CONTEXT-BASED KNOWLEDGE LOGISTICS FOR DISASTER MANAGEMENT

A.V. Smirnov, M.P. Pashkin, N.V. Chilov, T.V. Levashova, A.A. Krizhanovsky
St.Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences
39, 14th Line, St.Petersburg, 199178, Russia
smir@mail.iias.spb.su
tel: +7 (812) 328-8071, fax: +7(812) 328-0685

Keywords: knowledge management, logistics, disaster aid, web-service, distributed knowledge sources, knowledge integration

Abstract
Системы транспортировки играют существенную роль в решении проблем, возникающих в случае природных катализмов, стихийных бедствий и катастроф. Такие современные технологии как, например, Интернет делают возможным создание интеллектуальных систем транспортировки для расширения их возможностей для своевременного реагирования на эти катастрофы. Эта статья представляет подход к реализации Интернет сервисов для прокладки маршрутов в больших системах транспортировки, используя преимущества идеи логистики знаний. Логистика знаний основана синергетической интеграции знаний, приобретенных из распределенных источников необходимых для получения нового или дополнения существующего знания. Данная статья показывает масштабируемость и расширяемость представленного подхода при добавлении новых источников знаний.

Introduction
Nowadays organizations have to restructure in order to respond to their rapidly changing environment. This causes a growing recognition of the need for new kinds of organizational structures that could be distributed, mobile and flexible and therefore exhibit characteristics of innovation, resilience, and self-management.

One of the most widespread forms of organizational structures the form of networked organization can be mentioned. Among the main advantages of the networked organization the following ones are selected:
• scalability: new members can join a networked organization by establishing relationships with some of its members,
• robustness: a networked organization will continue to operate even if some of the network nodes stop,
• sensitivity and adaptability: when flexible enough the relationships between the organization's units (the network's arcs) may be easily and quickly readjusted in accordance with changes in the environment,
• intensive knowledge/skills/experience exchange between the organization's units resulting in maximization of the knowledge potential of the organization.

As it can be seen new forms of organizational structures including networked and virtual organization rely on intensive usage of knowledge and therefore on modern information technologies dealing with data and knowledge. Currently, knowledge often referred to as corporate knowledge in the contexts of the business and manufacturing is the key resource in the modern era of information.

We will proceed with the following definition, taken from [1]:
Context: any information that can be used to characterize the situation of entities (i.e. whether a person, place or object) that are considered relevant to the interaction between a user and an application,

27
including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects.

Growing importance of intelligent support of the knowledge customers causes a need for acquisition, integration, and transfer of the right knowledge from distributed sources located in an information environment. This knowledge has to be delivered in the right context to the right person, in the right time for the right purpose. These activities called knowledge logistics are required for global awareness, dynamic planning and global information exchange in the information environment.

Transportation systems play an important role in coalition-based application implemented as networked organizations. An intelligent transportation system may significantly enhance the transportation system abilities. Therefore the paper proposes an application of knowledge logistics based on the concept of open services in a distributed environment as an intelligent service for creation efficient routing plans (as one of the major tasks of transportation system management for responding disasters and organizing evacuations) under given constraints and preferences.

1 KSNet-Approach for Transportation System Management

As it is mentioned above, the being described approach is devoted to the knowledge logistics problem. It considers this problem as a problem of a Knowledge Source Network (KSNet) configuration, in this connection it has been referred to as KSNet-approach.

1.1 KSNet-Approach to Knowledge Logistics

Knowledge logistics assumes dealing with knowledge contained in distributed and heterogeneous KSs. As a result of this, the approach is oriented to ontological model providing a common way of knowledge representation. KSNet-approach proposes ontology-driven methodology to knowledge source network configuration. This approach is described in detail in [2].

Knowledge sources (KSs) to be used comprise end-users / customers, loosely coupled knowledge sources / resources, and a set of tools and methods for information / knowledge processing. In the context of the paper the configured KSNet is thought of as a networked organization, where the listed above constituents of the KSNet correspond to the organization nodes.

Because of distributed structure of networked organization, its behavior of open system, and orientation on the Internet as the e-business environment the technology of Web-services for the approach implementation has been applied.

As a formal model for knowledge integration the ontology model with the knowledge representation formalism of object-oriented constraint networks was chosen. This allows simplifying the formulation and interpretation of real-world problems which in the areas of engineering, manufacturing, management, etc. are usually presented as constraint satisfaction problems (e.g., [2, 3]). As a constraint-based tool ILOG tool has been chosen [5]. The system implementing the approach inherited its name; it is referred to as the system “KSNet”. The detailed description of the multiagent system architecture and its functionalities can be found in [4].

1.2 Health Service Logistics in Coalition Operations Other than War

Coalition operations other than war include a wide range of activities involving different people and organizations. In classical war operations the technology of control is strictly hierarchical, unlike operations other than war are very likely to be based on cooperation of a number of different, quasi-volunteered, vaguely organized groups of people, non-government organizations, institutions providing humanitarian aid but also army troops and official governmental initiatives. Here many participants will be ready to share information with some well specified community [6].

All joint doctrine and tactics, techniques, and procedures are organized into a comprehensive hierarchy as shown in (Figure 1). As a case study for the project the area of logistics was chosen because logistics problems can be widely used in a number of areas (e.g., other than war operations, supply chain management, transportation systems, etc.) and it is of a high importance for completion
of joint missions [7]. Focused logistics operations and/or Web-enhanced logistics operations address sustainment, transportation and end-to-end rapid supply to the final destination. Here the distributed information management and real-time information fusion to support continuous information integration of all participants of the operations are needed [8].

![Joint doctrine hierarchy](adapted from [7]).

Logistics support in coalition operations presents numerous challenges due to a variety of different policies, procedures and practices of the members of the operations, e.g., difference in doctrine, logistics mobility, resource limitations, interoperability concerns, and competition between participants for common support.

In [7], six major principles of joint activities logistics applying to operations other than war are selected. They include:

- **Objective.** There must be a clearly defined, decisive and attainable objective, and all the efforts of each operation member have to be integrated into the total effort of achieving strategic aims and cumulating in the desired end state.

- **Unity of effort.** There must be a close coordination of all the operation members provided leading toward the main goal and every subgoal.

- **Legitimacy.** Legitimacy involves sustaining the people's willingness to accept the right of the operation' leader to make and carry out decisions so that their activities would complement, not detract from, the legitimate authority of the leaders.

- **Perseverance.** In coalition operations strategic goals may be accomplished by long-term involvement, plans, and programs. Short duration operations may occur, but these operations have to be viewed as to their impact on the long-term strategic goals.

- **Restrain.** Coalition other than war operations put constraints on potential actions that can be undertaken by the operation's members to achieve their goals.

- **Security.** Security is a very important issue in coalition operations, especially in those related to healthcare and involving military forces. The operation's leaders and members have to ensure that they include security measures.

Coalition other than war operations may have different missions. E.g., they can be related to disaster relief, noncombatant evacuation, humanitarian assistance, peace operations, and other. For the project a task of disaster relief operation form the area of health logistics has been chosen; particularly, it is devoted to mobile hospital configuration.

### 1.3 Knowledge Sources for Creation Routing Plans

For the task of the routing plan creation the following knowledge sources can be considered: available suppliers (constraints on suppliers’ capabilities, capacities, locations); available providers of transportation services (constraints on available types, routes, and time of delivery); factors influencing on route availabilities as the geography and weather of the considered region (constraints on types, routes, and time of delivery, e.g. by air, by trucks, by off-road vehicles).

The problem of an automatic knowledge seeking is a future research. For the case study a list of KSs containing information for the user request processing was prepared by an expert team.
In the presented case study a fictitious Binni region [9] is considered. The aim of the used Binni scenario is to provide a rich environment, focusing on new aspects of coalition problems and new technologies demonstrating the ability of distributed systems for intelligent support to supply services in an increasingly dynamic environment. The transportation system is presented by a weighted graph of routes assigned with transportation time, costs and route type (highway, ground road, transportation by a plane, etc.). This information is stored in an external database accessed remotely.

Each supplier is characterized by its location, capabilities (which products it can produce), capacities (how many products it can produce by a certain moment), schedule (when it products can be picked up).

In the presented example the one-customer model is considered. The reason for this is that the considered transportation task is a part of a bigger task of a portable hospital configuration described in detail in [10].

In order to provide up-to-date transportation plans the system monitors the current situation in the region. For this purpose an emulated news Web site has been implemented (Figure 2). A specially designed wrapper reads news and finds which cities/areas are not currently available for transportation. Besides, it reads weather conditions and accordingly corrects transportation time and costs for appropriate routes.

This list of sources is not fixed. The scalable architecture of the system KSNet allows seamless attaching of new sources in order to get new features and to take into account more factors for tasks solved.

Figure 2 – Emulated news Web-site.
2 Knowledge Logistics as an Intelligent Web-Service

*Open services* is an emerging technology driven by the will to securely expose business logic beyond the firewall. Through open services organizations can encapsulate existing processes, publish them as services, search for and subscribe to other services, and exchange information throughout and beyond the enterprise. Open services will enable application-to-application e-marketplace interaction, removing the inefficiencies of human intervention.

As it was mentioned a networked organization environment is characterized as an open service system (i) in which users, units and other resources come and go on a continual basis, and (ii) in which entities provide services to each other under various forms of a contract (or agreement). The key components of service oriented architecture are as follows: *service owners* that offer *services* to *service consumers* under particular *contracts*. Each owner-consumer interaction takes place in a given *marketplace* whose *rules* are set by *market owner*. The service owners and service providers interact with each other in a particular *environment context*. The open service oriented model applied to the system "KSNet" looks as shown in (Figure 3). The system acts as a service provider for knowledge customer services and at the same time as a service requestor for knowledge suppliers.

![Figure 3 – Open service oriented model of networked organization.](image)

The conceptual scenario of Web services is shown in (Figure 4). A service requester sends a request for an appropriate service ("Find Service") to the UDDI Registry. The Registry returns a reference to an appropriate service provider to the requestor. Then, the requestor sends a request to the service and receives the result from it.

In the system "KSNet" the Web-based open service model is used. The proposed scenario is presented in (Figure 5). The main specific is that the service passes the request into the system where it goes through all the stages of the request processing scenario. When an answer for the request is found it gets to the service and then it is passed to the requestor.

![Figure 4 – Conceptual Web service scenario.](image)
3 Implementation and a Case Study

The user represented by a Web-service client enters a request into the system via the developed SOAP-based interface. It has been implemented using PHP [11] and NuSOAP Web Services Toolkit [12]. This combination enables rapid development of such applications as Web-services. Below, an example source code of the developed service is presented:

```php
$s = new soap_server;
$s -> register('sendRequest');
$s -> register('getStatus');
$s -> register('getResult');
$s -> service($HTTP_RAW_POST_DATA);
```

Besides such input parameters as the customer location, suppliers to be visited, etc., the system accepts such parameters as optimization preferences – what is more important: transportation time or costs. The user may choose his/her preference and the implemented fuzzy logic module allows finding more appropriate solution.

Presented example illustrates finding a routing plan for the same conditions but with different user preferences, namely: minimize time; minimize time, then costs; minimize both time and costs; minimize costs, then time; minimize costs. In (Figure 6–7) results for different choices are presented and compared. For illustration of the results a map is generated that uses the following notations. Green dots are the cities of the region. The city with red edge (Aida) is the city where the hospital is to be located – the location of the customer. The cities with blue edges are the cities where suppliers are located (Libar, Higgville, Ugwulu, Langford, Nedalla, Laki, Dado). Transportations routes are shown as lines. The grey lines are routes that are not used for transportation in the solution, the blue lines routes used for transportation, and the red lines are routes unavailable due to weather or for some other reasons. E.g., the routes through the city of Zaribe are not available because of the flooding. The colored trucks denote the routes of particular vehicles/vehicle groups.

Figure 9 represents a comparison of the routing plans created for different criteria. As it can be seen while importance of one of the parameters increases (e.g., importance for costs increases from left to right) the value of the parameter decreases (the red line with diamonds for the costs) and vice versa (the green line with squares for the time).
Conclusions

The paper describes the Web-service based approach to knowledge logistics and its applicability to transportation system management. The scalable architecture of the approach enables its extension in regard of knowledge/information sources number and, thereby, in regard of factors taken into account during complex problem solving. Implementation of the approach as a Web-service makes the system accessible from virtually any Web-enabled device (PC, PDA, or even a cell phone). Hence the knowledge base of the system can be continuously updated and the updated routing plans can be transmitted to users (e.g., truck drivers) in real time.

![Routing plan for the minimize time and minimize time, then costs preferences](image)

**Figure 6** – Routing plan for the minimize time and minimize time, then costs preferences (in this solution four vehicles/vehicle groups are used to provide maximum of concurrency).

Acknowledgment

Some parts of the research were done as parts of the ISTC partner project # 1993P funded by Air Force Research Laboratory at Rome, NY, the project # 16.2.44 of the research program "Mathematical Modelling and Intelligent Systems", the project # 1.9 of the research program “Fundamental Basics of Information Technologies and Computer Systems” of the Russian Academy of Sciences, the grant # 02-01-00284 of the Russian Foundation for Basic Research, and the contract with Ford Motor Company. Some prototypes were developed using software granted by ILOG Inc.

References


Figure 7 – Routing plan for the minimize both time and costs, then time preferences (in this solution three vehicles/vehicle groups are used).
Figure 8 – Routing plan for the minimize costs preference (in this solution one vehicle/vehicle group is used to provide minimum of costs).

Figure 9 – Routing plans for different criteria (time and costs minimization preferences).
Biography

**Alexander V. Smirnov**, Prof., received his ME, his PhD and D.Sc. degrees in St.Petersburg, Russia, in 1979, 1984, and 1994 respectively. He is a Deputy Director for Research and a Head of Computer Aided Integrated Systems Laboratory at St.Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences (SPIIRAS). He is a full professor of St.Petersburg State Polytechnical University and St.Petersburg State Electrical Engineering University. His current research interests belong to areas of corporate knowledge management, multi-agent systems, group decision support systems, virtual enterprises, and supply chain management. He has published more than 200 research papers in reviewed journals and proceedings of international conferences, books, and manuals.

**Mikhail P. Pashkin** received his MAM from St.Petersburg State University, Russia in 1992. He is a researcher at Computer Aided Integrated Systems Laboratory of SPIIRAS. His current research interests include multi-agent systems, ontology engineering and group decision support systems. He has published more than 40 research papers in proceedings of international conferences, books and manuals.

**Nikolai Chilov** received his ME in St.Petersburg State Technical University, Russia, in 1998. He is a researcher at the Computer Aided Integrated Systems Laboratory of SPIIRAS. His current research interests belong to areas of virtual enterprise configuration, supply chain management, knowledge management, ontology engineering and multi-agent systems. He is an author/co-author of more than 35 research papers published in proceedings of international conferences and books.

**Tatiana Levashova** received her ME degree at St.Petersburg State Electrical Engineering University in 1986. She is a leader programmer at Computer Aided Integrated Systems Laboratory of SPIIRAS. Her current research is devoted to knowledge-related problems such as knowledge representation, knowledge management, and ontology management. She has published more than 15 papers in reviewed journals and proceedings of international conferences.

**Andrew Krizhanovsky** received his ME in St.Petersburg State Technical University, Russia, in 2002. He is a researcher at the Computer Aided Integrated Systems Laboratory of SPIIRAS. His current research interests belong to areas of knowledge management, ontology engineering, multi-agent systems, and computer linguistics.