INTEGRATING A STANDARD COMMUNICATION PROTOCOL INTO AN E-COMMERCE ENVIRONMENT BASED ON INTELLIGENT AGENTS

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Abstract: Communication among intelligent agents which take part in negotiation protocols is not frequently considered as an important topic in the negotiation stage. These mechanisms are often designed for specific problems, without taking into account the interoperability among agents involved. In this paper, we suggest a standard communication protocol to ensure the interoperability among intelligent agents based on fuzzy logic in an E-Commerce environment. Moreover, this environment is integrated into a FIPA-compliant multi-agent system, formalizing the communication among agents at message and payload levels. The standard messages and the protocols used are described in depth, together with a detailed example.

1 INTRODUCTION

Electronic Commerce (E-Commerce) can be defined as any business form, administrative transaction, or information exchange carried out by employing communication and information technologies. There are two main types of E-Commerce: business-to-business (B2B) and business-to-consumer (B2C). Both models share six main tasks of the buying process: need of identification, product brokering, merchant brokering, purchase and delivery, and product service and negotiation. Several applications have been designed for automating all of these tasks or some of them. For example, an important class of these systems has been developed for automating the negotiation stage. Agent technology has become very popular in E-Commerce and, more specifically, in automated negotiation. Frequently, developers focus their effort on the agent design and other important topics, such that the communication ability of agents, do not get all the attention required. This way, the communication mechanisms employed are limited to particular approaches.

In this paper, we address the necessity of adding interoperability to a buyer agent previously developed (Castro-Schez et al., 2004b) to make negotiation easier. This buyer agent was designed from a functional point of view, without paying attention to its interactions with other agents in a standard way. The general scenario consists of a number of agents based on fuzzy logic, one acting as a buyer and the other agents acting as sellers. The buyer leads the interaction by receiving offers, by studying them, and by asking sellers for new proposals. To formalize this communication, we propose a solution based on the FIPA Iterative Contract Net Interaction Protocol which is deployed into a FIPA-compliant multi-agent system.

The paper is structured as follows. Section 2 addresses the importance of using standards in the negotiation stage. Section 3 exposes the application frame, formalizing the agent concept and describing a negotiation example. Section 4 describes the proposed solution in depth. Finally, concluding remarks and future works are discussed in Section 5.

2 PROBLEMATIC QUESTIONS

Currently, there are many protocols which have been designed to solve problems related to the negotiation among intelligent agents (Lomuscio et al., 2003). However, most of the researchers have created their own negotiation protocols without taking interoperability into account. In other words, researchers do not have a common reference to ensure that their negotiation protocols are standard. To solve this problem, we suggest two ways of obtaining standardization in the communication. First, a well-defined, flexible, and robust negotiation protocol should be

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adopted. Second, the representation of messages among agents should be structured into two levels: communication language level and content language level, that is, the envelope and the payload, respectively.

2.1 Related Work

Nowdays, there are many interaction protocols defined for tackling the negotiation process. Anthony P. et al. (Anthony and Jennings, 2003) presented an heuristic decision making framework to manage the problem of bidding across multiple auctions, but they did not define a negotiation protocol specifying the messages exchanged among agents. A more current work was developed by Mia M. et al. (Mia et al., 2005), who exposed a negotiation process without using any type of standard communication. If we take the communication problem into account, these works are incomplete because another software agent cannot communicate by employing unknown negotiation protocols in most cases. Skylogiannis et al. (Skylogiannis et al., 2005) presented a work in which they criticized the use of FIPA protocols and proposed their own negotiation protocol. Although their system uses FIPA standard communicative acts, they do not employ a standard interaction protocol.

Another important research line is related to the use of rules for specifying the protocol. Bartolini et al. (Bartolini et al., 2002) justified the inclussion of negotiation rules to explicitly specify the negotiation mechanism, controlling additional aspects of the negotiation (e.g. the criteria for accepting a bid in an English Auction).

2.2 Our Proposal

In this paper, we propose a solution to a scenario with many agents, one acting as a buyer and other acting as sellers. This solution is based on the FIPA Iterated Contract Net Interaction Protocol (Foundation for Intelligent Physical Agents FIPA, 2000), a protocol in which one agent (the Initiator) takes the role of manager which wishes to have some task performed by one or more agents (the Participants), and further wishes to optimize a function that characterizes the task. In our context, this function measures the similarity among offered products and the desired product depending on the characteristics that define it. We have chosen this protocol because it can be adapted to our negotiation scenario in a standard way, as discussed in Section 4. Moreover, we have implemented a FIPA-compliant multi-agent system (Foundation for Intelligent Physical Agents FIPA, 2004) to test this solution. The main benefit of using this approach is to obtain a high-interoperable environment where software agents can be easily integrated for making proposals in the negotiation process. This work will be mainly focused on the negotiation protocol by specifying the meaning of the communicative acts exchanged among agents.

3 APPLICATION FRAME

The number of participants is a significant property of negotiation in E-Commerce (Lomuscio et al., 2003). In fact, three main negotiation scenarios are distinguished attending to the number of participants involved in a negotiation: i) one-to-one, ii) many-to-one or one-to-many, and iii) many-to-many. The buyer agent used in this paper was designed to work in a scenario composed of many sellers and only one buyer. The main goal of the buyer agent is to buy a product or to acquire a service. In order to reach this aim, the buyer agent owns a description of such product or service through different characteristics (more than one). In addition, there is a competition among sellers to make a deal with the buyer agent. This way, the buyer agent obtains profit from this competition.

The buyer agent's behaviour consists of several steps. First, it receives offers from different sellers in accordance with the product or service desired. After comparing these offers, the buyer agent can accept an offer that is closed enough to the ideal pact. Otherwise, it orders them depending on the similarity regarding to the ideal value, making groups of three offers and showing to the supplier of the worst offer the other two of the list. The main goal consists of asking this last supplier for changing some characteristics or adding new characteristics that make its offer better than the others. By means of this process, the buyer agent obtains profit of the competition among sellers (Castro-Schez et al., 2004b).

The first stages of the negotiation often involves imprecise terms before reaching a deal. On the one hand, in these stages both the buyer and sellers do not know all the outstanding information of negotiation. On the other hand, this knowledge increases as the negotiation process evolves. For these reasons, we should provide agents with an intuitive and formal way of representing both precise and imprecise values. In this work, we use several data types for representing these restrictions (Castro-Schez et al., 2004a): ordered-discrete or ordinal (e.g. product state), unordered-discrete or nominal (e.g. supplier's country), boolean (e.g. new manufacture), ranking (e.g. quality), and continuous or numerical (e.g.

Table 1: First stages of the negotiation.

First stage	O_1	O_2	O_3	Second stage	O_1	O_2	O_3	Third stage	...
$d_n(O_i,O_x,Price)$	0.125	0.125	0	$d_n(O_i,O_x,Price)$	0.125	0.125	0	...	...
$d_n(O_i,O_x,Age)$	0.143	0.143	0.143	$d_n(O_i,O_x,Age)$	0.143	0.143	0.143	...	...
$d_n(O_i,O_x,Fuel)$	1	0	0	$d_n(O_i,O_x,Fuel)$	1	0	0	...	...
$d_n(O_i,O_x,Power)$	0.136	0.273	0	$d_n(O_i,O_x,Power)$	0.136	0.273	0	...	...
Similarity	0.327	0.865	0.964	$d_n(O_i,O_x,Mileage)$	0	0.5	0.25	...	...
				Similarity	0.719	0.792	0.921	...	...

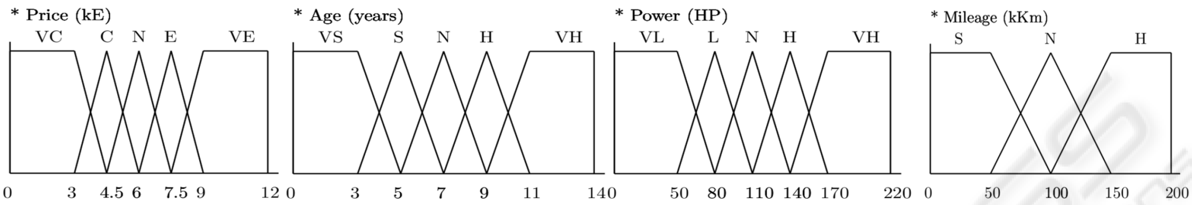

Figure 1: Description of the variables.

price). The representation of these values should ideally be flexible, linguistic, mixed, and uniform. Therefore, we suggest trapezoidal functions to represent the crisp and vague values mentioned before. Moreover, the treatment of the uncertainty in the first stages of negotiation can be efficiently carried out by using fuzzy logic. Thus, fuzzy logic makes this process intuitive and provides us with freedom when describing offers and requests.

The buyer agent (A_b) is defined as

$$A_b = \{V, DDV, P, S, B, O_i\}$$

where $V = \{v_1, v_2, \ldots, v_n\}$ is the set of product features, $DDV = \{DDV_1, DDV_2, \ldots, DDV_n\}$ is the set of values they take (both, V and DDV, composed the product description), $DDV_i = \{A_{i1}, A_{i2}, \ldots, A_{im}\}$, where each A_{ij} is a linguistic label defined through a trapezoidal function, $P = \{P_{v_1}, P_{v_2}, \ldots, P_{v_n}\}$ is the set of priorities attached to each variable (feature), S is the similarity function used to compare offers, B is the buyer agent's behaviour, and $O_i = \{x_1, x_2, \ldots, x_n\}$ is the ideal product desired by the buyer agent, where $x_i \in DDV_i$, $i = 1 \ldots n$.

Since all values are represented as trapezoidal numbers, the similarity between two offers, O_x and O_y according to a variable v_i, is assessed by means of a measurement based on the calculation of the area existing between the two fuzzy values, A and B, that take these offers, O_x and O_y respectively, in the variable v_i:

$$d(A,B,v_i) = \begin{cases} \frac{(a'-b)+(b'-a)}{2} & b \leq a', \\ \frac{b'-a}{2} & a' < b < b' \\ 0 & b = b' \end{cases} \quad (1)$$

where A and B are two fuzzy sets, defined by means of two trapezoidal functions with parameters (a,b,c,d) and (a',b',c',d'), and v_i is the variable where these values are taken. This measurement is theorically justified by Castro-Schez et al. (Castro-Schez et al., 2004a) and normalized as follows:

$$d_n(A,B,v_i) = \frac{d(A,B,v_i)}{d(min,max,v_i)} \quad (2)$$

where $d(A,B,v_i)$ is the measurement previously mentioned (see Equation 1) and $d(min,max,v_i)$ is the separation between the minimum (leftmost) and maximum (rightmost) values of the variable v_i.

This way, the Similarity S between two offers is obtained by assesing the distance in relation to the variables which compose the offers (Castro-Schez et al., 2004b):

$$Similarity(O_x,O_y) = 1 - \frac{\sum_{i=1}^{n} d_n(O_x,O_y,v_i)}{n} \quad (3)$$

Table 2: Descriptions of the products.

V/Prod.	O_{Ideal}	O_1	O_2	O_3
Price	Normal	Expens.	Cheap	Normal
Fuel	Gas	Oil	Gas	Gas
Power	High	Medium	Low	High
Age	Medium	Short	High	High

An important question related to the buyer agent's behaviour B is the negotiation stage, which is described as follows:

1. Take the best offers received and randomly make groups of three offers.
   (a) Establish the worst offer in each group.
   (b) Show the supplier of the worst offer the other two of the list.

(c) Ask such supplier for changing some variable or adding a new one that makes his offer better than the other two.

In step 1.c, we can use some method to give advices to sellers when making offers. A possible approach consists of using a measurement which pays attention to positive variables and their priority as indicator for improving offers (Castro-Schez et al., 2004b).

An example of negotiation is given in Table 1. Suppose a buyer interested in acquiring a second-hand car that has normal price, medium age, high power, and consumes gasoline (as first approximation), that is, the buyer's ideal second-hand car exposed in Table 2. The definition of such variables is covered in Figure 1. Suppose also three sellers offering three offers to the buyer: O_1, O_2, and O_3 (see Table 2). Under these assumptions, the buyer agent would calculate the Similarity between its ideal car and the others (see first stage of Table 1, where $d_n(O_i, O_x, v_x)$ represents the distance between the ideal car O_i and the offer O_x regarding to the variable v_x). Since the worst offer is O_1 due to the lowest Similarity value, the buyer agent asks the first seller for improving its offer. In this example the seller adds another variable, the mileage, and the buyer agent recalculates the Similarity between offers, and so on.

As mentioned previously, one of the advances of this work consists of formalizing the negotiation protocol among the buyer and sellers. Therefore, we redefine the buyer agent A_b as

$$A_b = \{V, DDV, P, S, B, O_i, C\}$$

where C represents the communication of the buyer agent A_b, defined as $C = \{P_{request}, P_{contract\_net}\}$. In this context, C is interpreted as the set of communication protocols used to negotiate. Both protocols will be covered in depth in Section 4.

4 DESCRIPTION OF THE COMMUNICATION PROTOCOL

In this section, we define the communication C needed to deploy the behaviour B of the buyer agent A_b presented in Section 3. We defined $C = \{P_{request}, P_{contract\_net}\}$, where $P_{request}$ represents the FIPA protocol used to discover agents of a particular type, and $P_{contract\_net}$ represents the FIPA protocol that we have adopted to carry out the negotiation. $P_{contract\_net}$ is the FIPA Iterative Contract Net Interaction Protocol (Foundation for Intelligent Physical Agents FIPA, 2000) (see Figure 2), formally defined as $\{cfp, refuse, propose, reject, accept, inform, failure\}$.

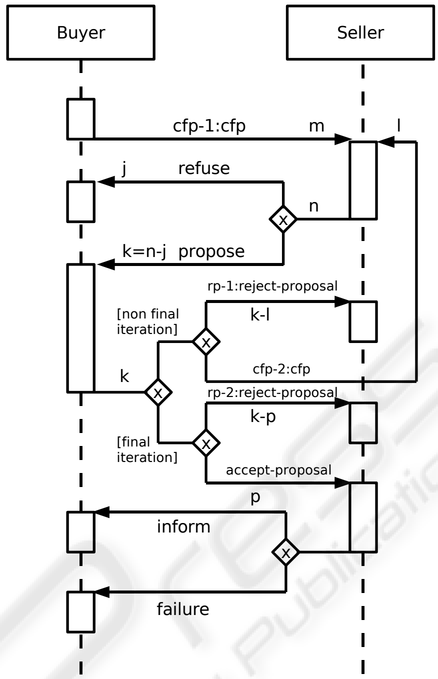

Figure 2: FIPA Iterative Contract Net Interaction Protocol.

When the buyer agent is able to communicate with seller agents, it can assume the Initiator role and send a call-for-proposal to the seller agents to inform them of its intention of buying a product or acquiring a service. In this message, the buyer agent should ideally specify the features of the product to acquire or the service to request should meet. Thus, we have to use an agent communication language (ACL) to ensure interoperability among the buyer and the sellers. Besides employing an ACL, we have to use a content language which allows us to precisely specify the product features. FIPA proposes a CCL content language to be used for agent communication (Foundation for Intelligent Physical Agents FIPA, 2001), and more specifically as a content language to be used with FIPA ACL.

Now we can describe the initial message sent by the buyer agent to the seller agents (this process is illustrated with the example proposed in Section 3). Suppose two of the variables to describe the cars: price and mileage (expressed in thousands of Euros and Kilometers, respectively). This way, the buyer agent would send the initial call-for-proposal (cfp-1) shown in Figure 3. If the buyer agent sends a call-for-proposal which does not start a new negotiation

```
 1: (cfp
 2:  :sender “buyer”
 3:  :receiver “seller1, seller2, ...”
 4:  :content
 5:   (Action: CSP-give-values
 6:    (Object: CSP
 7:     :CSP-ref “car-scenario”
 8:      :variables {
 9:       (Element: CPS-variable
10:          :name price
11:          :type fuzzy-continuous
12:          :domain
13:            {4500, 6000, 6000, 7500})
14:       (Element: CPS-variable
15:          :name age
16:          :type fuzzy-continuous
17:          :domain {5, 7, 7, 9})
18:         ....
19:      }
20:      :relations {}
21:      :exclusions {}
22: )))
```

Figure 3: Call-for-proposal message.

```
 1: (propose
 2:  :sender “seller1”
 3:  :receiver “buyer”
 4:  :content
 5:   (Action: CSP-give-values
 6:    (Object: CSP
 7:     :CSP-ref “car-scenario”
 8:      :variables {
 9:       (Element: CPS-variable
10:          :name price
11:          :type fuzzy-continuous
12:          :domain
13:            {6000, 7500, 7500, 9000})
14:       (Element: CPS-variable
15:          :name age
16:          :type fuzzy-continuous
17:          :domain {3, 5, 5, 7})
18:         ....
19:      }
20:      :relations {}
21:      :exclusions {}
22:  )))
```

Figure 4: Propose message.

(cfp-2 of Figure 3), he should send two offers made by other sellers for the third seller agent being able to compare them with its offer, as explained in the buyer agent’s behaviour (*B*) in Section 3. Lines 2 and 3 of Figure 3 specify the sender and the receivers of the call-for-proposal. Line 4 begins the message content, describing the action related to the message (line 5). In this first message, the buyer sends the initial description of the desired car by means of the variables initially involved in the negotiation, as shown in lines 9-13, 14-17, and 18. For example, the variable of the line 9 is the price, which is fuzzy-continuous, and its domain $A_{price,normal}$ (Euros) is defines as follows (see also Figure 1):

$$A_{price,\ normal} = (4500, 6000, 6000, 7500)$$

If the buyer agent sends a call-for-proposal which is not the beginning of a new conversation, that is, the cfp-2 of Figure 3, the content of the message may change. In this situation, the buyer agent may ask one seller for improving his offer by means of indicators. Regarding the previous example of the car sale, the buyer agent asked one of the sellers for making his offer better. This call-for-proposal (cfp-2) may consist of three different CSP objects: two of them describing the two best offers and the third one specifying a possible modification in the value of a certain variable (for example, a price reduction). In this example, this seller chooses to introduce a new variable, the mileage.

```
 1: (accept-proposal
 2:  :sender “buyer”
 3:  :receiver “seller3”
 4:  :content
 5:   (Action: CSP-give-values
 6:   (Object: CSP
 7:     :CSP-ref “car-scenario”
 8:      :variables {
 9:       (Element: CPS-variable
10:          :name price
11:          :type fuzzy-continuous
12:          :domain
13:            {4500, 6000, 6000, 7500})
14:         ....
15:      }
16:      :relations {}
17:      :exclusions {}
18: )))
```

Figure 5: Accept-proposal message.

The next step in the algorithm is to receive offers from the seller agents. This action can be translated into a proposal (propose). A seller agent can make an offer depending on the features requested by the buyer agent, as shown in Figure 4. By using this message, the communication related to the reception of offers on behalf of the buyer agent is formalized.

Another action to be formalized is the acceptance (accept-proposal) of a previously submitted proposal (if the buyer agent of the example proposed were accepted the offer of the third seller). By means of this message (an accept-proposal), the buyer agent can close a deal with its supplier. In the accept-proposal of Figure 5, the buyer agent (line 2) accepts and offer of one seller (line 3), seller 3 in this case. Basically, the buyer agent informs that seller about the full description of the offer to be accepted, specifying the variables related to the accepted offer (lines 9-13, for instance). On the other hand, and although it is not explicit in the algorithm, the buyer agent could reject a proposal through a reject-proposal message (reject-proposal).

When the buyer agent accepts a proposal and sends an accept-proposal message to a seller agent, this last agent must confirm the deal by sending an inform message (inform). This way, the contract between the seller agent and the buyer agent can be closed.

5 CONCLUSIONS AND FUTURE WORKS

Integrating a negotiation algorithm into a standard negotiation protocol allows us to obtain a high-level abstraction to tackle the negotiation among intelligent agents. We have deployed a standard communication mechanism to manage a specific one-to-many scenario into a FIPA-compliant multi-agent system. The main advantage of employing these standards is the high-level of interoperability reached.

Another decision which provides us with a high interoperability is the use of a standard content language: FIPA CCL. Under this approach, several important advantages have been achieved over other alternatives: i) the use of standars facilitates the adoption of the negotiation protocol by other researchers, ii) the use of a FIPA-compliant multi-agent system makes the communication with agents of other FIPA-compliant multiagent systems inmediate, and iii) the use of the FIPA Constraint Choice Language (with its associated ontology) allows us to represent products or services related to the negotiation by employing well-defined semantics.

Future works are related to the adaptation of the algorithm to more general scenarios, such as many-to-many, in which different seller agents negotiate with different buyer agents, and the definition of a generic ontology to represent the knowledge related to a negotiation domain.

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