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Drugs Trading in the Hospital Pharmacies Through a Multi-Agent Electronic Market

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Abstract

Several challenges involved in the reduction of hospital drugs expenditures are difficult to be solved, at least nowadays, but it is important to look for possible ways to undertake or reduce the problem. In this paper we propose an electronic market as a possible solution to reduce costs and time for the hospital pharmacies while increasing flexibility and access to new possibilities of negotiation. This electronic market is based on a Distributed Multi-Agent System which has a multi-criteria negotiation and uses ontology-based services to solve the interoperability problems. The potential solutions obtained through the electronic market interactions will compete with the solutions found by the hospital pharmacy own system. We believe that using our system architecture and services is a step forward in achieving the cooperation between hospital pharmacies and pharmaceutical drug manufacturers around the world. However, we are also aware of challenges and problems that might arise from using this approach.

Keywords:

hospital pharmacy, pharmaceutical medicine manufacturer, electronic market, multi-agent system, negotiation, ontology

Introduction

United States perspectives database were used in a study to evaluate trends in hospital drug expenditures [1]. The study presents these data consisted of drug purchasing information for 5230 hospitals in 2003. The hospital drug expenditures were approximately $23 billion in 2003, representing a 6.3% increase in drug expenditures compared with 2002. Authors identify that some of the factors affecting the trend in hospital drug expenditures included drug prices (2.3%), volume and therapeutic mix (2.1%), and new drugs (1.6%). They projected for 2005 a 10-12% increase in drug expenditures in outpatient settings, a 12-15% increase in clinics, and a 6-9% increase in hospitals. Authors conclude that "Pharmacy managers must remain vigilant in monitoring drug costs in their health system and take a proactive role in pursuing efficient drug utilization" [1]. Several barriers and challenges involved in the reduction of drugs expenditures are difficult to be solved, at least nowadays, but it is important to look for possible ways to undertake or reduce the problem.

One way would be to find the supplier (pharmaceutical drugs manufacturer) with the best price for each one of the needed drugs and also be able to negotiate based on hospital pharmacies (HP) preferences.

Nowadays, most of the HPs around the world buy drugs by contacting each pharmaceutical drugs manufacturer (PDM) that may provide the respective drug. There are several PDMs that may provide the same drug with different commercial names, prices, quality and delivery time. As an example, the HP could need antibiotic drugs, and in this case they could buy "Amoxil" developed by Glaxo-Smithkline, "Novocilin" developed by "Aché", Velamox developed by "Sigma Pharma", just to name a few. The HP could also buy the generic drug (amoxicillin) developed by Abbott, Eurofarma, Sanval, or Medley. It is not an easy task for the hospital pharmacy responsible looks for the best supplier around the world, for each needed drug.

An electronic market (TEM) for trading drugs could reduce costs and time for the HP that needs a specific drug, while increasing flexibility and access to new possibilities of negotiation. Moreover, the PDM would have more chances to sell its drugs.

Electronic marketplaces are enabling new kinds of services and interactions between suppliers and customers [2]. It is an application domain where thousands of heterogeneous companies, acting both as suppliers and customers and using different names to represent the traded products and different currencies to represent the prices, may be involved. Moreover, different companies tend to use knowledge representations (ontologies) that differ significantly either syntactically or semantically. This heterogeneity in the representation of the commercial products is a critical impediment to an efficient business information exchange and to the automation of the business-to-business (B2B) transactions. Furthermore, in a decentralized and distributed approach, companies may negotiate with other companies geographically distributed. The companies negotiate using their own product descriptions as well as their local currency. If each company uses

local currency, and they differ from the ones used by other companies then an interoperability problem occurs. The interoperability problems make the negotiation process more difficult and consequently make hard a final agreement.

We are proposing an EM based on multi-agent system (MAS) paradigm, where each HP and PDM will be represented by an agent. For helping to solve the interoperability problems (problems caused by the use of distinct terminology; and problems generated by the lack of standardization) the ontology-based services [3] are integrated in the EM proposed. In this context, ontologies play an important role since they provide the vocabularies used by the agents. Whereas, in homogeneous MAS, the adoption of a common ontology guarantees the intelligibility of the communication between agents, in open MAS, where the agents are intrinsically heterogeneous and have different private ontologies, the interagent communication is affected by unknown and, thus, incomprehensible terminology, as well as, by the *ad-hoc* use of disparate currencies to represent the price of products.

We believe our proposal is a step forward in achieving the cooperation between hospital pharmacies and pharmaceutical drug manufacturers decreasing time and price, while increasing the number of negotiation with different PDM around the world.

Electronic market solutions

Many electronic markets (EMs) or online pharmacies have been proposed, but they are mainly related with business-to-consumer (B2C) domain, as for example 101Pharmacy[1] and Acme Fresh Market[2]. To the best of our knowledge, this is the first proposal for an EM applied to this specific domain.

The EM proposed here is a permanently open virtual marketplace where registered PDM and HP (represented both by agents) can meet each other through the Web to purchase services according to established norms and rules.

Drugs trading electronic market architecture

Due to the fast growth of B2B e-commerce, the demand for agents is growing because agents are able to, on behalf of their owners, locate and retrieve information and make reasonable decisions based on the owner's profile. Agents negotiate with multiple suppliers, monitor multiple auctions, and use intelligent strategies to find the best deal for the users. Agents can also represent companies/organizations in a B2C and B2B context. This shows not only how agents can collaborate with one another to achieve a common goal, but also how an agent selects the best partners through negotiation [4]. A central point of the agent's paradigm of software development is that communities of agents are much more powerful than any individual agent, which immediately raises the necessity for interoperable agent systems.

In our multi-agent approach we will have at least five types of agents: (i) Facilitator Agent (FAg), (ii) the Customer Agent (CAg), (iii) the Supplier Agent (SAg), (iv) the Ontology-based Services Agent (OSAg), and (v) the External Agent (EAg). The FAg, CAg and SAg are cooperating through a website with the objective of providing or getting drugs, in collaboration, but keeping their own preferences and objectives. The OSAg supports the negotiation process in case the SAg has not understood the content of a message, and it helps in the calculation of prices (that may be necessary when dealing with different currencies).

The agents are deliberative, autonomous, intelligent entities that use different ontologies and apply goal driven reasoning to achieve their objectives. Agents have an inference engine which derives the recommendations from the knowledge base (ontologies) and problem-specific data in instances. In our scenario, the CAg (representing the HP) and the SAg (representing the HP) have the same objective: they want to trade products in the same application domain and still use their own private ontologies (the PDM and HP will not waste time and money converting their drugs catalogues, changing the drug names and involved knowledge). Due to this common objective, we provide an e-commerce ontology that defines an e-commerce vocabulary just for the trading, *i.e.,* a negotiation protocol. This vocabulary contains terms which are used during the negotiation process. Thus, we ensure that all agents will uniformly interpret the negotiation messages exchanged. This does not imply identifying correctly the specific content of the messages, *i.e.*, the requested drugs, since each agent interprets this information based on its own private domain ontology. A user interface allows the interaction between the users and the agents [3].

When a request for a drug is made by some of the registered CAg (HP), the FAg will look for the registered SAg (PDM) that may provide the respective drug. The OSAg enables appropriate conversations and makes possible to reach agreements between agents representing different HP and PDM. In order to avoid the EM indicating a drug that will satisfy the customer needs but will have later some special constraints, the FAg requests to the EAg the validation of the request.

These five types of agents play the following roles:

(i) **FAg** is the entity that matches the right agents and supports the negotiation process.

1 101Pharmacy.org, http://www.101pharmacy.org, November, 2006.

2 Acme Fresh Market, http://www.acmestores.com/pharmacy/pharmacy.html, November, 2006.

(ii) **CAg** represents HP interested in buying drugs. Several suppliers in the world may sell these drugs with different prices and conditions. The user representing the registered HP inserts the information an agent needs in order to ask for a drug and their negotiation preferences. This includes the attributes: drug name, quantity, and currency, with the respective HP negotiation preferences. The currency chosen will be the currency in which the CAg wishes to receive a proposal, *e.g.* Dollar (USD). If the SAg wants to make a proposal, but the drug is priced in another currency, *e.g.* Euro (EUR), the SEAg requests to the OSAg the currency conversion service.

(iii) **SAg** represents pharmaceutical medicine manufacturers interested in providing drugs. Whenever a drug is needed, the FAg conveys this announcement to all registered interested SAg (PDM). The SAg makes an offer if the announced drug is currently in stock and if it understands what the CAg is asking for (the drug name). At least one SAg has to be present in the platform so that communication can be established.

(iv) **OSAg** is responsible for providing the services that support the negotiation among agents. This approach is compliant with the Foundation for Intelligent Physical Agents (FIPA) [5] proposal of creating a specialized Ontology Agent (OA) [6] for open MAS platforms. The idea is to support the interoperability between agents with different individual ontologies by means of a dedicated agent. Our implementation of the ontology agent is named OSAg and follows the FIPA recommendation. It is responsible for providing services to the customer and supplier agents that help solving the interoperability problems. Its task consists of applying different methodologies to detect lexical and semantic similarities between two terms (in this case, between drugs), as well as providing currency conversion services. The OSAg is an autonomous server-side agent that does not require any direct user interaction. The user interface only controls the tasks performed by the OSAg responsible for providing services to other agents to enable them to effectively negotiate together.

(v) **EAg** represents drugs and healthcare products regulatory agencies responsible for enhancing and safeguarding the health of the public by ensuring that drugs and medical devices work and are acceptably safe.

Negotiation Protocol

Java Agent DEvelopment Framework (JADE) [7] is the agent development platform used to build our system. The main reason for choosing JADE lays on the fact that JADE implements the FIPA standards. JADE encloses implementations of the FIPA library of behaviours and interaction protocols. All agents in our platform communicate by exchanging FIPA Agent Communication Language (FIPA-ACL) messages. A FIPA-ACL message contains a set of one or more message parameters, *e.g.*, type of communicative act (performative verb), participants in communication, content of message, description of content, and control of conversation. The communication follows the FIPA Contract Net Interaction Protocol (FIPA-CNP) [8]. The type of communicative act, defined by the performative parameter, is a required parameter of all FIPA-ACL messages. The participants consist of sender and receiver.

The implementation of our negotiation round combines the FIPA-CNP with an additional protocol called ontology interaction protocol (OIP). The former represents the general scenario of agents trading goods or services proposed by FIPA. Alike other interaction protocols, it structures complex tasks as aggregations of simpler ones. The latter implements the message flow necessary for solving the problems of interoperability, including the interaction of customer and supplier agents with the OSAg.

In our context, the CAg plays the role of the initiator while the SAg is the participant during the FIPA-CNP. The initiator wishes to have some task performed and further wants to optimise a function that characterises the task. In this context, the CAg announces in the market the need for a specific drug. For a given task, the participants (SAg) may respond with a proposal or a refusal to negotiate (sell drugs). Negotiations then continue only with the SAg that offered proposals. The CAg (representing the HP) selects, among all proposals received, the best offer based on its own cost-benefit criteria and replies to all SAg (representing the PDM) that made offers with an acceptance or rejection message, depending on the case.

In the former case, once the SAg has completed the task, it sends a message to the CAg in the form of an inform-done performative or, using a more explanatory version, in the form of an inform-result performative. However, if the participant fails to complete the task, a failure message is sent. Three different situations may occur when a SAg receives a CFP (Call-for-Proposal) message: (i) the SAg refuses the CFP, (ii) the SAg accepts the CFP or (iii) the SAg contacts the OSAg because it is unable to fully understand the CFP.

In the first case, the SAg answers with a refuse performative. In the second case, the SAg responds with a propose

performative based on a multi-criteria negotiation (explained later) stating its conditions to sell the drug. The SAg's conditions should be compatible with the conditions originally contained in the CFP. In the last case, after having received a CFP and not being able to interpret the requested item, the SAg sends a message with the performative not-understood to the OSAg, identifying both the sender of the CFP (CAg) and the name of the unknown drug. The OSAg generates and sends a query-ref message to the CAg inquiring about the unknown drug.

- The CEAg analyses the request and answers with an inform performative containing all the information about the required drug. The price is taken from its pricelist.
- After receiving all the information about the item under negotiation the OSAg applies the similarity detection methods [9] trying to find the correspondent drug in the SAg ontology. These similarity detection methods aim at detecting syntactic and semantic similarities between terms. Every candidate term (SAg drug) is compared with the requested term (CAg drug).
- The OSAg informs the SAg of the outcome of the process, *i.e.*, sends the name of the best match or informs that it was unable to find any corresponding item. If necessary, the CAg requests the unit conversion service.
- The SAg is then able to respond to the CAg CFP, either with a proposal (based on the multi-criteria negotiation) or with a refuse performative according to the FIPA-CNP.

Multi-criteria negotiation

The CAg (PH) is responsible for selecting among a set of SAg (PDM) the subset that will provide the needed drugs. As already explained, the CAg negotiates with several SAg to select among them the ones that are the most promising, at the moment, to satisfy its actual need. The negotiation results in a process of multiple rounds.

The negotiation is a kind of decision making where two or more parties jointly search a space of solutions with the goal of reaching a consensus [10]. This search usually is a single dimension process (usually the price) where the different agents, involved in the negotiation process, mutually adapt their price offers in order to reach their goals (to sell or to buy a good). However, this process is inflexible and often unrealistic because more than one single issue has to be negotiated in order to find out an adequate agreement [11]. The first step is to translate the human preferences in attributes that can be analysed, communicated and negotiated by agents.

Each CAg (PH) has some negotiation preferences based on attributes as price, delivery time, or specific PDMs, which have to be taken into consideration during the negotiation round. These preferences mean the PH cost-benefit criteria.

The CAg request describes the needed drug, represented in a private ontology and describes also the CAg preferences, which are codified in the relative order by which attribute are defined in the product structure definition: $Product_x=\{Atb_{x1}, Atb_{x2}, Atb_{x3}\}$ with $Atb_{x1} >_{imp} Atb_{x2} >_{imp} Atb_{x3}$, where $>_{imp}$ means "more important than". In this case it means that Atb_{x1} is more important than Atb_{x2}, and Atb_{x2} is more important than Atb_{x3}. This order is relevant for the negotiation process. Each attribute has also dependencies associated with the different attribute's values (Dep_i). These dependencies may be of three types: time, event and value. $Dep_i=\{\{Dept_i\}, \{Depe_i\}, \{Depv_i\}\}$, where time dependencies constrains the attribute's values in specified time intervals, event dependencies constrains the attribute's values when some specified event happen, and the value dependencies constrains the attribute's values to other attributes' values of other components. During the negotiation process, the SAg formulates proposals in an adaptive way, learning with qualitative feedbacks formulated by the CAg in previous negotiation rounds [12].

The selection of the SAg (PDMs), which will provide the requested drugs, is done through a negotiation algorithm called Q-Negotiation. The Q-Negotiation algorithm uses a reinforcement learning strategy based in Q-learning [Rocha and Oliveira, 2001] for the formulation of new proposals.

In particular, Q-learning enables on-line learning, which is an important capability for B2B negotiations where agents may effectively learn in a continuous way during all the negotiation process, with information extracted from each negotiation round, and not only in the end of the negotiation. The adaptation of the Q-learning algorithm to our scenario, leads to the inclusion of two important features (the reward value calculation and the decrement of the exploration space) detailed in [13].

The distributed dependencies satisfaction algorithm, besides reaching the optimal solution, keeps agent's information as much as possible private. Each agent involved in the distributed dependent problem resolution should know all possible values for its own dependent attributes. Agents will then exchange among them alternative values for the dependent attributes, in order to approach an agreement. As in any iterative negotiation process, agents start the negotiation by proposing its optimal solution and, in the next rounds start trying to reach a consensus. A more detailed description of this algorithm may be found in [13].

Conclusions and future work

An electronic market, including ontology-based services, to solve the trading drugs problem between hospital phar-

macies and pharmaceutical drugs manufacturers has been proposed.

We have implemented a prototype with one agent representing a hospital pharmacy and several agents representing pharmaceutical drugs manufacturers cooperating through a website. To support the negotiation of products, we provide an e-commerce ontology which is shared by all agents and defines a domain-independent business vocabulary. This ontology ensures a meaningful e-commerce communication since all agents will uniformly interpret the intention of the messages exchanged and the generic business terms used. Besides this e-commerce ontology, each agent has its own private drugs domain ontology. Since in a real-world business context, the companies will use different ontologies and adopt diverse ontology representation formalisms, our approach also envisages this possibility: the ontologies may be developed by any ontology development tool and stored in any standard format.

A facilitator agent and an ontology-based services agent were integrated in order to monitor and support the negotiation process. The agents representing the external agencies were not integrated in this phase.

We have implemented a multi-criteria negotiation where CAg may order their preference for using during the selection of the best SAg.

An important requirement in this process, is that information must be kept private to individual companies, since they are competitive by nature and do not want to reveal their market strategy to others. The Q-Negotiation algorithm has the ability to maintain information private and, at the same time, it includes the capability to evaluate multi-attribute proposals, to guide learning during the negotiation process, and to resolve attributes' mutual interdependencies.

Regarding the trading of drugs, things are not so linear, hospital internal rules and country specific rules, just to mention a few, and they have to be taken into account when approach this subject. Our proposed EM already deals with these subjects, in an elementary way, but there is still space to make several improvements. Others issues like communication between different information systems, security, privacy and authorization, are also problems that we will have to address in our proposed EM as well as specific EM subjects like contracts.

We know that it is a hard job but we believe that, after solving all the questions related with the previous mentioned subjects, our proposed EM might be a profitable one for hospitals as well as for pharmaceutical drugs manufacturers that might be created just specialized in supplying solutions to these problems.

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