary business model shows that buyers and suppliers seek distinct goal oriented information capabilities from the infomediary – they provide decision parameters through their individual demand or supply functions and they seek buyers or suppliers who can meet their requirements. This discovery activity involves buyers and suppliers searching for a match of their requirements, through the infomediaries enabled eMarketplace. This discovery process may be influenced by historical information including the past experiences of other buyers' reliability and trustworthiness of the supplier. Infomediaries become vital repositories of knowledge about buyers, suppliers and the nature of exchanges among them. The infomediary can provide valuable information to business decision processes by serving as the repository of experiential knowledge of transactional histories for both buyers and suppliers.

We implement the knowledge role of infomediaries through the Knowledge services architecture. Figure 6 illustrates a schematic for extended infomediary-based eMarketplaces. In providing decision parameters through their expressed individual demand and supply functions, participants in an eMarketplace look for the discovery of buyers and suppliers who meet their needs. The infomediary provides valuable information to this decision process by serving as the repository of experiential knowledge of transactional histories for both buyers and suppliers. To maintain and enable these knowledge services of infomediaries, transaction information from buyers and suppliers is collected to develop knowledge to inform the discovery process for subsequent transactions.

Summary

Recent developments in EC focus on the development of collaborative value chains between organizations to deliver value to customers. The transparent flow of information and problem specific knowledge across collaborating organizations, over systems that exhibit high levels of integration, is required in order to enable such strategies. The knowledge services architecture presented here, applies domain ontologies, web services, and multi-agent systems in developing a mechanism to deliver context specific domain knowledge to partner organizations. We show the development of Knowledge Services for EC, as domain specific knowledge available over heterogeneous information platforms through web services technology, using a multi-agent systems framework. This is illustrated through the application of the knowledge services architecture to infomediary-based electronic market places. In addition, such eMarketplaces are interconnected and exposed to each other through authenticated monitoring agents that gather and share market-related information in providing information transparency throughout the entire e-supply chain. Such knowledge infused processing capability is missing from eMarketplace and is critically needed. It is clear that information transparency in the entire supply chain is a required component. The growing complexity in information sources and business processes requires an alliance of mechanisms for the ad-hoc availability of knowledge, to supplement human analysis, intuition and judgment. The use of knowledge services and intelligent agents to monitor developments in multiple infomediary-based eMarketplaces makes the entire e-Supply chain transparent and reduces the cognitive load on human decision makers by enabling a knowledge rich environment.

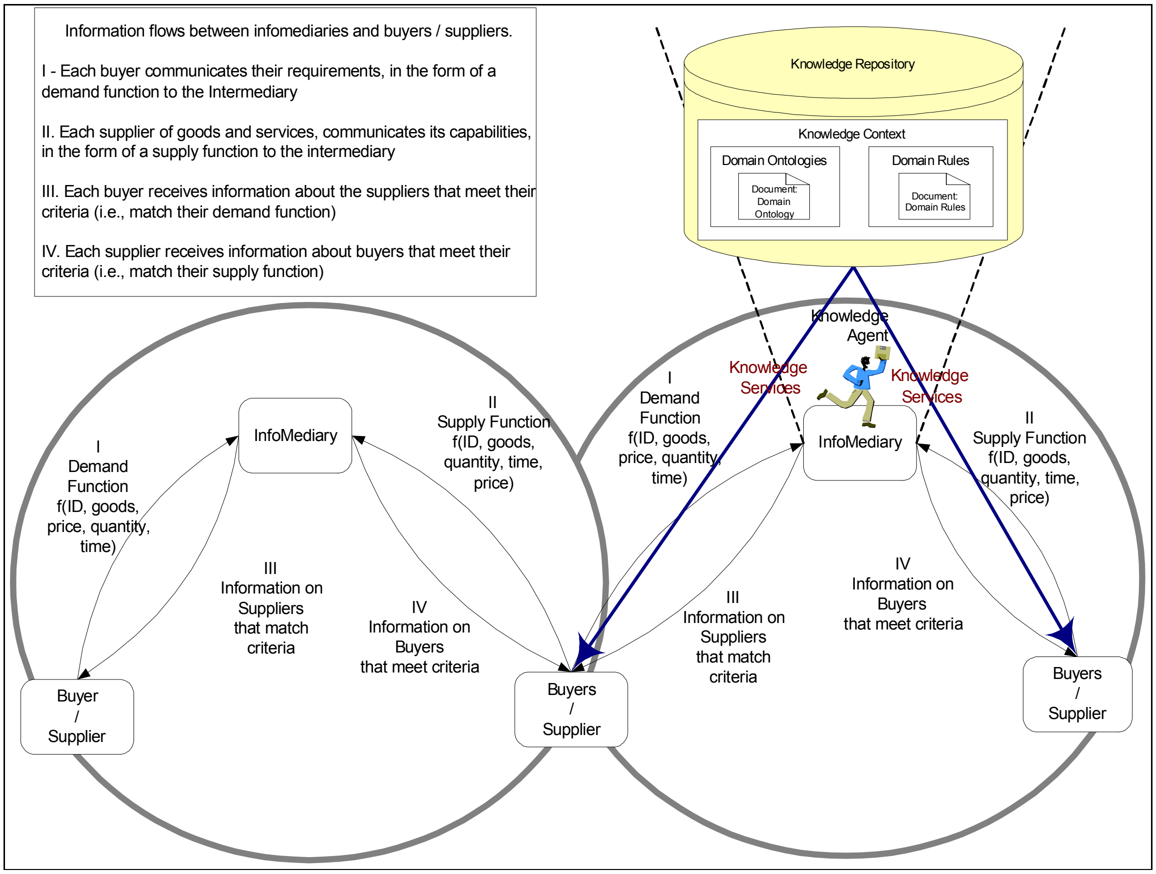


Figure 6. The Role of Infomediaries in eMarketplaces Facilitating Transactions Between Buyers and Suppliers over Multiple Links in the Supply Chain

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