INTELLIGENT AGENTS TO SUPPORT INFORMATION SHARING IN B2B E-MARKETPLACES

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Abstract:
This article proposes an architecture to support information and knowledge exchange between collaborating business partners. The focus is on knowledge representation and exchange by intelligent agents to support collaborative business functions through agents that exchange problem-specific information in standardized formats. The article then shows the application of the proposed architecture in the context of an infomediary-based B2B E-marketplace.

Article:
Emergent internet technologies already have had significant impacts on the business processes of today's organizations. New ways of conducting business with other businesses (B2B), directly with end consumers (B2C), and via new E-marketplaces have been implemented to facilitate transaction processing and coordinate processes among business partners. Increasingly, the Internet is seen by business organizations as a vehicle to create value. With an increasing number of parties involved in managing such a complex supply chain, the timely sharing of accurate information among collaborating partners becomes crucial to the efficiency of workflows and business operations (Rabin. 2003). However, a lack of systems and process integration, and the resultant lack of end-to-end value chain visibility, continue to hinder collaborative and mutually beneficial partnerships (Rabin, 2003).

Information exchange, facilitated through technologies such as the Internet with its global connectivity, enables the creation of information partnerships among participants engaged in collaborative work across the entire supply chain. Information partnerships require system models that enable and support information integration, knowledge exchange, and thus improved collaboration among business partners. Such systems must provide trusted collaborating partners with "intelligent" capabilities for the seamless and transparent exchange of dynamic market information, including supply and demand conditions both synchronously and asynchronously, to attain their full business potential. Weber and Aha (2003) identified requirements for organizational knowledge management systems (KMS) where the central unit is a repository of knowledge artifacts (Holsapple and Joshi, 2001) collected from internal or external organizational sources. Here, knowledge repositories play a central role in the storage, distribution, and management of knowledge in an organization (Bolloju et al., 2002). Implementing and managing such knowledge integration capabilities over distributed and heterogeneous information platforms, such as the Internet, is a challenging task; yet, realizing this task can have huge benefits for organizations that embrace collaborative business paradigms.

Recently, intelligent agents have gained significant interest as powerful modeling abstractions for B2B applications (Papazoglou, 2001). The assumption here is that the usage of software agents for processing information and knowledge flows can help increase the efficacy of an E-marketplace for its participants. Software agents work together by sharing process knowledge to achieve operational synergies for the goal-oriented activities of individual entities in the system. Together -with emerging technologies like extensible Markup Language (XML) and Web Services, they provide opportunities to develop integrative E-marketplaces with suppliers or customers.

This study focuses on the translation of data, information, and knowledge into XML documents by software agents, creating a foundation for knowledge representation and exchange by intelligent agents. We propose an architecture that incorporates a consolidated knowledge repository- to store and retrieve knowledge, captured in XML documents, by software agents to support information sharing between collaborating partners in B2B E-marketplaces. The realization of the proposed architecture is explicated through an infomediary-based E-marketplace example where agents facilitate collaboration by exchanging knowledge using XML in unambiguous formats to facilitate semantic integration. The intent of this study is to bridge a gap in the literature by integrating emerging technologies such as XML. the Web Services architecture, ?-business XML (ebXML), and multi-agent intelligent software systems for the specific needs of B2B E-marketplaces.

This architecture is applicable to both commodity and specialized product markets. Typically, price is a differentiating factor in commodity markets. To ensure that items are priced right, supply and demand information should be exchanged in a timely manner. In the absence of such mechanisms, prices can be artificially inflated by the supplier to improve margins. The proposed architecture enables the seamless transformation of supply and demand information, thus reducing the uncertainties that might impact pricing. In specialized markets, collaboration among partners is critical to ensure that complex product requirements can be shared effectively.

In both commodity and specialized cases, streamlining supply chain transactions and connecting various trading partners can benefit multiple players. Potential benefits to suppliers and customers include improved order accuracy, access to product specifications and offerings, access to real-time supply and demand information, enhanced automation, and improved inventory management (Giaglis et al., 2002).

POTENTIAL BENEFITS FROM COLLABORATIVE COMMERCE

The advent of electronic data interchange (EDl) established the preliminary basis for B2B transactions, whereby organizations electronically share data using standardized semantics. Since the 1990s, we have also seen the evolution of integrated application software modules to support the firm's back-office systems (ERP) and its extended supply chain (SCM) that go beyond mere automation by streamlining internal and interorganizational processes. These SCM applications in particular have contributed to the maturation of the idea of multiple organizations involved in a business transaction being partners on the same team.

The evolution of the Internet led to the adoption of B2B ?-commerce and E-marketplaces for exchange of information and transactions between business partners (Carroll, 2001). While organizations have achieved transactional efficiencies with these online marketplaces, the lack of systems and process integration has led to a lack of end-to-end value chain visibility, hindering the creation of partnerships characterized by the sharing of information and knowledge for the benefit of all participants. Consequently, the next logical step is to look for ways to eliminate these market inefficiencies and enable the sharing of information and knowledge for collaborative work across partners in E-marketplaces.

Ferreira et al. (2001) define C-commerce (collaborative commerce) as "a means of leveraging new technologies to enable a set of complex cross-enterprise business processes allowing entire value chains to share decision making, workflow, capabilities, and information with each other." The aim of C-commerce is to achieve dynamic collaboration among internal personnel, business partners, suppliers, and customers throughout a trading community or market through information and knowledge exchange. Organizations can harness the potential of the Internet to gain such benefits as optimized inventory levels, higher revenues, improved customer satisfaction, increased productivity, and real-time resolution of problems and discrepancies throughout the supply chain (Anderson, 2000).

INTELLIGENT AGENTS AND THEIR APPLICATION

An intelligent agent is "a computer system situated in some environment and that is capable of flexible autonomous action in this environment in order to meet its design objectives" (Jennings and Wooldridge, 1998). The terms agents, software agents and intelligent agents are often used interchangeably in the literature.

However, not all agents necessarily have to be intelligent. For example, Jennings and Wooldridge (1998) require that an agent be flexible to be considered intelligent. Such flexibility in intelligent agent-based systems requires that the agents should be (Bradshaw, 1997; Jennings and Wooldridge, 1998):

* Cognizant of their environment and be responsive to changes therein

* Reactive and proactive to opportunities in their environment

* Autonomous in goal-directed behavior

* Collaborative in their ability to interact with other agents in exhibiting the goal-oriented behavior

* Adaptive in their ability to learn with experience

Additionally, Klusch (2001) points out that the specific autonomous behavior expected of intelligent agents depends on the concrete application domain and the expected role and impact of intelligent agents on the potential solution for a particular problem.

Intelligent agents are action-oriented abstractions in electronic systems, entrusted to carry out various generic and specific goal-oriented actions on behalf of users. The agent paradigm can support a range of decision-making activity, including information retrieval, generation of alternatives, preference rankings of options and alternatives, and supporting analysis of the alternative-goal relationships (Whinston, 1997). In this respect, intelligent agents have come a long way from being digital scourers and static filters of information to active partners in information processing tasks. Such a shift has significant design implications on the abstractions used to model information systems, objects, or agents, and on the architecture of information resources that are available to entities involved in the electronic system.

Agent-based systems may consist of a single agent engaged in autonomous goal-oriented behavior or multiple agents that work together to exhibit granular as well as overall goal-directed behavior. The general multi-agent system is one where the interoperations of separately developed and self-interested agents provide services beyond the capability of any single-agent model. Multi-agent systems provide a powerful abstraction for modeling systems where multiple entities exhibiting self-directed behaviors must coexist in an environment and achieve the systemwide objectives of the environment. According to Muller (1997), there are three minimal criteria for the application domain to meet in order to apply the agent technology:

1. Show natural distributivity (e.g., autonomous entities, geographical distribution, distributed data).

2. Have a need for flexible interaction (e.g., there is no a priori assignment of tasks to actors, there are no fixed processes).

3. Be embedded in a dynamic environment (e.g., our physical world, artificial worlds like the Internet, the world of finance).

Agent-based E-marketplace systems (Kang and Han, 2002) exhibit distributive, flexible, and dynamic environments that are well suited for application of multi-agent systems providing cognitive support to end users. Multi-agent systems can be used to enhance collaboration among supply chain partners. These intelligent agents can participate in harmony with human agents to organize, store, retrieve, search, and match information and knowledge to effectively collaborate among supply chain participants. A fundamental requirement here is that the knowledge needed can be made available in formats that allow its representation and manipulation by software applications, including software agents. This requirement can be met by emerging Semantic Web standards (www. w3c.org). Specifically, the Web Ontology Language (OWL) has recently become a recommended standard from W3C for knowledge representation and reasoning using OWL Reasoners.

KNOWLEDGE MANAGEMENT SYSTEMS

From an organizational perspective, the management of corporate knowledge can improve a range of organizational performance characteristics by enabling an enterprise to be more "intelligent acting" (Wiig, 1994; Papazoglou, 2001). Many organizations have invested in knowledge management systems (KMS) designed specifically to facilitate the sharing and integration of knowledge across its dispersed internal units. Key objectives of such KMS projects in practice are knowledge creation and storage, knowledge codification and coordination, and knowledge transfer (Davenport and Prusak, 1998). The KM principles necessary to achieve intra-organizational knowledge bases include the use of corporate data to derive and create higher-level information and knowledge, and the provision of tools to transform scattered data into meaningful business information (Ba et al., 1997), While KMSs vanon the type of knowledge artifact stored, the scope and nature of the topic described and their orientation, knowledge repositories play a critical role in the storage, distribution and management of knowledge in an organization (Weber et al., 2003).

However, to accomplish the level of collaboration required for an extended supply chain (i.e., with suppliers or customers), businesses need a solution to facilitate information sharing between business partners. Just as a common method for publishing data on the Web spawned the commercialization of the Internet, a common means for publishing information about business services can make it possible for organizations to efficiently discover the right trading partner from the millions online. It will also aid in conducting business transactions once preferred businesses are discovered and create an industrywide approach for businesses to quickly and easily integrate systems and business processes with their business partners on the Internet. The facilitation of such transparent flows of information about their products and services, or service-centric computing, requires businesses to discover each other, to make their needs and capabilities known, and to integrate systems and services using each business' preferred technology, Web services, and commerce processes. These activities transpire in the context of mutually agreeable contractual agreements. Each organization's ability, then, to establish connectivity, put product or service information online, access and interact with a broad range of customers, process transactions, and fill orders will influence the level of collaboration that can be achieved among its business partners using heterogeneous sources and systems.

Access to knowledge and its seamless transfer is critical to enable collaboration among trusted business partners (based on mutually agreeable contractual agreements). This article focuses on developing an architecture in which intelligent agents are used to provide the relevant information and knowledge to decision makers in multiple organizations, in a timely manner.

EMERGING TECHNOLOGIES AND SUPPORT FOR E-COMMERCE

Despite the simplicity provided by HTML for usage and content presentation, it has limited extensibility for data description, which limits its use. The use of XML and its related set of standards, developed by the World Wide Web Consortium (www.w3c.org) is a key enabler for content sharing by application software in distributed environments where software applications, including software agents, are expected to work with available data, rules, and knowledge without human intervention. In addition, organizations such as the Organization for the Advancement of Structured Information Standards or OASIS (www.oasis-open.org), International Organization for Standards (ww.iso.org), RosettaNet (www. RosettaNet.org), and others have driven the development, convergence, and adoption of E-business standards. The Consortium produces standards for security, E-business, and standardization efforts in the public sector and for application-specific markets.

Short descriptions of the role of XML, the Semantic Web, and Web services to enable information sharing across business partners and automated processes to reduce human interventions are provided in Table 1. These technologies, along with other initiatives, should allow for the development of intelligent agent-based systems that are both practical and viable for facilitating collaborative commerce.

However, although these initiatives are extremely promising for agent interoperability and reasoning, they are in their early stages of development. Standards for these technologies are also of critical importance; for example, 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 (Kwon, in press).

TABLE 1 XML, ebXML, Semantic Web, and Web Services Technologies

XML:

Unambiguous understanding of the content of customized XML tags by interested parties requires description of both the content and structure of XML documents. This description of structures in XML documents is provided by the XML Schema, which can be written following the set of standards called XML Schema Language (www.w3c.org) as adopted and standardized by the W3C. The XML Schema describes the specific elements, their relationships, and the specific types of data that can be stored in each of these elements. Essentially, an XML Schema describes the structure of XML documents and their contents.

XML documents can be parsed and validated by application software provided either the DTD or the XML Schema of the corresponding document is made available. XML parsers written in C, C++, or Java can process and validate XML documents (containing business rules and data) based on XML Schemas written based on either the DTD or the XML Schema specification. Application software appropriate parser utilities are able to read or write to XML documents following the W3C standards and specification. This provides the foundation technology, built upon agreed and accepted standards from the W3C, for the capture, representation, exchange, and storage of knowledge represented by business rules and related data in XML format that can be potentially used and shared by software agents.

ebXML:

To support a dynamic setup of business processes among independent organizations, a formal standard schema for describing the business processes is required. The ebXML (www.ebxml.org) standard and framework provides such a specification for defining business processes crossing organizational boundaries. ebXML provides a modular suite of specifications that enables businesses of any size and in any geographical location to conduct business over the Internet (Kim, 2002). ebXML specifications emphasize business processes rather than business documents. The intent of the ebXML specification and its application is to capture all the bits of information that are required to completely describe a business process so that it can be registered, classified, discovered, and reused by businesses that may want to participate in C-commerce.

Semantic Web:

Some recent promising initiatives to develop technologies for what is being called the "Semantic Web" (Berners-Lee et al., 2001) attempt to make the content of the Web unambiguously computer-interpretable, thus making it amenable to agent interoperability and automatic reasoning techniques (McIlraith et al., 2001). Two important technologies for developing Semantic Web are already in place — XML and the Resource Description Framework (RDF). The W3C developed the RDF as a standard for metadata to add a formal semantics to the Web, defined on top of XML, to provide a data model and syntax convention for representing the semantics of data in standardized interoperable manner (McIlraith et al., 2001). The RDF Working Group also developed RDF Schema (RDFS), an object-oriented type system that can be effectively thought of as a minimal ontology modeling language. There have been several efforts to build on RDF and RDFS with more AI-inspired knowledge representation languages such as SHOE, DAML-ONT, OIL, and DAML+OIL (Fensel, 2000). Recently, the W3C has made the Web Ontology Language (OWL) a recommended standard for knowledge representation. OWL is built upon XML, RDF, and RDFS standard specification.

Web Services:

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. The Web Services framework consists of the Web Services Definition Language (WSDL, 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, 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, that can be dynamically discovered and used by human and software agents seeking specific information and processing capabilities.

TABLE 1 ***XML, ebXML, Semantic Web, and Web Services Technologies***

A PROPOSED ARCHITECTURE: FUNDAMENTAL COMPONENTS

As described above, a KMS for intraorganizational KM include facilities for knowledge creation, knowledge exchange, storage and retrieval of knowledge in an exchangeable and usable format, and the use of knowledge repositories in decision-making activities. The proposed architecture uses intelligent agents as the basic abstraction for knowledge encapsulation and exchange to supporting collaborative activities. The agent abstraction is created using objects as the base class and incorporates additional features as warranted by agent functionality. Software agents also interact with a knowledge repository to actively affirm the accuracy of the decision models used by the knowledge agents and serve as the active component of the decision support system. A domain knowledge object represents information about a specific problem domain. The domain knowledge object contains information about the characteristics of the various domain attributes that are important to the problem domain. The domain knowledge object also contains rules that specify decisions using the domain attributes of the domain knowledge object (see Figure 1). Therefore, the domain knowledge object represents a description of the problem context (in terms of an agreed-upon ontology) and a description of the rules for making decisions in the problem context. The ontology represents descriptions of domain concepts that have shared meaning among participants so that knowledge represented using the agreed-upon ontology can be easily shared.

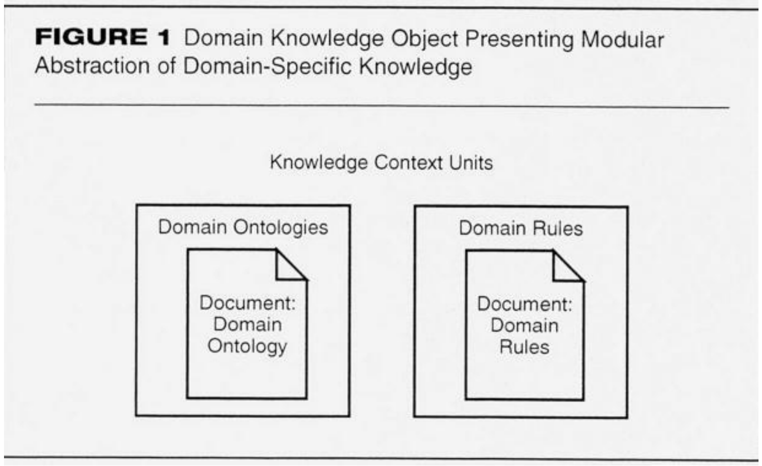


FIGURE 1 ***Domain Knowledge Object Presenting Modular Abstraction of Domain-Specific Knowledge***

There are many benefits to storing this knowledge in XML format, including standardization of semantics, validation ability and "well-formedness," ease of use. reuse and storage, and the ability to exchange complete XML documents in a format that conforms to established standards published by the World Wide Web Consortium (www.w3c.org). The domain knowledge object represents the abstraction used for creating, exchanging, and using modular knowledge objects.

The architecture uses intelligent agents as the mechanism for the encapsulation and exchange of knowledge between agents at the site of knowledge creation and the site of knowledge storage. Intelligent agents are also utilized for the delivery of the knowledge to the user interface to support decision-making activity. Knowledge exchange and delivery are facilitated through the exchange of the domain knowledge objects among intelligent agents. The domain knowledge object contains behaviors to inform its containing agent of the name of the problem domain, share information about the various domain attributes that are pertinent to the specific knowledge context, and share rules about making decisions for their specific problem domain. We use these core components to develop the functionality of the architecture and domain attributes from raw data, create domain specific knowledge, share it with other agents, and apply this knowledge in either solving domain specific problems or domain-specific collaborative activities with users. Once the attributes and domain rules are captured in the domain knowledge object, using standard XML Document Object Model (DOM) format, they can be exchanged between agents.

Figure 2 provides a schematic of the collaboration process. The architecture is designed for a distributed platform where the knowledge is available to the agents in the system, on an intranet and an Internet-based platform. By enclosing the domain knowledge objects in SOAP wrappers, the knowledge broker functions of the knowledge agent are available as a Web senace.

The learning agent interacts with a repository of raw data and extracts raw data that is used to generate domain-specific knowledge. The proposed model does not specify the storage representation in order to signify the fact that the data contained in the repository may be of multiple representation formats, including flat files, data stored as relational tables that can be extracted using multiple queries into a record set, or data represented using XML documents (Nemati et al., 2002). The process of extracting the data from the repository provides the context and syntactical representation of the information to create the domain attributes that are pertinent to the decision problem context. The objective of this step is to generate domain-specific knowledge, in the form of domain attribute information, and rules for making decisions in the specific problem context. The system ensures that this knowledge is generated in a format conducive to sharing and using the information across a distributed and heterogonous platform. We use the domain knowledge object as the modular abstraction for knowledge representation and knowledge exchange facilitation.

Once created, domain knowledge is made available to all agents in the system through sharing the domain knowledge object between the learning agent and the knowledge agent. The knowledge agent manages the knowledge available in the knowledge repository and allows other agents to be aware of, request, and receive the domain knowledge in the system. The system utilizes the domain knowledge object as the modular knowledge abstraction for communication of knowledge between the multiple agents of the system. Therefore, when the domain knowledge object is shared with an agent of the system, the agent becomes aware of the problem context descriptions and the rules that govern decision making for the specific problem context. The knowledge agent is responsible for maintaining the collection of domain knowledge available in the system through its interactions with a knowledge repository. The knowledge agent contains methods to generate rules to support ad hoc queries by the user agent. This is supported through the interactions of the knowledge agent with the knowledge repository. The knowledge repository is implemented using a set of XML documents that is stored in a repository capable of storing XML documents, such as the Oracle 10g family of information management products (www.oracle.com). The knowledge repository allows for easy storage and retrieval of the knowledge contained in a domain knowledge object. Thus, the knowledge is available to all the agents in the system through the activities of the KM behaviors of the knowledge agent object. In this respect, the interactions among the agents in this system are modeled as collaborative interactions, where the agents in the multi-agent community work together to provide decision support and knowledge-based explanations of the decision problem domain to the user.

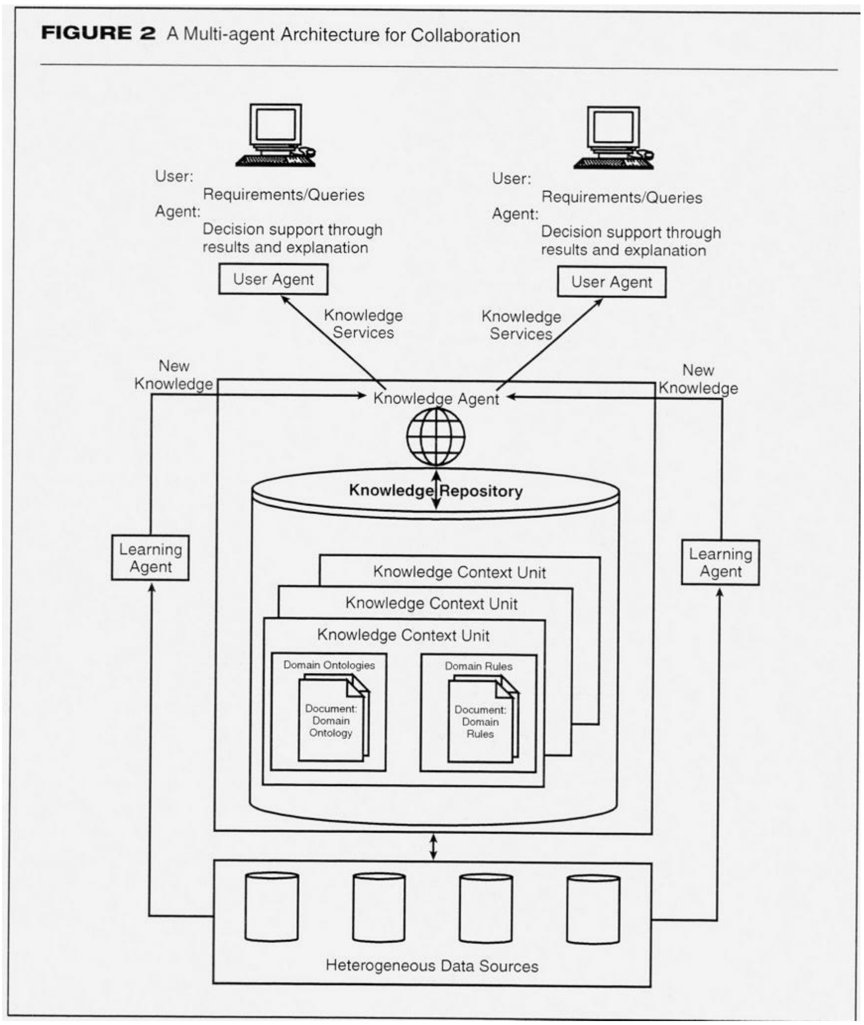


FIGURE 2 ***A Multi-agent Architecture for Collaboration***

The users can interact with the system through user agents that are constantly aware of all domain knowledge contexts available to the system, through a registry of domain contexts of the domain knowledge objects. This registry is published and managed by the knowledge agent. This allows every user agent, and hence every user, to be aware of the entire problem space covered by the system. The user agent requests and receives the knowledge available for a specific problem domain by making a request to the knowledge agent, at the behest of the user. The knowledge agent, upon receiving this request, shares a domain knowledge object with the user agent, thereby making problem domain information and decision rules available to the user agent. The knowledge agents also service any ad hoc queries that cannot be answered by the user interface agents, such as queries regarding knowledge parameters that are not available to the user interface agents. In such cases, the knowledge agent, with direct access to the knowledge repository, can provide such knowledge to the user agents for the benefit of the user. This information is shared in the form of two W3C-compliant XML DOM objects, Domain Ontology and Domain Rules, as shown in Figure 1. These documents represent an enumeration and explanation of the domain attributes that are pertinent to the problem context and the rules for making decisions in the specified problem context. Once the domain knowledge object is available to the user agent, the user agent becomes problem domain aware and is ready to assist the user through a decision-making process in the specific problem domain.

The following benefits are derived due to the ability of the architecture to provide decision support and explanation facility to the end users where agents are able to explain how they arrived at a particular decision:

* The end user is able to understand how the decision was made by the software agent.

* The end user is able to make a clear assessment of the viability of the decision.

* The end user is able to learn and gain more knowledge about the problem domain by studying the decision paths used by the agent.

Because agents are able to explain the rules and parameters that were used in arriving at the stated decision, nontechnical end users are able to easily understand how a problem was solved through inductive learning and decision tree model-based explanations, as compared to more complex machine learning and problem-solving methods such as neural networks, and statistical and fuzzy logic-based systems (Sung et al., 1999). The architecture can provide collaborative support to internal processes, as well as processes that interface with external partners. In both cases, the proposed architecture incorporates the W3C Web Services architecture to use the Simple Object Access Protocol (SOAP) and XML (Swamynathan et al., in press). This allows for the synchronous and asynchronous exchange of information and knowledge among the collaborating partners. The incorporation of this architecture creates a flexible means of exposing the services of the agents using the Web Services architecture by a company to its potential or existing global population of customers and suppliers.

Example: Collaboration in an Infomediary-Based B2B E-marketplace

This section provides an infomediary-based E-marketplace example to show how the proposed architecture can facilitate collaboration among business partners. Infomediary-based E-marketplaces are an advanced form of E-business exchange with emphasis on information exchange between participants (Grover and Teng, 2001). Technical elements and rudimentary proofs of concept to create E-marketplaces using emerging technologies exist. For example, SpinCircuit (www.spincircuit.com) is an infomediary-based E-marketplace designed to bring together geographically dispersed designers and manufacturers of electronic components. SpinCircuit Inc. is a business-to-business (B2B) E-commerce company that made its debut as a first-ever Internet gateway bridging the gap between the design desktop and the electronic supply chain network. Spin-Circuit came into being through a strategic collaboration between Cadence Design Systems Inc., Flextronics International Ltd., and Hewlett-Packard Co. "SpinCircuit utilizes the Internet to link product development and manufacturing in a way never before done" (EDP Weekly's IT Monitor, April 10, 2000, p. 1). This is similar to the B2B collaborative initiative from the automotive industry participants in forming Covisint to facilitate connection, communication, and collaboration among its member organizations (www.convisint.com).

A conceptual analysis of the infomediary business model (Singh et al., 2003, 2005; Papazoglou, 2001; Grover and Teng, 2001) shows that the individual buyers and suppliers seek distinct goal-oriented information capabilities from the infomediary. The process usually begins with buyers and suppliers providing decision parameters through their individual demand or suppry functions. This initiates discovery activity where buyers and suppliers search for partners that match their requirements. For buyers, the result is the discovery of a set of suppliers capable of meeting the buyers' needs. Typically, buyers will then engage in internal decision-making activity to select a supplier from the discovered set that best meets their needs. This decision can be influenced by historical information such as past experiences of the buyers, including the reliability and trustworthiness of the supplier.

TABLE 2 Contributions of Agent-Enabled Infomediary-Based E-Marketplace

Discovery — of buyers and suppliers that meet each others' requirements

Facilitation — of transactions to enable the flow of information and tangible goods and services between the buyers and suppliers in a knowledge-rich environment

Support — of knowledge-intensive decision processes that lead to deep collaborative relationships between partners in the supply chain

Value-Added Services — deciphering complex product information and serving as a repository of knowledge for future transactions

TABLE 2 ***Contributions of Agent-Enabled Infomediary-Based E-Marketplace***

The infomediary can provide valuable information to this decision by serving as a knowledge repository of current demand requirements, supply capabilities, and transactional histories for both buyers and suppliers. Once a supplier is identified, the infomediary performs a transaction facilitation role and enables the flow of information between the buyer and supplier, which leads to the flow of tangible goods or services. To maintain and enable its services, the infomediary must collect and maintain information from both buyers and suppliers on current and past transactions. This information is used as knowledge for the discovery process for subsequent transactions. Thus, the infomediary can serve a larger purpose than facilitation of individual transactions in some situations; that is, it can enable collaborative relationships between buyers and suppliers that are founded on trust based on information or prior usage (Welty and Becerra-Fernandez, 2001). Table 2 lists the primary contributions of an infomediary in E-marketplaces (Singh et al., 2003, 2005).

FIGURE 3 Collaboration in a Multi-agent Infomediary-Based E-marketplace

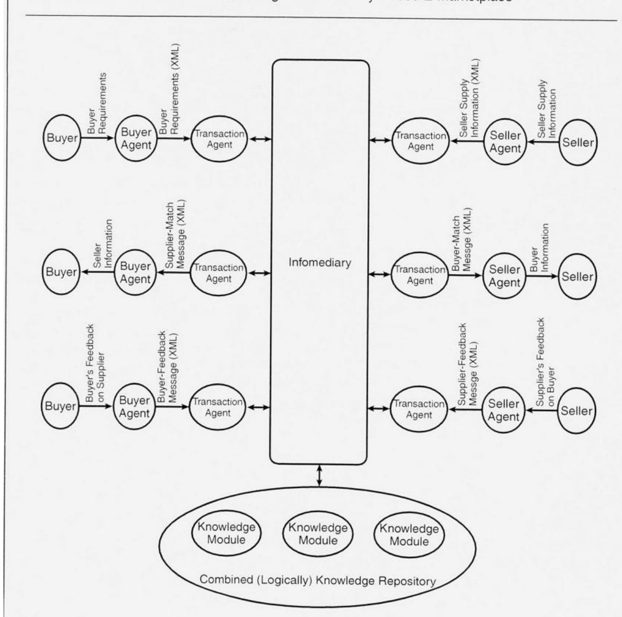
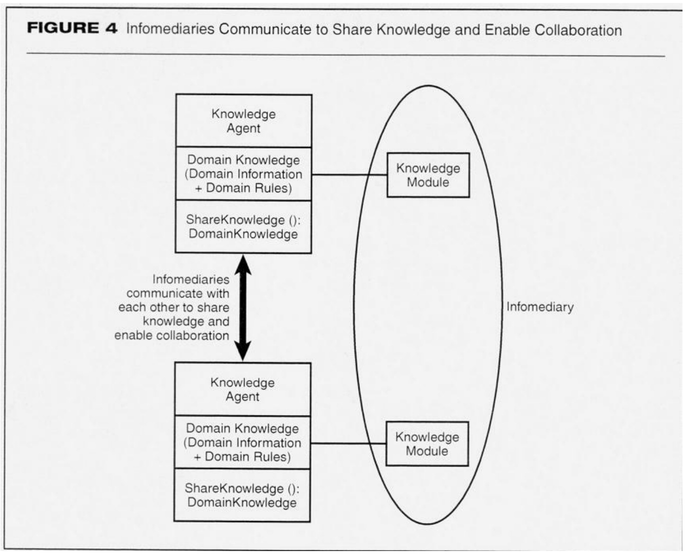


FIGURE 3 ***Collaboration in a Multi-agent Infomediary-Based E-marketplace***

In Figure 3, a buyer and a seller are represented in the virtual marketplace by a buyer agent and a seller agent, respectively. These agents convert the raw input from buyers and sellers into XML documents and pass it to the infomediary through transaction agents. This is then stored in a combined knowledge repository (see Figure 4). As discussed earlier, each agent has the ability to share its knowledge, in the form of the domain knowledge component, by invoking the ShareKnowledge behavior.



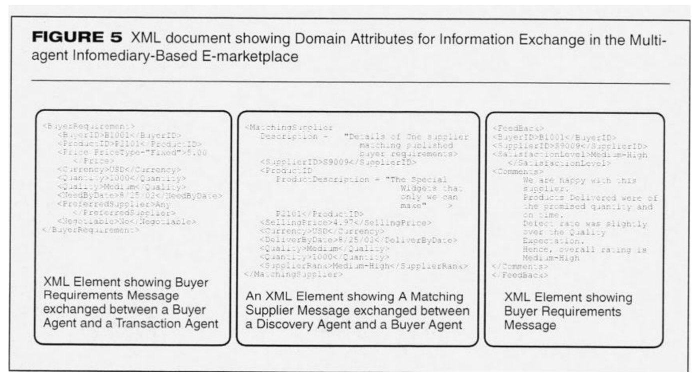


FIGURE 4 ***Infomediaries Communicate to Share Knowledge and Enable Collaboration***
FIGURE 5 ***XML document showing Domain Attributes for Information Exchange in the Multiagent Infomediary-Based E-marketplace***

The discovery agents of the infomediary are then responsible for matching buyer requirements with supplier capabilities. The information pertaining to the matching is passed on to the buyer and seller agents by the discovery agent as XML documents. Figure 5 shows the XML document containing domain attributes for information and knowledge exchange in the multi-agent infomediary-based E-marketplace.

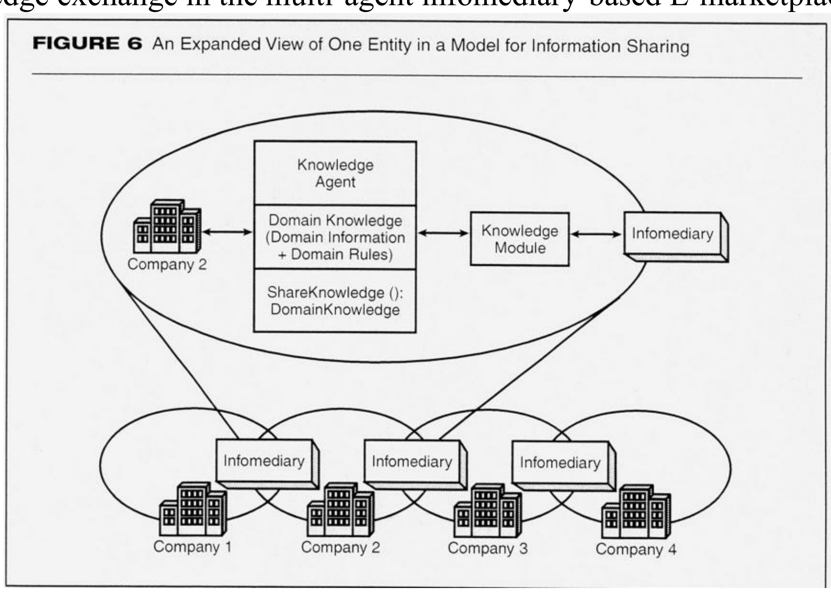


FIGURE 6 ***An expanded View of One Entity in a Model for Information Sharing***

The buyer and seller agents can then provide the results to the buyer and seller in a meaningful format with necessary explanations. Thus, the integration of multiple infomediaries can facilitate transparency by allowing the exchange of the needed real-time information about trading partners in E-marketplaces. Figure 6 shows an expanded view of one entity in a multi-agent infomediary-based model for knowledge sharing.

The use of intelligent agents to monitor developments in multiple infomediary-based E-marketplaces not only makes the supply chain transparent, but also reduces the cognitive demands on human decision makers by providing explanations and managing the information about various facets of the decision problem domain.

SUMMARY AND DIRECTIONS FOR FUTURE RESEARCH

Seamless information and knowledge transparency among business partners is a critical requirement for organizations engaged in B2B E-marketplaces. To facilitate this requires new models and applications to support and enable information integration, knowledge exchange, and improved collaboration among business partners. Such models will help organizations improve business process efficiencies through effective sharing and use of business knowledge. Such a system should also be able to support local optimization decisions for operational efficiencies of each process that are consistent with systemwide goals of delivering the value proposition to customers.

This article presented an architecture for agent-based collaborative work in B2B E-marketplaces. An integral building block of the architecture is the translation of data, information, and knowledge into XML documents by software agents, thereby creating the foundation for knowledge representation and exchange by intelligent agents to support collaborative work between business partners. The architecture also incorporates a consolidated knowledge repository to store and retrieve knowledge, captured in XML documents, to be used and shared by software agents within the multiagent architecture (Singh, Salam and Iyer, forthcoming). Using an infomediary-based E-marketplace as an example, we showed how intelligent agents can facilitate collaboration using XML and related sets of standards. Future research in the utility of such models to enable collaborative knowledge exchange is a much needed endeavor.

[Sidebar]
The assumption here is that the usage of software agents for processing information and knowledge flows can help increase the efficacy of an E-marketplace for its participants.

[Sidebar]
Not all agents necessarily have to be intelligent.

[Sidebar]
A common means for publishing information about business services can make it possible for organizations to efficiently discover the right trading partner from the millions online.

[Sidebar]
The architecture can provide collaborative support to internal processes, as well as processes that interface with external partners.

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