USING INTELLIGENT AGENTS FOR MEDICAL LOGISTIC SYSTEM

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Abstract: *E-business, e-government and e-health care applications require real time cooperation and open standard-based information knowledge exchange between all the participants in a global information environment. As a result, a new direction of knowledge logistics has emerged. The problems approached by the logistic system are typically complex, particularly the planning of a distributed logistic system that implies several constraints. Among these constraints we can mention cooperation between the different organizational entities of the system, taking into consideration the diversity of the routed products and the categories of the targeted client.*

Key words: *distributed logistic system, multi-agent system, holonic agents, e-health, mobile hospital.*

1. Introduction

The paper describes a developed system addressing the knowledge logistics in hospital related problem. The needs/ problems of processes flow in various domains (e.g healthcare, clothing industry, food industry etc.) are indicated by information systems placed in relevant indicative zones of the process. We want to optimize the routing of the process from one zone to another as well as to satisfy the needs in every zone, knowing that these are different according to several criteria. An ontology-driven methodology for knowledge sharing and reuse is described first. The paper also describes a multi agents community implementation designed as a part of the research of the knowledge logistics system. Results of the developed multi agents' community application to coalition based operations support are presented via a portable hospital configuration case study.

The logistics that was developed as concept in the army was introduced thirty years ago in the enterprises and hospitals. The goods distribution companies and automotive industry were first to use the logistics. It became a fully-fledged function in the middle of seventies [1].

The introduction of logistics in the manufacturing determined the need to structure the activities inside the organisation and, as well, to introduce an hierarhization of the processes and to set up the corresponding logistic flows [3], [4].

Nowadays, logistic companies must constantly improve their processes to remain competitive, in order to answer clients' needs and expectations. The systems that fulfill such requirements, must maintain an elevated flexibility level. The flexible logistic systems use manufacturing flow and impose very severe constraints regarding the reliability because minor dysfunctionalties of the system that can affect the manufacturing

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process. The resource management of the logistic system of production are essential to support a flexible and effective process of production [2], [3].

The Multi-agents system offer a setting of modeling and simulation of the logistic system of production while proposing to represent their elements, their behaviors and their interactions directly under the shape of computer entities having their own autonomy [6].

A coalition operation is based on temporary alliances of loosely associated groups of agents (organization units, tools, people etc.) that have their own level of commitment to the coalition, each with its own agenda, and each engaged in a limited role within the operation. The increase in the amount of required knowledge and intensive cooperation in the coalition operation have caused a need to create an efficient knowledge sharing and exchange between members of the global information environment so that the proper knowledge from distributed sources can be integrated and transferred to the right person within the right context at the right time for the right purpose [2], [6].

Applications based on coalition operation model require a specific 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.

In the framework of the hospital logistic research project an approach to the knowledge logistic (KL) systems organization was developed. This approach utilizes such technologies as ontology management, intelligent agents, user profiling, constraint programming, soft computing etc. In order to find appropriate knowledge, users input requests into the system via designed interfaces and receive responses. Every user request consists of two parts: (*i*) structural constituent (containing the request terms and relations between them), and (*ii*) parametric constituent (containing additional user-defined constraints). For the request processing, an auxiliary knowledge source (KS) network configuration is built defining when and what KSs are to be used for the request processing in the most efficient way. The system's knowledge repository including ontologies library, knowledge map, user profiles and internal knowledge base is used for this purpose [5].

Due to distributed nature of the KL problem the approach assumes an agent-based architecture. The chosen agent-based system architecture is based on FIPA Reference Model [8-10] as an infrastructure for definition of agent properties and functions. Results of the application of the developed multi-agent community to coalition-base operations support are presented via a study case based on a medical surgery.

The paper presents a virtual implementation of a logistic system (supply flows and information flows) of a mobile hospital. The paper offers an alternative solution for managing the above mentioned flows. The concept of mobile hospital involves a generic location because it has to move often. This implies a different point of view about logistic systems because it has to be distributed.

2. The Proposed System

2.1. Distributed Logistic System

The management of the flows of a Distributed Logistic System (DLS) spreads on several zones of treatment while leaving from the supplier of resources and the product to zones is a complex process submitted to several constraints. The communication challenges between the different zones that is an essential element for the pipeline of the information and the management of the products circulating through this chain, introduce the constraints to which the distributed system must overcome.

Another shutter of the general problematic of our DLS that is just as complicated as the communication challenges between the zones is the optimization of the flows. We chose as optimization tool: the statistical estimators that will have the role to inform about the quantities of expanded resources or the routing speeds of the flows.

In the current times, the dynamic treatment of the information by the estimators is integrated in a process to help the decision of the DLS. We achieve some models to control the dynamics or even the viability of a system that can help the decision making and that can predict the possible evolutions.

The distributed logistic system can be considered according to two different ways. First approach is the traditional one where the supplier is offering (pushing flows) products/services to the customer. In the second approach, the supplier is that one that imposes (drawing flows) to the supplier what products/services to acquire and, then, to offer to him. In such situations, the cooperation and the relations of responsibility are essential. The independent treatment of the zones can generate redundancies of information or erroneous data since every zone has the incomplete information and capacities limited to solve the problem. These limits will be able to influence the global behavior of the system.

For this reason, the coordination of the zones proves to be a key element for the reliability of the system. Thus, every actor of the chain is going to be able to play its own rule in the zone to which it is affected on the one hand and associate to the other neighbour zone actors on the other hand. Lately the Multi-agent modeling has been adopted for the resolution of the problems due to the complexity of the distributed logistic system.

2.2. Multi-agent System

Object for a long time of research in artificial intelligence, the Multi-agents System form an interesting type of modeling of societies, have very large application field.

A Multi-agent System (MAS) is a set of agents situated in a certain environment that interacts between them according to a certain organization. An agent is an entity characterized by the fact that it is, at least partially, autonomous. This may be a process, a robot, a human being etc.

The solution is achieved due to the individual behaviors and interactions of the agents. Then the Multi-agents System represents a new approach for the analysis, the conception and the implantation of the computing complex systems.

The MAS are characterized then by:

- A partial perception of the environment for every agent;
- The limited expertise that don't allow them to solve the problem individually;
- A decentralization of information;
- The treatments in asynchronous balanced mode.

A MAS is a network of agents (solvers) weakly coupled that cooperate to solve the problems that pass the capacities or every agent's individual knowledge. These agents are autonomous and can be of heterogeneous natures. The modeling is going to consist at the establishment of a certain number of distinctions to analyze this complex reality. The first distinction consists of the separation of the structure of the system of agents actual of the one of the domain in which it operates. In our example, we consider the development of the following concepts: flows and treatment zones.

We will bring into attention the modeling of a MAS. There are three essential components:

- Models of agents (taking into account the individuality of the agents);
- Models of interactions (choose under shape of rules: the same agent capable to play several different roles);
- Organizational models (representing the global properties of the society of agents).

The Multi-agent System proposed is constituted of four types of agents: pilot Agent Agp, regrouping resources agent AgR, intermediary zone agent Ag1, and terminal zone agent AgT. The Table 1 will include the nature, the rule and every agent's interaction with its neighbours.

Description of the agents Table 1

Agent	Designation	Rule	Interaction
AgP	pilot Agent	Supervise various structures of the DLS	AgR Agi1…Agin AgT1…AgTm
AgR	regrouping of the resources Agent	Storage the resources and flows	AgP Agi1…Agin
Agi1 Agin	intermediary zone Agent	Receive resources and flow and distribute them towards final zones	AgP AgT1…AgTm Agi+1…Agin
AgT1 AgTm	final zone Agent	Receive the resources and flow from intermediate zone	AgP Agi1…Agin AgTi+1…AgTm

Every agent is responsible for its zone, it can answer to a request coming either from the pilot agent, either from an agent that is hierarchically his superior.

An agent and its sub agents form a holonic system. The whole system can be considered as an overlapping of holonic systems. In the case of a distributed logistic system compound of different zones, each zone is a holonic agent which is an interface between its parents and its sub elements. That means all the transactions between the parents and the sub agent will go through it. For the sub agent the only pa rent is the agent itself.

The Figure 1 presents the different holonic agents of the system. Holonic Agent1 only sees Holonic Agent 2 which represents all the Sub holonic system. The sub agents 3 and 4 only know Holonic Agent 2: it is the whole part of their relative system. Especially in the terminal zone, we have a variable speed of consumption, that's why we have to estimate, in the better manner, the need of different flows (medicines, clothes, food...).

The Need Estimating Agent (NEA) is an interface for a whole holonic system which is supposed to indicate to a zone agent what it will need; using all the data that the zone agent can provide it.

Each zone agent has to know its own needs in order to ask for them to the head

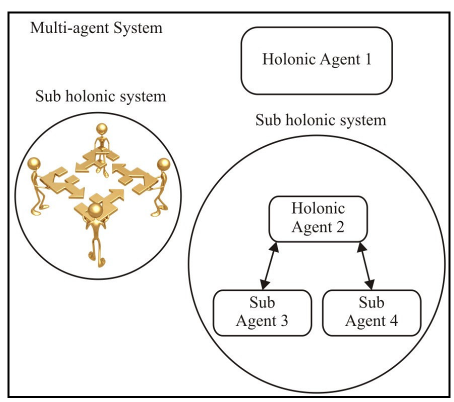

Fig. 1. *Holonic Multi-agent organization*

zone which supplies it. The zone agent may itself be a supplier for other zone agents in a sub holonic system. Its sub agents ask it for what they need.

The zone agent pools their requests to ask its own supplier the whole at the same time. It is also able to satisfy the most urgent needs with a special stock their suppliers had sent anticipating the consumption.

All the requests received are precise and directly useful without processing them.

A zone agent is a supplier for their sub agent, but it is also a consumer for its own needs. There are patients to feed, engines to fill in etc. To estimate their needs, the system provides a tool that each agent can use. This tool is a complex holonic system called Need Estimating Agent (NEA).

The most of sub agents, the only ones which are part of one and only one holonic system, are only consumers. They just have to use the NEA to know what to order.

In Figure 2 is depicted a need estimating holonic system.

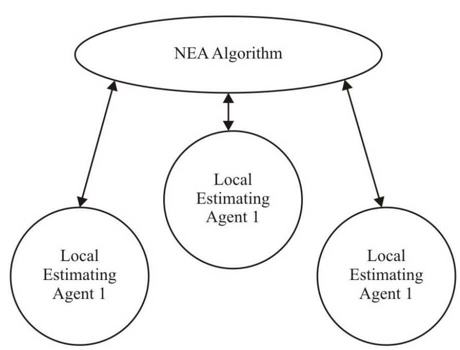

Fig. 2. *Need estimating holonic system*

3. The Mobile Hospital Logistic System

The system architecture (Figure 3) takes into account such modem requirements to applications as [7], [11-15]:

- flexibility;
- learning from the user;
- integrity;
- velocity;
- open connectivity;
- reasoning;
- customizability.

The system works in terms of common application ontology (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 ontology library.

Each user/user group works in terms of 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:

- a structural constituent (containing the request terms and relations between them);
- a parametric constituent (containing additional user-defined constraints).

An auxiliary 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 and terms is performed using KS ontologies.

A scenario was chosen as a case study for the proposed architecture.

The aim of the scenario is to provide a Multi-agent 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. The Multi-agent environment is adequate for DLS because it adapt alone very easy. The environment of DLS is very dynamic and this implies a compatible environment.

The experimentation with this scenario is intended for demonstration of how a Multi-agent system can be used for supply chain management, logistics and other coalition operations problems.

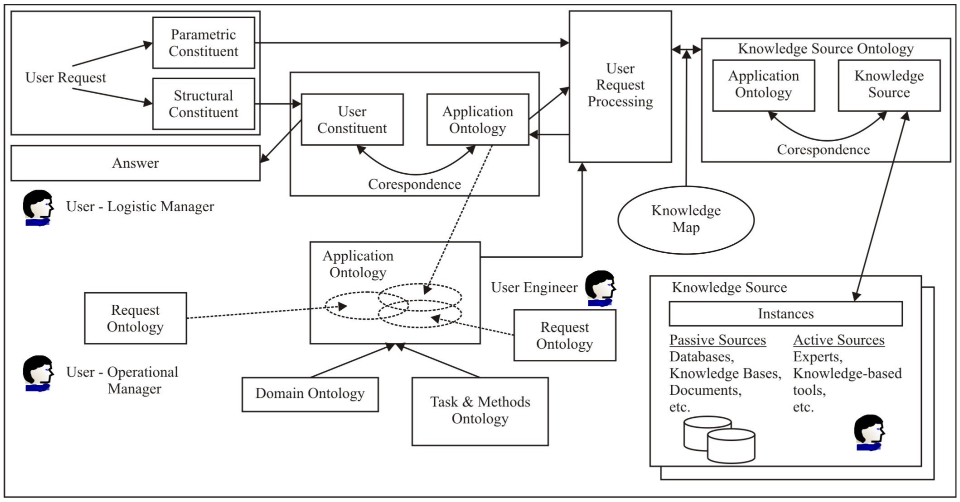

Fig. 3. *Conceptual scheme of the ontology driven system for supply chain management*

As an example, a task of the portable hospital configuration as a health care application for an isolated given location is considered.

An analysis of the task showed 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, constraints on suppliers' capabilities, capacities, locations);

• available and friendly providers of transportation services (constraints on available types, routes, and time of delivery);

• geography and weather of the 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).

Example requests can be as follows:

• by what time a hospital of given capacity at given location can be built?

• where is it better to built a hospital;

• find the best route to deliver something from point A to point B;

In the presented small example the following request is considered:

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

Parts of ontologies corresponding to the described task were found in Internet's ontology libraries.

An application ontology (Figure 4) and task ontology (Figure 5) for this health care task were built and a connection of the found sources was made by the proposed system.

Reused ontology classes (the classes adopted from the Internet's ontology libraries) are shown by firm lines.
Reused classes that were renamed are shown by dotted lines, new ontology classes (the classes included by experts) are outlined by thick lines, firm unidirectional arrows represent hierarchical relationships "is-a", dotted unidirectional arrows represent hierarchical relationships "part-of", double-headed arrows show associative relationships. Ontology part corresponding to AO for the user request processing is represented by the shaded area.

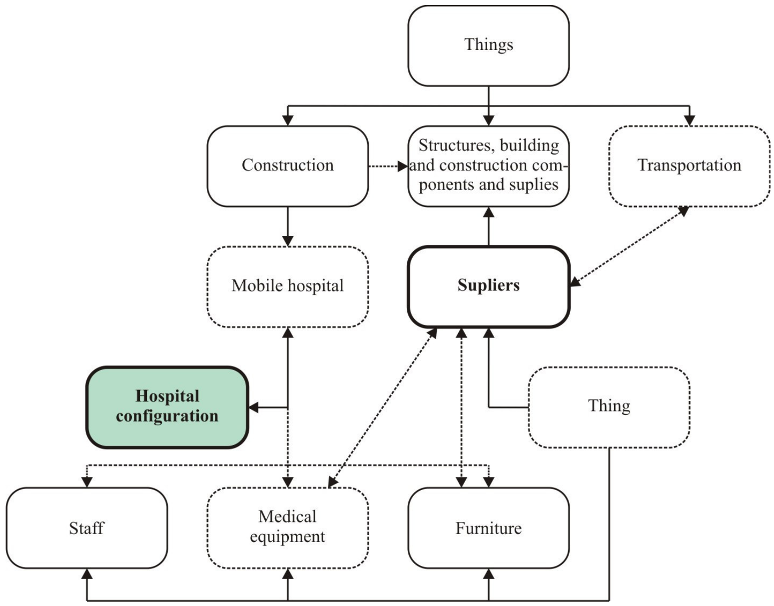

Fig. 4. *Result ontology "Mobile hospital"*

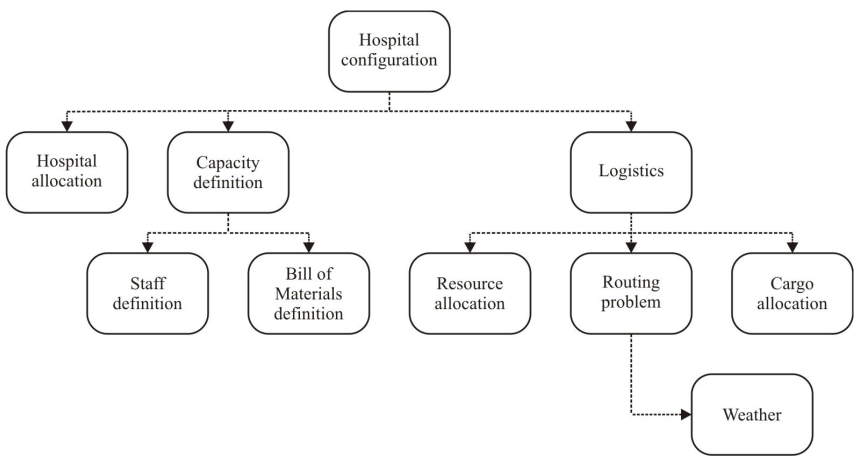

Fig. 5. *Task ontology "Hospital configuration"*

This scenario considers the virtual building of a mobile hospital.

Initially a user sees a screen with a map of the region with cities and roads shown. Then, the user points on the map to the desired 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.

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. Besides a hospital destination the system asks additional hospital characteristics such as hospital capacity or furniture and medical equipment quantity.

The characteristics are the result of the ontologies analyses and, as a rule, correspond to attribute values needed to the task solution.

After the user enters the requested information the system starts the request processing.

For the request processing the constraint satisfaction/propagation technology is used.

4. Conclusions

The paper describes an ontology-driven methodology based on knowledge source networks.

The described problem of knowledge logistics is a new direction of knowledge management for "anytime-anywhere" services of knowledge customers what is essential for coalition-based e-applications that require open information knowledge exchange in real-time.

Agent-based technology is a good basis for knowledge logistics since agents can operate in a distributed environment, independently from the user and use ontologies for knowledge representation and interchange.

Utilizing intelligent agents increases system efficiency and interoperability.

An applicability of this approach to the areas of e-business, e-government and e-health (portable hospital configuration for a given location taking into account a current situation in the locations' region) demonstrate possibility of its usage for information support of coalition-based operations.

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