BUSINESS KNOWLEDGE LOGISTICS: KSNET-APPROACH AND ITS IMPLEMENTATION

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Abstract

E-Business requires cooperation and open standard-based information/knowledge exchange between all the participants of global business information environment (e-Business environment) in real-time. As a result a new scientific direction of knowledge logistics has emerged. The paper describes a developed KSNet-approach addressing the knowledge logistics problem. An ontology-driven methodology for knowledge sharing and reuse suggested by the approach is described first. Then, a system "KSNet" implemented as a prototype of this approach and its multiagent architecture and web-based implementation are discussed. At the end of the paper an application of the approach to a case study inspired by a coalition-based Binni scenario is presented.

Keywords

e-business, knowledge management, knowledge logistics, ontology management, agent-based systems.

INTRODUCTION

As firms compete in global markets they assume complex organizational forms, such as Supply Chain, Virtual Enterprise, Web-Based Enterprise, Production Network, e-Business, and e-Manufacturer. Common traits of these organizations are: (i) willingness to cooperate, (ii) global distributed processes, and (iii) high level of coordination and communication. These traits have led to the trend of transformation from a *capital* to *intelligence* intensive business environment and from product-push to consumer-pull strategies. Figure 1 represents this evolution from traditional forms of enterprise organization to the smart company or "intelligent enterprise" (Olin, et.al., 1999).

An intelligent enterprise is any enterprise envisions getting the right information, in the right context, to the right person, in the right time, for the right business purpose stated. Here there are a lot of available knowledge sources (KSs) based particularly on a wide gamma of modern standards as DAML, RDF, etc.

The shift from electronic data interchange based on fixed business relationships to agent-based systems oriented to flexible and dynamic business relationships requires a change in business paradigms. While the traditional thinking about business involves people, process, and technology, e-Business considers two additional factors: infrastructure and strategy. One of the major constraints to the widespread acceptance of e-business communities is the difficulty of collectively bringing together many disparate industry competitors, non-industry players, and other participants/units, and ensuring a common level of knowledge, understanding, and commitment. e-Business communities require cooperation and an open exchange of information among all participants.

e-Business strategy focused on the transformation aspects and fundamental shifts in value creation in the digital marketplace. The focus of current business model is to increase supply chain efficiency and to reduce costs. This is achieved through the following means – supply chain integration, e-procurement, and auctions. Some of the elements of the low cost business model include *configuring to order*, *direct shipment*, *outsourcing*, *assembly*, *logistics*, e-*service*, *and on-line marketing.* Here there are a lot of possible types of business organizations and a lot of possible types of product configurations.

In e-business area modern management systems have to collect, integrate and evaluate a continual stream of information at the highest level of system component interoperability which is characterized by the ability to globally share integrated information (data & knowledge) in a global information environment / distributed information space.

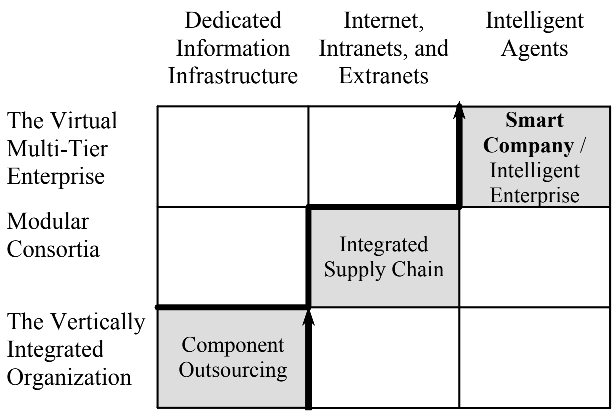

Figure 1. Evolution of enterprise organizational forms (Adapted from (Olin, et.al., 1999))

The critical difference between modern management system and other type of information systems is the fact that management systems are directly aimed at supporting the process of production, interpretation and conversation of mental knowledge for the user. Knowledge is no longer just a support function. It has become as important to management goal success as the active system components themselves. Only the continuing process transformation, substitution, analysis, and reflection of knowledge held by the user in the current management situation, ensures effective management (Smirnov, 2001b).

Besides, e-business requires cooperation and open standard-based information/knowledge exchange between all the participants of global business information environment (e-Business environment) in real-time. As a result, there arises a need to develop a cost-effective approach to acquisition of the right knowledge from distributed sources, its integration and transfer to the right person within the right context, at the right time, for the right purpose (knowledge logistics or KL) in e-Business environment (Smirnov, et.al., 2001a, Smirnov, et.al., 2002).

E-Business requires KL system to react dynamically to unforeseen changes and unexpected user needs, to keep up-to-date resource value assessment data, and to support rapid conducting of complex operations in new locations, crisis and consequence management. For this purpose new information technologies such as intelligent agents and ontology management are widely used (Fikes & Farquhar, 1997; Fischer, et.al., 1996; Jennings, 2000; Noy & Musen, 1999; Smirnov, 1999; Smirnov & Chandra, 2000; Wooldridge & Jennings, 1995).

The main goal of the presented case study is to test implementation of the described KSNet-approach to complex dynamic system – "product – process – business organization (business)" system with a list of different configuration types: (i) marketing/order configuration, (ii) product configuration, (iii) upgrade/add-on configuration, (iv) distributed process configuration, (v) business network unit configuration, and (vi) whole business network configuration.

KSNET-APPROACH

Related Works

KM consists of the following tasks: knowledge discovery (knowledge entry, capture of tacit knowledge, knowledge fusion, etc.), knowledge representation (knowledge base (KB) development, knowledge sharing and reuse, knowledge exchange, etc.), knowledge mapping (identifying KSs, indexing knowledge, making knowledge accessible) (Rasmus, 2000; Jarrar, et.al., 2002; Park, et.al., 1997; Vail, 1999). There are a number of different approaches proposed and tools developed for these tasks solving based on the algorithms of data searching and retrieving in large databases, technologies of data storing and representation, etc. Among them the following ones can be pointed out: Text-To-Onto (Maedche & Staab, 2000) for knowledge searching and retrieving from different types of documents; Disciple-RKF (Disciple-RKF, 2002), EXPECT (Blythe, et.al., 2001), OntoKick (OntoKick, 2002) fro knowledge acquisition from experts and tacit knowledge revealing; Protégé (Protégé, 2002), OntoLingua (Ontolingua, 2001), OntoEdit (OntoEdit, 2002), etc. for ontologies engineering; HPKB (Pease, et.al., 2000), AKT (AKT, 2002) etc. for KBs organization and development; KRAFT (Visser, et.al., 1999), InfoSleuth (Nodine & Unruh, 1997), Observer (Mena, et.al., 1998), etc. for knowledge and information integration. All these approaches solve particular tasks but do not provide a whole KL problem solution.

A Concept

The approach presented here is based on the assumptions that (i) knowledge as a complex resource is characterized by structure, cost, location, access time and life-time, and (ii) a knowledge worker is an owner of knowledge and a member of a team/group.

The KL problem in the KSNet-approach is considered as a network configuration that includes end-users/customers, loosely coupled knowledge sources/resources, and a set of tools and methods for knowledge processing located in the e-business environment. Such network of loosely coupled sources will be referred to as the knowledge source network or "KSNet" (Figure 2). The upper level represents a customer-oriented knowledge model based on a fusion of knowledge acquired from the underlying KSNet units/knowledge sources constituting the lower level and containing their own knowledge models.

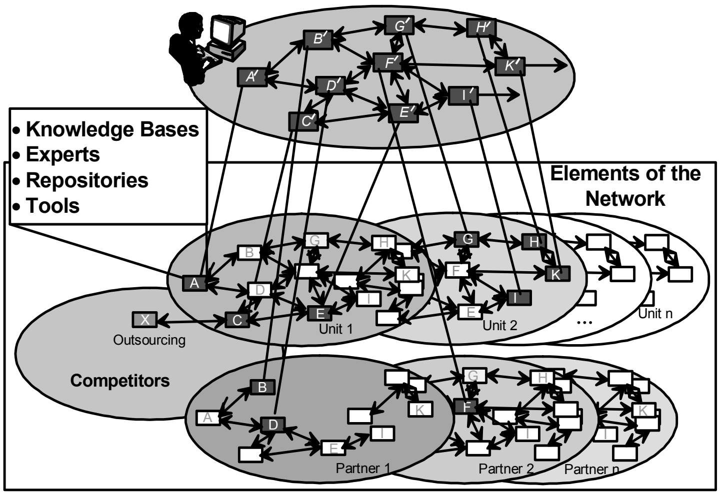

Figure 2. Knowledge source network (adapted from Golm & Smirnov, 2000)

The main principles considered during development of this approach and a KL system based on it originated from the characteristics of modern "e"-applications. These applications widely use ontologies as a common language for business process / enterprise modelling (Goossenaerts & Pelletier, 2001, O'Leary, 2000, OILEd , 2002, Protégé, 2002, Semantic Web, 2002). Thus, this approach focuses on utilizing reusable knowledge through ontological descriptions (Guarino, 1998), with an object-oriented constraint network paradigm being considered as a common knowledge notation (Smirnov, 2001a). According to this knowledge can be defined as classes, attributes, constraints, and methods that are assumed to exist in some area of interest. This perspective of knowledge representation correlates well with the semantic metadata representation concept developed under the Semantic Web project (Semantic Web, 2002).

The application of intelligent agents representing their knowledge via ontologies (Weiss, 2000) was motivated by the KL system's need for flexibility, scalability, and customizability. A multi-agent system architecture, based on the FIPA Reference Model (FIPA 2002) was chosen as a technological basis for the definition of agents' properties and functions.

Ontology Representation Paradigm

A formalism of object-oriented constraint networks has been chosen for ontology representation (Figure 3). An abstract KSNet model is based on this formalism. This abstract model unifies main concepts of languages, such as standard object-oriented languages with classes, and constraint programming languages. It supports the declarative representation, efficiency of dynamic constraint solving, and problem modelling capability, maintainability, reusability, and extensibility of the object-oriented technology.

According to the above described formalism ontology (A) is defined as: $A = (O, Q, D, C)$ where

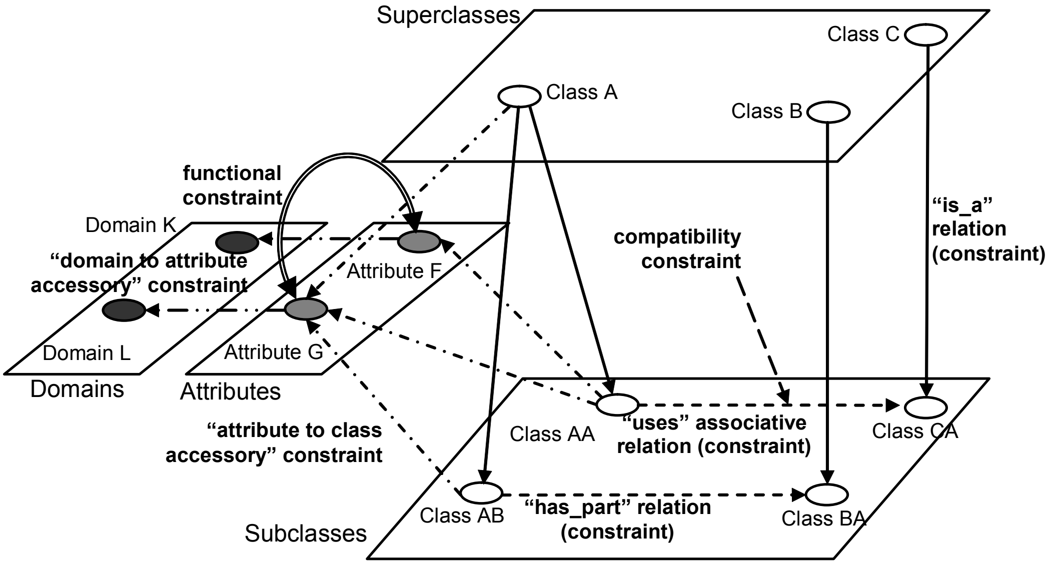

Figure 3. Object-oriented constraint network paradigm of knowledge representation formalism

O – a set of *object classes* ("*classes*"). Each of the entities in a class is considered as an *instance* of the class. This set consists of two subsets $O = O^I \cup O^{II}$:

$O^I = \{o: \exists\, instance(o)\}$ – a set of *non-primitive* classes i.e. classes which can have instances, and

$O^{II} = \{o: \neg\exists\, instance(o)\}$ – a set of *primitive* classes i.e. classes which cannot have instances (FIPA 2002);

Q – a set of class attributes ("*attributes*");

D – a set of attribute domains ("*domains*");

C – a set of *constraints*. For chosen notation the following six types of constraints have been defined $C = C^I \cup C^{II} \cup C^{III} \cup C^{IV} \cup C^V \cup C^{VI}$:

$C^I = \{c^I\}$, $c^I = (o, q)$, $o \in O$, $q \in Q$ – accessory of attributes to classes;

$C^{II} = \{c^{II}\}$, $c^{II} = (o, q, d)$, $o \in O$, $q \in Q$, $d \in D$ – accessory of domains to attributes;

$C^{III} = \{c^{III}\}$, $c^{III} = (\{o\}, True \vee False)$, $|\{o\}| \geq 2$, $o \in O$ – classes compatibility (compatibility structural constraints);

$C^{IV} = \{c^{IV}\}$, $c^{IV} = \langle o', o'', type \rangle$, $o' \in O$, $o'' \in O$, $o' \neq o''$ – hierarchical relationships (hierarchical structural constraints) "is a" defining class taxonomy (*type*=0), and "has part"/"part of" defining class hierarchy (*type*=1).

The most abstract class of the ontology (the top of the ontology's taxonomy) is "Thing".
$C^V = \{c^V\}$, $c^V = (\{o\})$, $|\{o\}| \geq 2$, $o \in O$ – associative relationships ("one-level" structural constraints);
$C^{VI} = \{c^{VI}\}$, $c^{VI} = f(\{o\}, \{q\}) \rightarrow True \vee False$, $|\{o\}| \geq 0$, $|\{q\}| \geq 0$, $o \in O$, $q \in Q$ – functional constraints referring to the names of classes and attributes.
$o \in O$, $q \in Q$, $d \in D$, $c \in C$ are considered as ontology elements.

The following ontologies types for the KL systems were defined: (i) top-level ontology describes notation for problem domain description, (ii) application ontology (AO) contains terms and structure of knowledge describing a particular problem domain, (iii) preliminary KS ontology contains KS' knowledge terms and structure in the top-level ontology notation, (iv) KS ontology contains correspondence between terms of KS and AO, (v) preliminary request ontology contains terms which can be used by a user for request input and structure in the top-level ontology notation, (vi) request ontology contains correspondence between terms of preliminary request ontology and AO. The ontologies are stored in the common ontologies library (OL) that allows reusing them.

Also OL includes two types of auxiliary ontologies: (i) domain ontologies (represent static knowledge about a particular domain) and (ii) tasks and methods ontologies (represent problem-solving knowledge: how to achieve various goals). AO is a conceptual model that describes a real-world application domain depending on particular domain and problem and obtained by integration of tasks & methods ontologies and domain ontologies.

Two types of ontologies are used for translation of knowledge between KSs' terms and AO's terms (KS ontologies), and between users' terms and AO's terms (request ontologies).

Ontology-Driven Methodology

The system architecture (Figure 4) takes into account such modern requirements to applications as (i) flexibility, (ii) learning from the user, (iii) integrity, (iv) velocity, (v) open connectivity, (vi) reasoning and (vii) customizability.

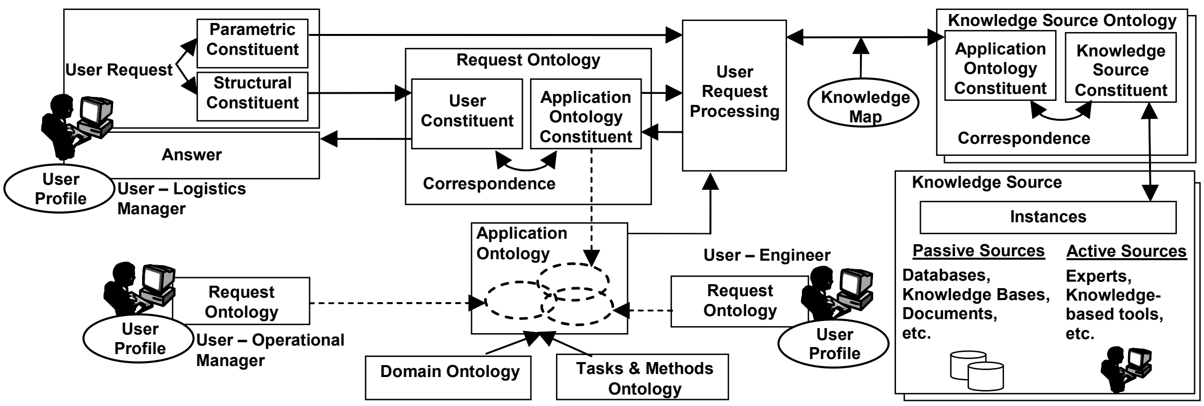

Figure 4. Conceptual scheme of the user-oriented ontology-driven KF methodology for a case study of supply chain management

The system works in terms of a common AO that describes a problem domain and is stored in an ontologies library. The AO is based on domain, tasks and methods ontologies, which are also stored in the OL. Each user/user group works in terms of an associated expandable user request ontology and thereby with a part of the AO pertinent to the user/ user group. User profiles are used during interactions to achieve efficient personalized service. Every user request consists of two parts: (i) a structural constituent (containing the request terms and relations between them), and (ii) a parametric constituent (containing additional user-defined constraints). An auxiliary KSNet configuration defining when and what KSs are to be used would be built to maximize the efficiency of. request processing. For this purpose, a knowledge map including information about locations of KSs is used. Translation between the system's and KS' notations & terms is performed using KS ontologies.

SYSTEM "KSNET"

Standards and Architecture

The operational principles and the architecture as well as a research prototype of the KF system called "KSNet" have been developed to illustrate the KSNet-approach.

In accordance with up-to-date technologies and standards, the information kernel for knowledge management is built as shown in Figure 5. As described above, knowledge is represented by an aggregate of interrelated classes, their attributes, attributes' domains and relations between them. An object scheme for working with the knowledge and a database structure for its internal storage are designed on the basis of this notation. Access to the database is performed via ODBC as a standard data access mechanism under MS Windows OS. Remote access to the knowledge is performed via common HTTP Internet protocol. Representation is done via either interactive HTML+VRML Java enabled pages for users or DAML+OIL-based format for knowledge-based tools. Client-server software architecture is shown in Figure 6.

Multi-Agent Environment

A multi-agent architecture for the "KSNet" includes two types of agents. FIPA-based technological kernel agents used in the system are: *wrapper* (interaction with KSs), *facilitator* ("yellow pages" directory service for the agents), *mediator* (task execution control), and *user agent* (interaction with users). The following problem-oriented agents specific for KL and scenarios for their collaboration were developed: *translation agent* (terms translation between different vocabularies), *KF agent* (operation performance for KF), *configuration agent* (efficient use of KSNet), *ontology management agent* (ontology operations performance), *expert assistant agent* (interaction with experts), and *monitoring agent* (KSs verifications). The system users and agents are shown in Figure 7 and

Table 1.

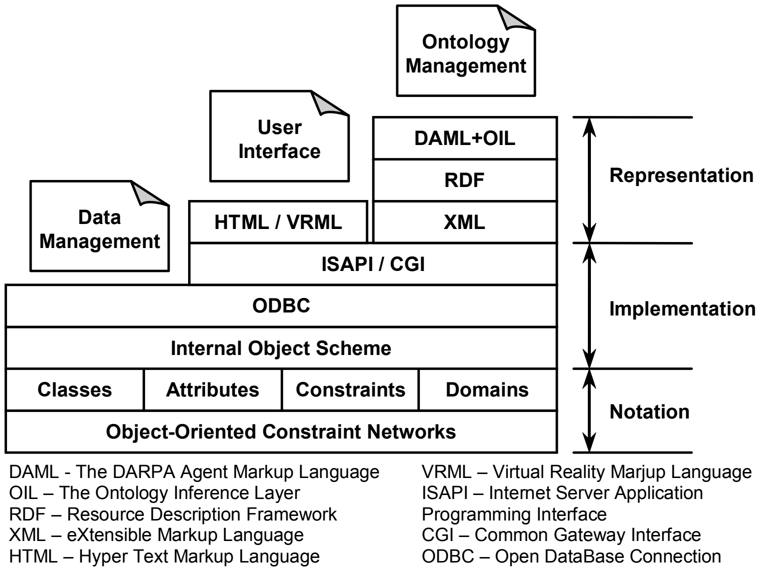

Figure 5. Standards of knowledge logistics information kernel

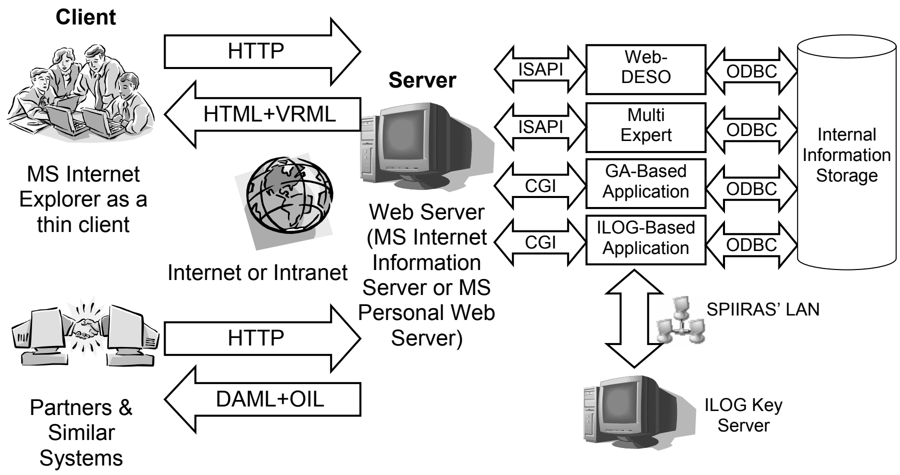

Figure 6. Client-server user interface architecture

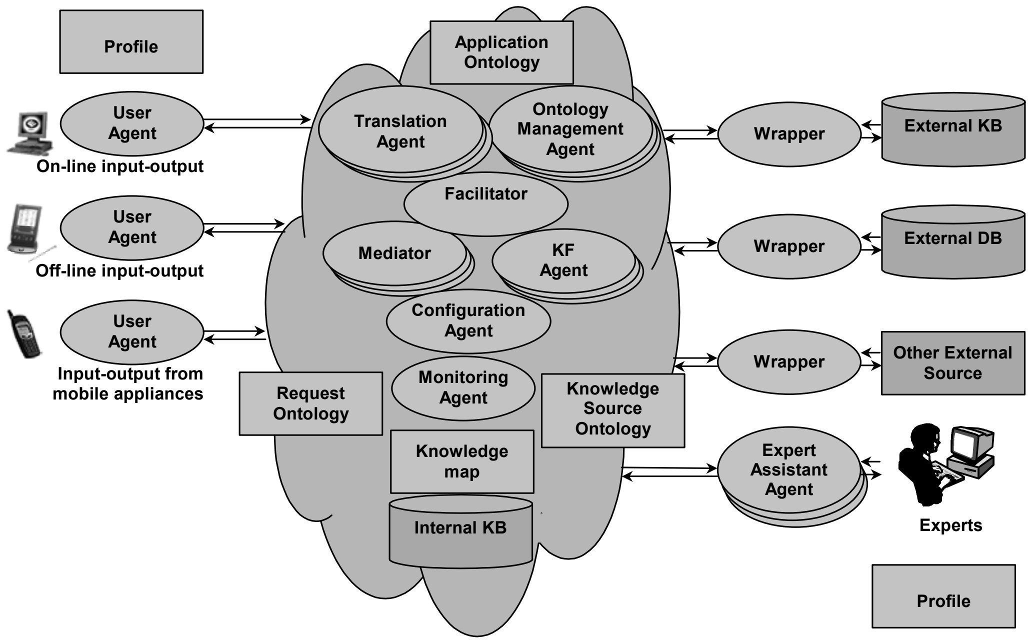

Figure 7. Basic components of multi-agent environment of rapid knowledge fusion system

The main technological issues related to the system's functioning are shown in Figure 8. An ontology-based knowledge representation is described in the next section.

VRML-Based User Interface

Prototyping of the interface part of the described here approach is done via integration of the VRML technology and developed earlier Web-DESO ontology management system (Smirnov, et.al., 2001b) as a major component of the user agent.

Current level of VRML technology (Web3D, 2002) maturity supports most of the requirements to knowledge visualization interface. It increases efficiency of knowledge entry due to combination of modelled images with our natural 3D perception of the world. It may support navigation over and through the knowledge, not supported by most of Web-based hypermedia systems, which include a navigational tool for the structure of the documents rather than for the knowledge nodes (Salis & Masili, 2002). On the other hand there are a number of VRML-based technologies for collaborative browsing (e.g., Blaxxun, 2002; Broll, 1997; DeepMatrix, 2002).

Table 1. KM areas support by users and agents

Area of KM	Users	Agents
Knowledge storage	• Administrator • Software engineer	• Monitoring agent • Ontology management agent
Knowledge sharing	• Ontology engineer • Software engineer	• Ontology management agent • Wrapper
Knowledge reuse	• Ontology engineer • Knowledge engineer • Software engineer	• Configuration agent • Monitoring agent • Wrapper
Ontology management	• Expert • Ontology engineer • Knowledge engineer	• User agent • Expert assistant agent • Ontology management agent • Mediator • Translation Agent
Knowledge revealing	• Ontology engineer • Knowledge engineer	• User agent
Knowledge generation	• Software engineer	• KF agent
Knowledge entry	• Expert • Knowledge engineer	• User agent • Expert assistant agent • Mediator
Knowledge integration	• Knowledge engineer • Software engineer	• KF Agent • Monitoring agent • Ontology management agent
Knowledge transportation	• Software engineer	• Wrapper • Mediator
Knowledge search	• Experts • Ontology engineer • Knowledge engineer	• Monitoring agent • Ontology management agent
Knowledge indexing	• Administrator	• Monitoring agent

Figure 9 demonstrates a sequence of prototyped VRML-based screens for "in-depth" search from transportation vehicle taxonomy to helicopter structure and collaborative browsing for a case of two experts.

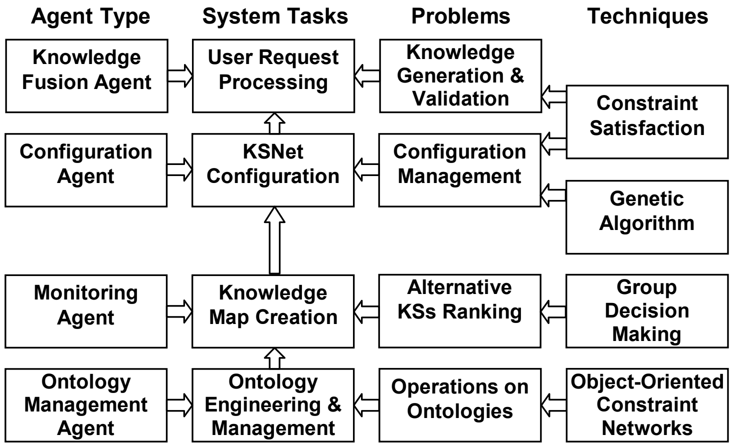

Figure 8. Main system tasks and techniques

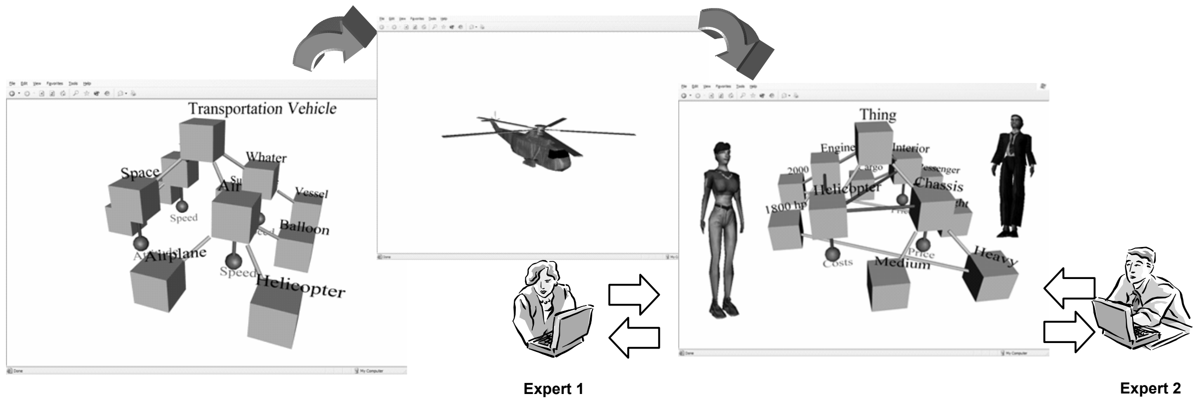

Figure 9. Example of VRML-based screenshots and collaborative browsing

A CASE STUDY

An application of the approach is presented using a case study inspired by a coalition-based Binni scenario. The aim of Binni scenario (Rathmell, 1999) is to provide a rich agent technology environment, focusing on new aspects of coalition problems and new technologies demonstrating the ability of coalition-oriented agent services function in an increasingly dynamic environment. This was a main reason of using this scenario as a case study for the system KSNet in regard to the KF technology. The goal of the presented here scenario is to demonstrate an application of the developed KSNet-approach to supply chain management and logistics related problems. The considered task is a portable hospital configuration for a given location in the Binni region.

The following request is considered:

Define suppliers, transportation routes and schedules for building a hospital of given capacity at given location by given time.

An analysis of the request shows a necessity of finding and utilizing KSs containing the following information/knowledge:

- hospital related information (constraints on its structure, required quantities of components, required times of delivery)
- available suppliers (constraints on suppliers' capabilities, capacities, locations)
- available providers of transportation services (constraints on available types, routes, and time of delivery)
- geography and weather of the Binni region (constraints on types, routes, and time of delivery, e.g. by air, by trucks, by off-road vehicles)
- political situation, e.g. who occupies used for transportation territory, existence of military actions on the routes, etc. (additional constraints on routes of delivery).

AO of this humanitarian task is built and connection of the found sources is performed. After this the request is processed.

Created AO can be later used to solve other tasks of the same nature in the Binni region. Example requests can be as follows:

- by what time a hospital/camp… of given capacity at given location can be built?
- where is better to built a hospital/camp…?
- find the best route to deliver something from point A to point B., etc.

Parts of ontologies corresponding to the described task were found in Internet's ontology libraries (Clin-Act, 2000; Cyc, 1998; Loom, 1997; NAICS, 2001; UNSPSC, 2001). The analyzed ontologies represent a hospital in different manners. Some of those representations are given in Figure 10 - Figure 12. In the figures hierarchical relationships "is-a" are shown only.

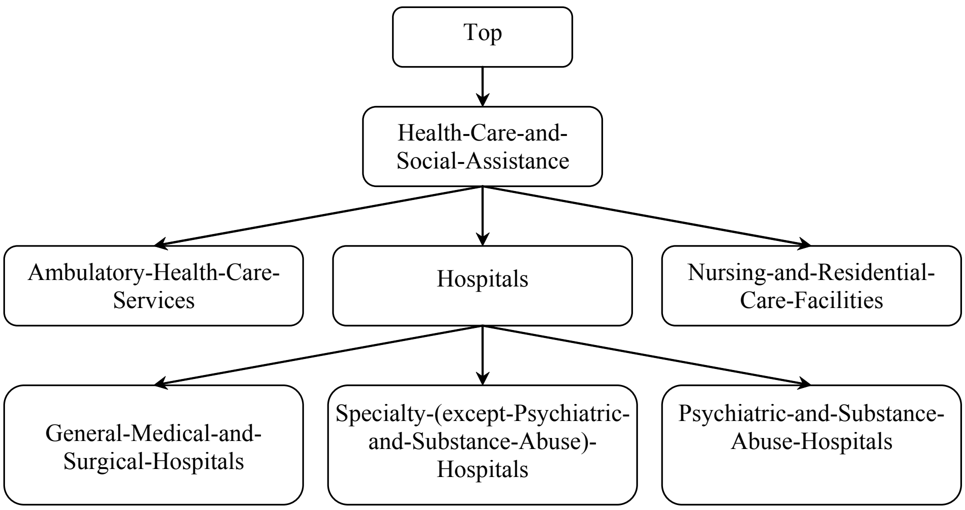

Figure 10. Hospitals in (NAICS, 2001) ontology

Figure 14 presents the class "hospital configuration" entirely. In the considered example the method for staff definition is not taken into account as class "Staff" related to it is not included in the part being under consideration (shaded area in Figure 13).

This scenario considers a task of the portable hospital erection. Initially a user sees the screen presented in (Figure 15). This screen presents a map of the Binni region with cities and roads

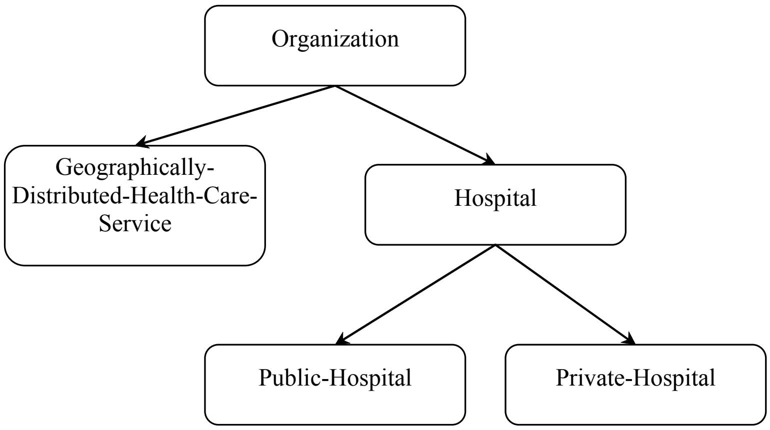

Figure 11. Hospital in (WebOnto, 2002) organisation ontology

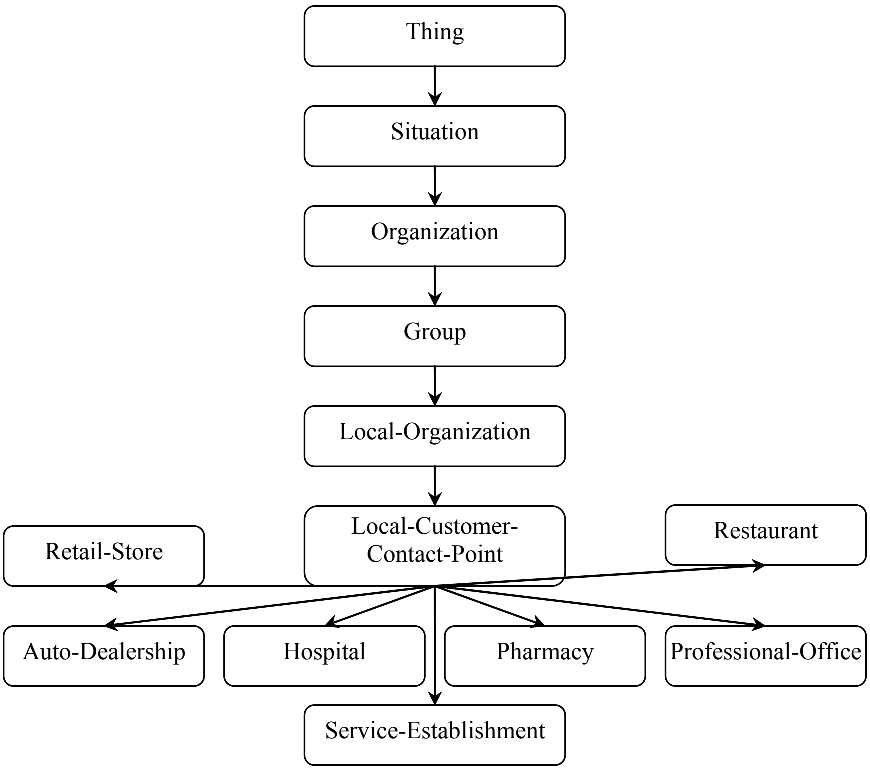

Figure 12. Hospital in (Cyc, 1998) upper-level ontology

shown. Then he/she points on the map a desirable location of the hospital to be built. The map is updated and possible locations closest to one pointed by the user are shown by triangles (Figure 16). These locations are entered into the system by experts taking into account such facts as availability of water resources, roads, surrounding areas and cities. The user selects a desirable destination from ones suggested by the system (Figure 17). Then the user chooses options of the hospital configuration and starts the request processing.

For visualization of agents activities during different scenarios processing the Gantt chart diagrams were utilized. They allow presenting each agent's task as a bar on a time-based grid. Such diagrams help to define the agents most loaded on the various tasks.

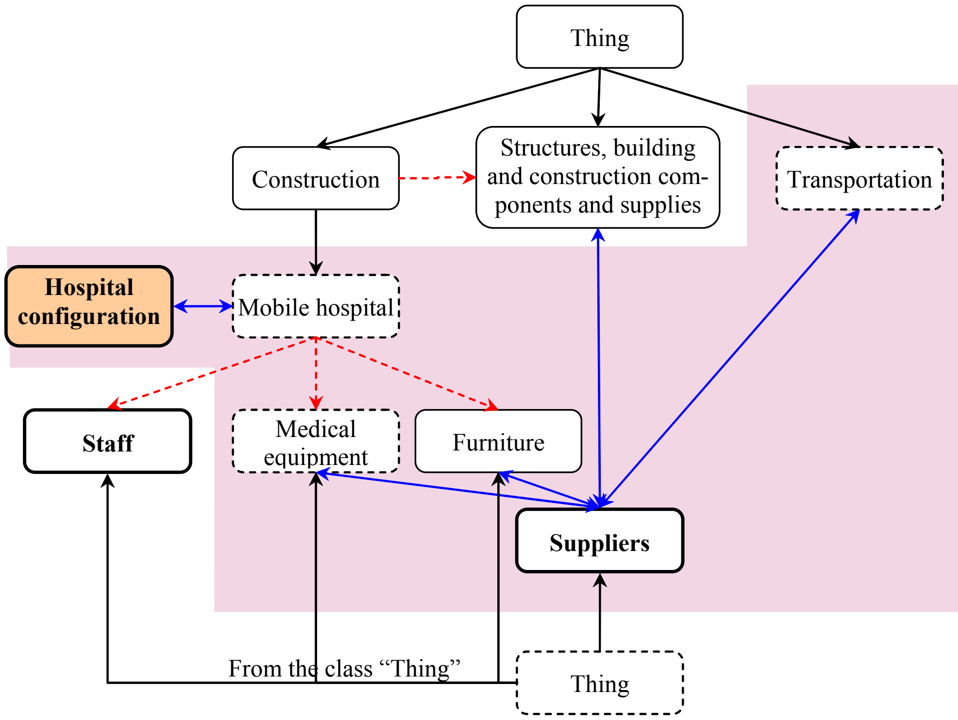

Figure 13. Result ontology "Mobile hospital"

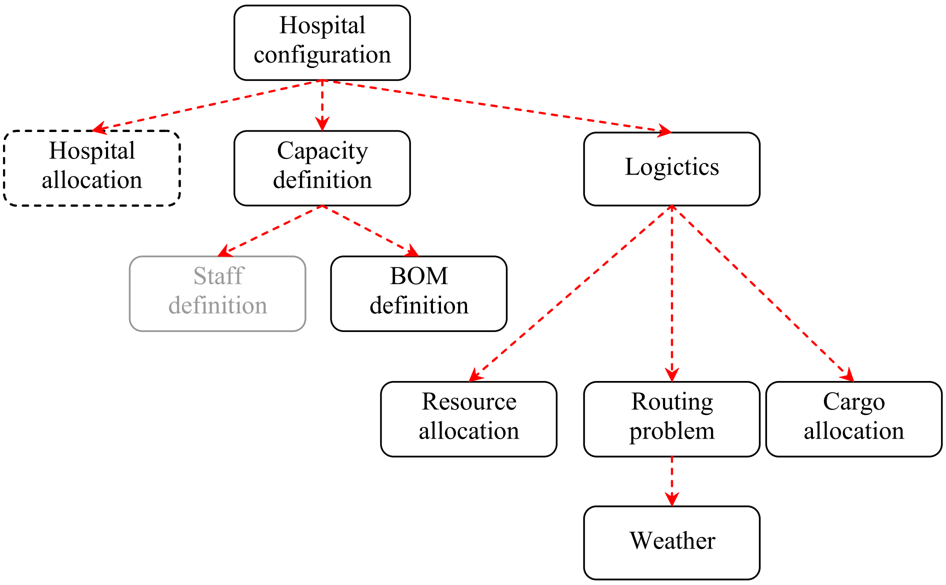

Figure 14. Task ontology "Hospital configuration"

An analysis of a large amount of Gantt chart diagrams for different scenarios has been performed. The results show that during user request processing the most of the time is spent by: (i) wrappers when they serve slow KSs, (ii) KF agent when it processes a large amount of constraints, (iii) translation agent when it recognizes long user requests and (iv) configuration agent when it finds a configuration of KS networks consisting of a large number of KSs.

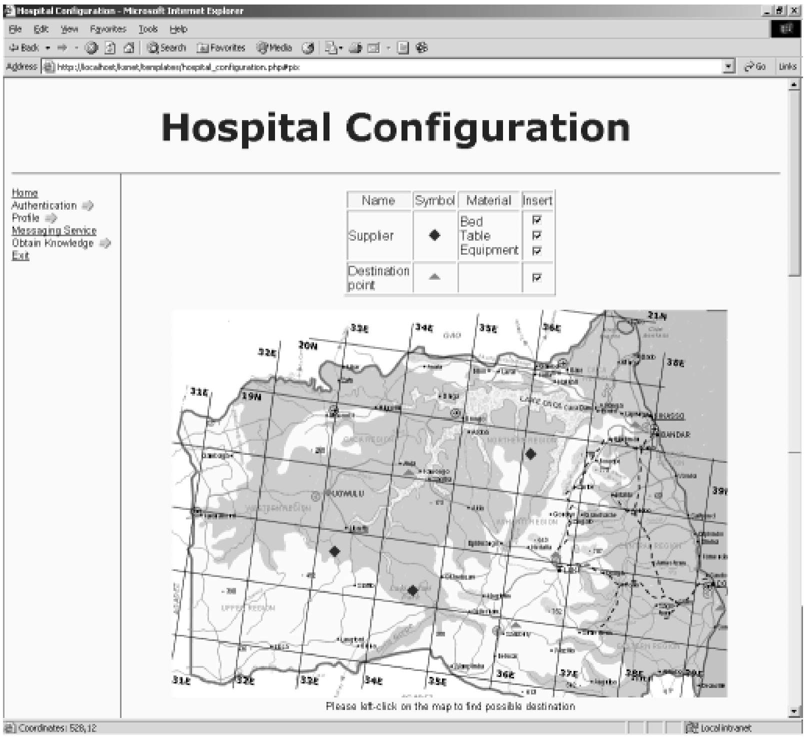

Figure 15. Initial screen of the hospital configuration scenario

CONCLUSION

The paper describes an ontology-driven methodology based on knowledge source networks configuration called KSNet-Approach. The described problem of knowledge logistics is a new direction of knowledge management for Just-Before-Time Service of knowledge customers what is essential for e-business applications that require open standard-based information/knowledge exchange in real-time.

Among the advantages of the presented here system “KSNet” the following can be selected: (i) agent-based architecture increases scalability, efficiency and interoperability of the system; (ii) utilizing user profiles and request ontologies increases customizability and velocity; (iii) translation of ontologies from advanced formats (e.g. DAML+OIL) into internal representation and back enables ontology interchange and sharing; and (vi) application of constraint networks allows rapid problem manipulation by adding/changing/ removing components (objects, constraints, etc.).

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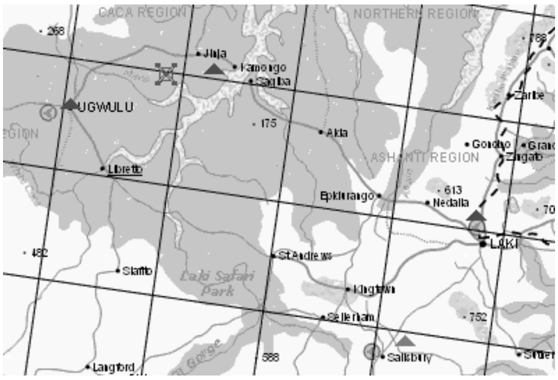

Figure 16. User points a desirable destination point and systems displays closest possible destinations

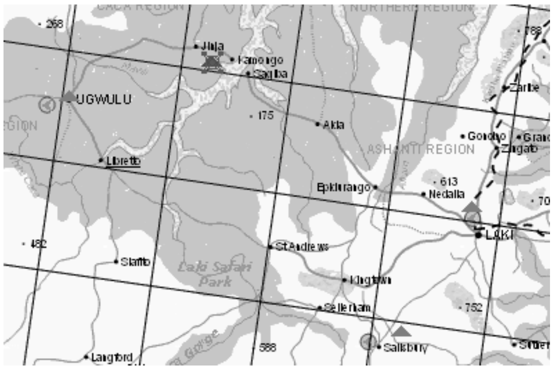

Figure 17. User selects desirable possible destination

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