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DEVELOPMENT OF A FUZZY-BASED MULTI-AGENT SYSTEM FOR E-COMMERCE SETTINGS

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Abstract

In this paper we present our experience in developing a fuzzy-logic based multi-agent e-commerce system capable of achieving a mutually beneficial deal for the seller and buyer using a negotiation process. We use fuzzy logic to assist users to express their preferences about a product in fuzzy terms such as low, medium and high. Our system evaluates offers based on a fuzzy utility function and feeds utility scores to a fuzzy inference system which then computes its next counter offer. Our paper presents issues involved in the development of a multi-agent system for e-commerce settings using the JADE platform - a modern agent development environment. In this paper our focus is on implementing agents of different types/roles engaged in activities usually encountered with buying and selling in an e-commerce environment. Our concluding remarks and future research are presented.

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1. Introduction

Today e-commerce provides businesses efficiency, cost savings and productivity in their business processes. Recently software agents have been used to solve complex problems in e-commerce[3, 8]. For example, agents have been used successfully to filter information, match people with similar interests, and recommend products and services to customers. In multi-agent systems, software agents cannot directly control other agents because every agent is an independent decision maker. In such situations, negotiation becomes the necessary mechanism to achieve mutual agreement between agents.

In this paper our aim is to implement a fuzzy-based negotiation system and evaluate its strengths and suitability for e-commerce. We use the scenario of purchasing a laptop as an example to illustrate the process. For our scenario we consider multi-issues such as low price, high popularity and medium memory, and use fuzzy logic to support bilateral agent negotiation. The key issues in such autonomous negotiation are bargaining agreement and bargaining strategy. The bargaining agreement is to manage a set of rules that govern the interaction between agents and some of the events that change the state of the negotiation process where as the bargaining strategy represents an agent's expectation and intent during the negotiation process[11, 12]. We argue that bilateral agent negotiation is indeed an interesting and valuable tool to automate some complex e-commerce transactions. We describe our efforts and experience in the development of a fuzzy-based multi-agent system for buying and selling consumer products. The techniques and strategies used in the development of a prototype system are described. Our experimental results are presented and discussed.

2. Agent-Based E-Commerce Modelling

In recent times the capabilities of software agents have been applied to electronic commerce, promising a revolution in the way we conduct transactions, whether business-to-business, business-to-consumer, or consumer-to-consumer[2, 3]. Automated bilateral negotiation has been widely investigated both in computational intelligence and in electronic commerce communities [6, 7, 8, 9]. In a multi-agent e-commerce environment, there would be specialised agents which carry out the tasks of parties involved in an e-commerce transaction. There would be a buyer, who is trying to get the best combination of a few different variables (e.g. price, quality, delivery time). The seller would be the bargaining agent who would try to entice the buyer into buying a product at the highest possible revenue. Reaching a mutual agreement in a bargaining situation involves finding an acceptable solution for both the buyer and the seller.

During a bargaining process a buyer inputs his/her requirements about a product in terms of its attribute choices. In such an e-marketplace a buyer agent will help the buyer to find the possible offers and bargain with suitable seller agents by exchanging offers and counter offers. The buyer agent may receive offers from the seller agents representing their product information. The buyer agent will then evaluate these offers based on the buyer's preferences and make a suggestion (counter offer). The buyer agent continues until an agreement can be reached with the seller agent. On the other hand, if the buyer or the seller agent rejects the current incoming offer conditions, the negotiation process will terminate with a 'no deal' state. Figure 1 shows a typical bargain protocol between two agents.

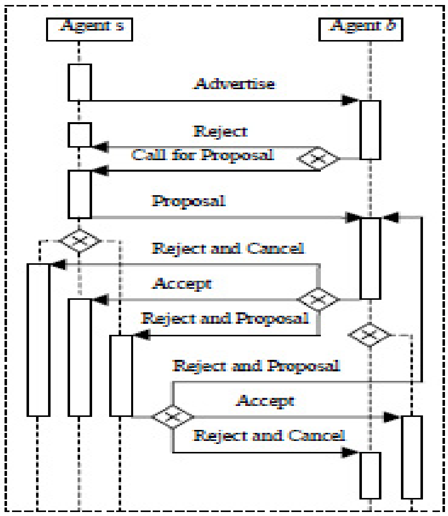

Fig. 1. A typical bargain protocol between two agents.

3. A Multi-Issue Bilateral negotiation Model

If the bargaining process was centred over a single issue (such as the price), then it is relatively straightforward. The buyer will search for the lowest price offered for an item of their choice. Once the lowest price is found, that is the optimal solution to the problem. However, in real world bargaining situations, it is never this simple. There are always multiple issues to consider such as the price, quality, quantity, warranty, delivery date etcetera. In this section we present a multi-issue negotiation model for e-commerce in which agents autonomously negotiate multi-issue terms of transactions in a bargaining environment. We use three agents in our model: a buyer agent, a seller agent, and a facilitator agent. The seller agent allows a seller to determine his/her negotiation strategies for selling merchandise. Similarly, the buyer agent allows a buyer to determine his/her negotiation strategies for buying merchandise. The facilitator agent serves to handle the negotiation strategies for both the buyer and the seller agents. In our approach, agents' preferences are expressed in fuzzy terms. The case study for our prototype implementation is buying and selling laptop computers. The negotiation model we have chosen for our study is illustrated in Figure 2. In this model, issues within both the buyer's request and the seller's offer can be split into hard constraints and soft constraints. Hard constraints are issues that have to be necessarily satisfied in the final agreement, whereas soft constraints represent issues they are willing to negotiate on. The facilitator agent collects information from bargainers and exploits them in order to propose an efficient negotiation outcome.

The negotiation facilitator receives requests and registers the buyers. Once this is done, the negotiation process can begin with the sellers. The negotiation facilitator requests the sellers to provide offers conforming to the restrictions imposed by the buyer agent. Please note that each restriction has an importance rating (0% to 100%), which means there is some leniency in the restrictions imposed by the buyer. For example if the buyer wants the colour Red, but provides an importance rating of 50%, it is quite lenient and the negotiation facilitator will request sellers to make offers for a range of different colours. The negotiation facilitator and sellers go through several rounds of negotiation until they reach the maximum number of rounds. Then the best offer (optimal set) is sent back to the buyer agent. The buyer agent then displays the results of the negotiation process to the end user who is ultimately responsible for making the decision on which item to buy.

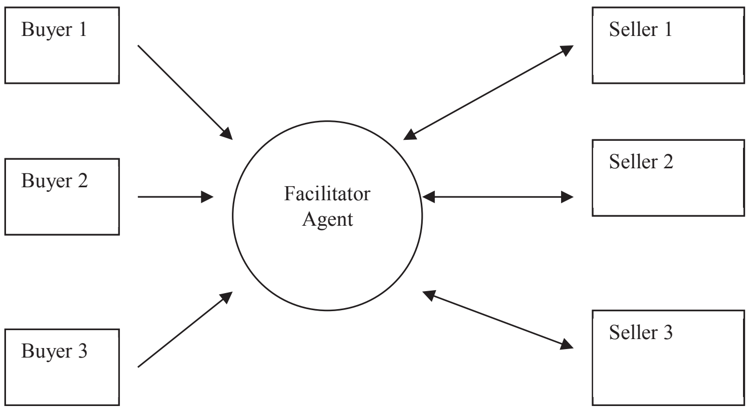

Fig 2. A one-to-many negotiation model.

4. Representation of User Preferences using Fuzzy Logic

When a buyer wants to express his/her preferences about a product, the experience tells us that, he/she works with uncertain information about the product or product attribute level choices. Under these circumferences it may be difficult for a buyer to estimate the attribute levels with exact numerical values but with natural languages. When the buyer provides the imprecise information about his/her product choices in natural languages, it is most desirable to look for a tool to handle such linguistically defined terms effectively. Fuzzy logic is a viable methodology which in general meant to represent and manipulate such linguistic and vague concepts in a numerical form.

Fuzzy sets and linguistic variables are best suited in approximating the buyer's linguistically defined terms. For example, a product feature such as 'price is low' or 'speed is high' can be represented using appropriate triangular fuzzy numbers. A triangular fuzzy number is a particular case of fuzzy sets. It has a triangle-shaped membership function, which can be viewed as possibility distribution.

Table 1 below lists some of the commonly used fuzzy linguistic terms and their corresponding triangular fuzzy numbers.

Table 1. Fuzzy linguistic terms and their corresponding triangular fuzzy numbers.

Linguistic Term	**Triangular Fuzzy Numbers**
Very low (VL)	(0, 1, 2)
Low (L)	(1, 2, 3)
Medium low (ML)	(2, 3, 4)
Medium (M)	(3, 4, 5)
Medium high (MH)	(4, 5, 6)
High (H)	(5, 6, 7)
Very high (VH)	(6, 7, 8)

Figure 3 shows the fuzzy membership functions for the linguistic terms[3, 10].

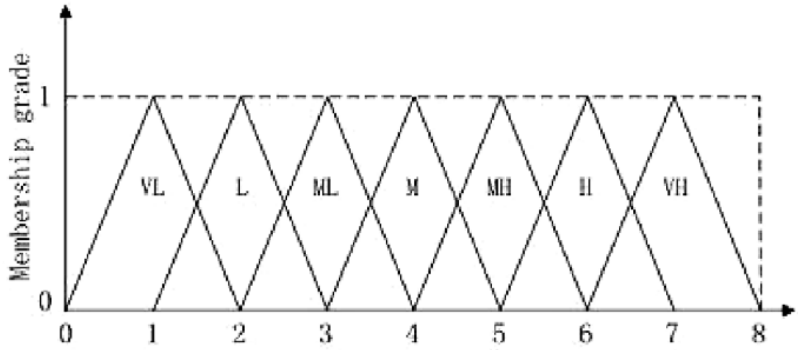

Fig. 3. Fuzzy membership functions for the linguistic terms listed in table 1.

4.1 A Case Study

When someone wishes to buy a computer/laptop, they have to go through a process to determine which one is best suited to their needs and requirements. For example, in a laptop purchasing problem, a customer may want to specify a set of requirements as illustrated below:

Price: The price of the laptop should be low.
Screen Size: The screen size should be medium.
Speed: The speed should be high.
Memory: Memory should not be very low.
Popularity: Popularity of the laptop should be hi

5. Prototype Development

We now present our implementation efforts towards the development of a fuzzy-based multi-agent system using the JADE platform [13, 14]. The main focus in this implementation has been the negotiation component which implements the multi-issue bargaining model described in the previous sections. One goal of JADE is to simplify development while ensuring standard compliance through a comprehensive set of system services and agents. It provides the following mandatory components for agent's management:

- AMS (Agent Management System), which besides providing white page services as specified by FIPA, it also plays the role of authority in the platform.
- DF (Directory Facilitator) provides yellow pages services to other agents.
- ACC (Agent Communication Channel) which provides a Message Transport System (MTS) and is responsible for sending and receiving messages on an agent platform.

The JADE framework provides a special agent called sniffer agent. When you sniff an agent (or a group), any messages sent to/by the agent are visualized in a kind of UML sequence diagram. When an agent is created or destroyed, the Sniffer Agent is informed by the AMS.

5.1. JADE Implementation

The model of a hypothetical system developed in the previous sections is used to implement a prototype system capable of demonstrating the bargaining negotiation strategy. The proposed multi-issue negotiation system was implemented using the JADE environment [13, 14]. The system provides graphical user interfaces for users (buyers and sellers) to define scoring functions, weighting factors, negotiation tactics. It also has a customer management system for the system administrator. In our system, there are three different types of agents, namely the buyer, the seller and the facilitator. The roles of the three agents in the negotiation process are described below:

The Buyer Agent - The buyer agent is designed to get the preferences from the user, register with the facilitator and then receive the results of the negotiation process. From the point the user clicks on search, there is no interaction between this agent and the end user, until the negotiation results are returned. At the beginning, the end user selects their preference values and importance factors. This information is used by the facilitator during the bargaining process.

The Facilitator Agent - The facilitator agent receives registration requests from both the buyer and seller and then process the request (either accepts or denies the registration request). Once all the information for a round of negotiation is available, the facilitator looks after the bargaining process with the supplier. Once the maximum number of negotiation rounds has been completed, the facilitator sends the best offer back to the buyer.

The Seller Agent - The seller agent is responsible for registering with the facilitator and sending a list of sale items which are available. This agent also manages the counter offers received from the facilitator. The agent has a threshold limit as to how much it is able to negotiate.

One of the most useful tools to use when developing a multi-agent system with JADE is the Sniffer agent. This is another agent built into JADE which allows the user to see the message interactions taking place in real time. It can be seen in Figure 4 below that the interactions depicts the type of message, the sender and receiver and when it was sent within the lifetime of the system.

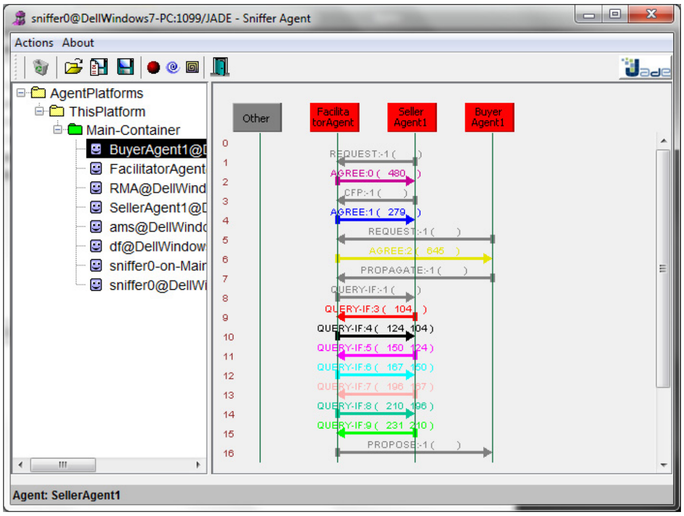

Fig. 4. A screenshot of the JADE sniffer agent

If more information is required about any of the agent messages, the user can double click the specific arrows and it will display full details.

6. The negotiation process

The negotiation module in our system consists of three components: negotiation object, decision making model and negotiation protocol. The negotiation object is characterised by a number of attributes for which the agents can negotiate. The decision making model consists of an assessment part which evaluates an offer received and determines an appropriate action, and an action part which generates and sends a counter-offer or terminates the negotiation. The assessment part is based on the fact that different values of negotiation issues are of different values for negotiating agents. We model the value of negotiating issues by utility functions[4]. Although there can be more than one instance of the buyer and the seller, there can only be one instance of the facilitator running **at any one time.**

We consider the buyer's tendency to pay more is higher if the degree of match between the product and the user preferences is higher, and is lower if the degree of match between the product and the user preferences is lower. If the price offered by the seller is within the high acceptance set, the buyer agent will concede very little. The strategy for determining the rate of price increase has been encoded as a set of fuzzy inference rules as shown in Figure 5.

- If (utility is medium) and (price is highAcceptance) and (nego_round is long) then (Price_Increase_Percentage is none)
- If (utility is medium) and (price is lowAcceptance) and (nego_round is long) then (Price_Increase_Percentage is none)
- If (utility is medium) and (price is mediumAcceptance) then (Price_Increase_Percentage is low)
- If (utility is high) and (price is lowAcceptance) then (Price_Increase_Percentage is low)
- If (utility is high) and (nego_round is short) then (Price_Increase_Percentage is moderate)
- If (price is highAcceptance) then (Price_Increase_Percentage is none)

Fig. 5. Fuzzy Inference rules that determine the price increase percentage

6.1 An algorithm for offer generation

During the negotiation process both the buyer and the seller generate their offers. An offer generation algorithm has been implemented in the system as illustrated using Pseudo code in Figure 6.

In evaluating an offer, an agent needs to calculate how closely the offer matches the preferences set by their client. When handling multiple attributes, each attribute will have a weight that corresponds to the importance of that attribute and a utility score that falls into a normalised interval of [0, 1]. The total utility of the product is then calculated as the weighted sum of the utility scores of individual attributes.

```
Max_round, buyer_offer_base, buyer_max, seller_offer, seller_min, seller_concession_rate
k=1
Deal=false
While (k <= max_round) & (Deal = false)
      If seller_offer > buyer_offer_base
                  increase_rate  = evaluation(utility,seller_price, k)
                  buyer_offer =  buyer_offer *(1+increase_rate)

             If seller_offer > buyer_offer
                 buyer_offer = seller_offer
                 Deal=true
            Else if buyer_price > buyer_max
                buyer_offer = buyer_max

            Else   buyer_offer
            End If
     Else   Deal=true
     End If k=k+1

     If buyer_offer<seller_offer
                  seller_offer = seller_offer*(1- seller_concession_rate)
                  If seller_offer < buyer_offer
                         seller_offer = buyer_offer
                         Deal=true
                   Else if seller_offer < seller_min
                        seller_offer  = seller_min
                   Else   seller_offer
                   End If
      Else
                  Deal=true
      End If k=k+1
 End While
```

Fig. 6. The offer generation algorithm.

6.2 Experimental Results

We have evaluated the negotiation process by varying user preferences on laptop attributes and price and compared the result with fixed conceding tactic (5% rate). Performance of tactic employed by the agent is measured based on the total concession made when agreement is reached, divided by distance of initial seller's and buyer's offer.

Table 2 shows how the agents concede when laptop utility score is high, i.e. 0.8476 and when the utility score is low, i.e. 0.6609. At the beginning of negotiation, agents maintain their offers closely to the initial offer, however as negotiation reaches its end, the agents concede more by raising their offer higher. When the utility score of laptop is lower, the buyer agent keeps its offer close to its initial offer as the laptop matches its user preferences less and the negotiation does not result in an agreement. When using a fixed conceding tactic, the agents can reach a deal in a shorter time but, with less payoff as the deal is made at a higher price.

Table 2. Offer for each negotiation round with different settings of preferences.

Negotiation round	Buyer's (odd round) and seller's Offer (even round) with conceding rate (for item with utility score of 0.8476)	Buyer's Offer and Seller's Offer with conceding rate (for item with utility score of 0.6609)	Buyer's offer and Seller's offer with fixed concession rate
0	880	880	880
1	651.0689(0.1644%)	651.0689(0.1644)	682.5000(5%)
2	836	836(5%)	836(5%)
3	651.9946(0.1422%)	651.9946(0.1422%)	716.6250(5%)
4	799.2	794.20(5%)	794.20(5%)
5	652.8571(0.1323%)	652.8271(0.1323%)	752.4563(5%)
6	754.49(5%)	754.49(5%)	754.49(5%)
7	694.4511(6.3711%)	653.7930(0.1433%)	Accept
8	716.7655(5%)	716.7655(5%)	
9	Accept	654.8349(0.1594%)	
10		680.9272(5%)	
Agreement Reached?	Yes	No	Yes
Agreed price	716.7655		754.49

7. Summary and Conclusions

In this paper, we have attempted to model multi-attribute negotiation in the e-commerce environment. We showed how a bilateral negotiation could be implemented by co-ordinating a number of agents and a facilitator agent. The agents use a multi-attribute based fuzzy utility for the evaluation of the optimal offers. The system provides facilities for its user to express preferences in fuzzy terms instead of exact range value. This is very useful as it is difficult for people to define their preferences with exact values. Linguistic terms such as low, medium or high are easier for human to understand and express.

We have implemented a fuzzy evaluation system which is capable of determining which of all available offers has closest attributes to preferences defined by the user. The fuzzy inference module takes the current offer, utility score and negotiation remaining time as an input and generates a counter offer. The experimental results show that the proposed intelligent agent raises its counter offer slightly at the beginning of the negotiation and raises more when negotiation is ending. However, by how much an agent raises its counter offer depends on the utility score of the item being negotiated and the current seller's offer. An agent concedes more for an item that has higher utility score (i.e. matches client's preferences better) and concedes less for an item with lower utility score. This model performs better compared to fixed concession rate in the perspective of the buyer, i.e. the buyer pays less for the same item.

The System has met the functionalities expected and has been tested for the domain of buying a laptop computer for given user preferences. The concepts and models utilised in this paper are very promising for the future e-commerce applications.

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