COGNITIVE MODELING OF INTERACTIONS DURING A NEGOTIATION PROCESS

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Abstract: This article presents a study on human negotiations in order to improve the BDIGGY model of agent with negotiation skills. This study is based on logs of real negotiation rounds, obtained through a psychological experiment. We propose an utterance model including performatives applied to mental states and a dialog model using timed automata, both based on the BDI concepts.

1 INTRODUCTION

Negotiation is required in various situations: by phone in a trading room, in an interview with one's manager to discuss a raise. In the context of e-business, negotiation can be required between humans and/or artificial agents. Be it in a commercial, social or political setting, it is above all a human process. In the animal kingdom, the balance of power removes all possible negotiations.

In order to enable negotiation between artificial agents and humans, it is necessary to first study the processes set up between humans. Therefore, we aim here at modeling human negotiation between a seller and a buyer. The originality of this work stems from the fact that it is based on a psychological experiment where subjects are involved in a negotiation task. We are interested in the formalization of the messages sent and their dynamics, without taking into account the decision making of the subjects in itself.

To extend the model of agent called BDIGGY (Pauchet *et al.,* 2007) by adding negotiation skills, we derive negotiation protocols for software agents from the observation of human negotiation during the experiment. Section 2 describes related work on negotiation and Section 3 presents the BDIGGY system. The psychological experiment is explained in Section 4 and the analysis of the logs is given in Section 5. Section 6 proposes a model of interaction for negotiation. In Section 7, conclusion and perspectives close this paper.

2 NEGOTIATION IN MAS

Negotiation is addressed here in the point view of multi-agent systems (MAS).

2.1 Notion of Negotiation

(Rahwan *et al.*, 2007) propose the following definition of negotiation: "a form of interaction in which a group of agents, with conflicting interests and a desire to cooperate, try to reach a mutually acceptable agreement on the division of scarce resources". However, negotiation does not concern only resource sharing. We can also negotiate interpretations, responsibilities, …

(Chang and Woo, 1994) emphasize the competition aspect of negotiation. Negotiation begins with the observation of a disagreement caused by dissimilarities of preferences. This definition is restrictive because negotiation can fail to reach a compromise.

Considering that these definitions are not satisfactory enough, we propose the following formulation: "the negotiation is the process to find an agreement between several players having different preferences that may change with time".

2.2 Models of Negotiation

The literature on models of negotiation between software agents or humans is extensive.

Some researchers are interested in modeling preferences and in the mechanisms of negotiation

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(Bellosta *et al.*, 2004). Others develop applications in e-business (Chavez and Maes, 1996) and solve resource allocation problems with utility functions. Negotiation by argumentation is treated in (Kraus *et al.*, 1998) and (Schroeder, 1999). (Bartolini *et al.*, 2002) and (Matthieu and Verrons, 2004) develop generic systems by implementing different types of negotiation.

2.3 Negotiation Protocols

The first example of protocol is Contract Net (Smith, 1980), which makes a manager and contractors interact through contract exchanges. Contractors are responsible for the task execution and for the result transmission, whereas the manager is responsible for the task managing and for the result treatment.

The Sian protocol (Sian, 1991) allows a MAS to interpret objects of the environment. The perception is distributed and the agents negotiate in order to choose a common interpretation of the environment. The agents interact *via* a blackboard. The discussion always finishes with an agreement consisting in accepting or withdrawing a hypothesis on the blackboard.

The SANP protocol (Chang and Woo, 1992) models a negotiation between two agents. The speaker tries to make his proposition accepted by the interlocutor. The protocol comprises several stages: the beginning, the bid formulation and the receipt of the answer (acceptance or refusal), the attack, the tactic, the problem solving and the result. According to the reasoning of the agent, a set of strategies and automata corresponds to each phase. To evaluate their model, Chang and Woo asked subjects to use their system to solve conflicts. Their method is very different from ours because they get human involved once the model is built. In our approach, we obtain behaviors of negotiation by experiment and the model is built according to what we observed.

3 THE BDIGGY SYSTEM

The BDIGGY system (Pauchet *et al.*, 2007) was built to understand and simulate how human elaborate plans in situations where knowledge is incomplete and how they interact to obtain missing information. It implements a human planning model and a human interaction model through the BDI concept. We detail here only the interaction model.

3.1 The Dialog Model

To consider sequentiality and temporality of the sent messages, exchanges are represented through timed automata. Managing time is useful when subjects tend to delay their answer to a question. This can lead to sending re-queries and the exchange can be considered closed by the protagonists without an explicit ending message.

Eight (4x2) automata have been built: one for each interlocutor and one for each type of exchange (information query, information proposal, spontaneous sending, error processing).

3.2 The Utterance Model

To refer to the speech act theory, the observed speech acts (performatives) are either descriptives, directives or commissives. A performative is applied to a mental state (a belief or a desire) and is linked to the content of the message:

- A descriptive is applied to a belief. It describes how the sender perceives the world.
- A directive is applied to a desire of the sender. The sender wants to receive information and he sends this desire to the subject who has the information.
- A commissive is applied to a desire of the receiver. The sender supposes that the receiver has a certain desire.

The semantics of each performative is given by a generic reduction rule describing formally the pre-conditions of the sending and the reception of a message and the actions to be done. It is linked with the timed automata and the mental states of the modeled agent.

3.3 The BDIGGY Architecture

BDIGGY is based on the BDI concept and includes:

- a perception module, which analyzes the environment and generates beliefs,
- a human planning module, which builds abstract plans in an opportunistic way,
- a plan interpreter, which works as the BDI interpreter,
- and a communication module, which implements the human interaction models (the utterance model, the dialog model, the semantics of the performatives).

4 THE EXPERIMENTAL FRAMEWORK

This section describes the experiment we have set up to observe human behaviors and record logs during interactions of negotiation.

4.1 The Problem

The problem we chose is the game « Négoces » (http://www.negoces.fr), in which the players are compelled to negotiate to reach their goals.

At the beginning of the game, each player receives fifteen gold coins (that all players can see) and eight "merchandise" cards (that the other players cannot see) comprising two series of four identical cards (corresponding to exclusive control on two merchandises). To win, a player has to obtain eight different cards, keeping at least ten gold coins. Time is not limited. There are several auctions during one game.

The first round enables to select the initial seller. The card "Diamond" is sold by auction but there is no negotiation. All the subsequent auctions are done by negotiation. The player who has nine cards is the seller. He chooses one of his cards and proposes it for auction. The buyers negotiate with the seller the acquisition of the card, in any order. They can propose one card, gold coins, or one card plus gold coins. One offer can increase, decrease or be removed until the auction of the card. The buyers cannot exchange cards each other. The seller will eventually have to accept an offer, even if he is not satisfied.

The *discussion* is limited to the current auction until the *transaction* is done (exchange of cards and coins). One *game* comprises several auctions (at least five) until one player has won.

4.2 The Experiment

In order to observe the behaviors of the players, we developed a system allowing to play this game over the network. The subjects are isolated in different rooms and they interact through the user-interface. It contains a communication panel, allowing the players to chat, and an action panel, to perform actions related to one auction. The possible actions are different according to the player (seller or buyer): the seller can sell a card and accept an offer, whereas the buyers can propose an offer or leave. All actions and all interactions during the game have been recorded in a text file called log.

We chose to imply four players. This number is sufficiently high to expect complex negotiation behaviors like a coalition and sufficiently low to carry out the experiment. Fourteen groups of four players (secretary, PhD students, researchers and teachers) participated to our experiment. We had to remove one of these groups because the subjects had difficulties to understand the rules of the game. Thus, we obtained thirteen usable logs.

A fragment of log is presented below:

```
[15:28:10] 127, ACCEPT_SELL (Jack, COINS -, CARD
honey, Averell, COINS -, CARD coffee)
[15:28:33] 128, William SAY I have to be careful!
[15:28:41] 129, Jack SAY Who does want a card
cigar or a card spice?
[15:28:58] 130, Averell SAY I propose 2 coins
[15:29:16] 132, Jack SAY Averell, I am ok
[15:29:27] 133, Jack AUCTION cigar
[15:29:29] 134, William SAY I propose 3 coins for
cigar
[15:29:34] 135, William PROPOSES (Jack, COINS -,
CARD cigar, William, COINS 3, CARD -)
[15:29:35] 136, Averell TAKE_OUT
[15:29:36] 137, Jack SAY Ok William
[15:29:37] 138, ACCEPT_SELL (Jack, COINS -, CARD
cigar, William, COINS 3, CARD -)
```

This log corresponds to only one auction. Players are named Averell, William, Joe and Jack to preserve anonymity. The lines with the word "SAY" correspond to interactions in the chat panel and others correspond to actions.

5 ANALYSIS OF LOGS

This section presents our analysis of the thirteen logs.

Although the situation implies four players, negotiations are always established between the seller and one buyer. The buyers rarely talk to each other. But when they do, they use humor or they comment on what the others do and we decided not to model these interactions.

One auction can be broken down into exchanges according to the discursive goal of a player. These exchanges are classified into the following types:

- Auction (from the seller),
- Information query,
- Reminder,
- Discussion (to achieve an agreement),
- Spontaneous sending of information,
- Warning.

All these types of exchanges are not used during each auction but there is at least one *auction* and one *discussion*. The discussion can begin in different ways: the buyer proposes an offer to the seller or the seller asks for an offer from the buyer.

In the second case, the seller actually wants to negotiate with the buyer. This is more than a reminder: the seller initiates the negotiation.

The negotiation process does not always begin with the auction of one card. That is why the auction is differentiated from the discussion between the protagonists. In six groups, more than 50% of the sells begin with an action different from `auction`. The auction begins with a discussion about the card to be sold. The players send information queries, offers and reminders.

The discussion between the seller and a buyer ends either when the buyer leaves, or when the seller accepts or refuses the offer.

During the information queries, many questions remain unanswered. It seems that the players are intensely focused on the game and that the speed of offers and interactions is too high. In some cases, the players do not want to answer (for example, to conceal their owned cards).

As for the reminders, they can arise from the seller or a buyer.

We also observed menaces, coalitions, promises and conditional offers. But these interactions were not numerous enough to be taken into account in our study.

Table 1: List of observed performatives.

Performative	Description
Auction	The seller sells one card Joe SAY I sell tea
takeOut	One buyer leaves Jack SAY I leave
inform	A player sends information spontaneously Jack SAY I am interested in spices
query / reply	With a *query*, a player asks information to an other player who answers with a *reply* Joe SAY who can offer to me a card honey against a card cigar? Jack SAY I do.
bid	A buyer makes an offer William SAY I offer 5 coins and tee
acceptBid	The seller accepts an offer with *acceptBid*. Then, he informs the others with *sold* Jack SAY 4 coins, ok !
refuseBid	A player refuses an offer Jack SAY 1 coin is not enough
request	The seller asks the buyers to make new offers, or to modify an offer Jack SAY push up Joe
relaunch	A player reminds other players Averell SAY, Go on Jack!
warning	A player warns other players about an offer Averell SAY If you sell to Joe, he will win!

All the logs were manually analyzed. The list of the speech acts observed in the logs is given in Table 1. Three of them (*inform*, *query* and *reply*) are already used in the BDIGGY model.

Table 2 presents the observed types of exchanges. Each of these exchanges is guided by the dialogical goal of the speaker, according to the first performative he sent.

Table 2: List of observed types of exchange.

Types of exchange	Dialog goal	First performative	Closing performative
information query	directive	query	reply / -
discussion	commissive of the buyer	bid	acceptBid / leave
	directive of the seller	request	acceptBid / leave
spontaneous sending	descriptive	inform	inform
reminder	directive	relaunch	relaunch
warning	descriptive	warning	warning

Each exchange has been annotated in the logs by its first performative and its type.

None of the models mentioned in Section 2 enable to represent entirely these observed exchanges. For example, they do not allow sequences such as refuse/accept or modify/accept: the seller can accept an offer he has previously refused or an offer he asked for modification without success. Decisions made by the players can evolve during the negotiation process according to the interactions and time that goes by.

The speech act list should not constrain the interactions between the protagonists.

Moreover, according to us, a contract is the result of a negotiation and its modalities are discussed. However, in the Contract Net protocol, the manager proposes the contract and the contractors cannot ask for modification of it. We think that the contractors should have the possibility to modify the current contract and they do not have to create a new one.

Among our needs, the following possibilities are not offered by other models:

- give an answer between agreement and refusal,
- propose modifications for all protagonists ,
- express the reason of a refusal,
- decide not to enter the negotiation…

It is more the question of negotiating the content of a contract than the question of signing an existing contract.

6 THE INTERACTION MODEL

This section describes our interaction model: the dialog model and the utterance model.

6.1 The Dialog Model

As mentioned in Section 5, the players can decide not to answer a question, or refuse to negotiate or leave the negotiation. We have to model these behaviors to make software agents as human-like as possible. BDIGGY already models a lack of response through a timed automaton. This model has to be extended in order to take into account the negotiation processes observed in the logs.

The negotiations are established between a buyer and the seller. Thus, the automata can be opened between two players. Our model includes ten automata (5x2): one for the speaker and one for the interlocutor of each type of exchange.

The set of timed automata used is: Q_{ini}, Q_{int}, I_{ini}, I_{int}, D_{ini}, D_{int}, W_{ini}, W_{int}, R_{ini}, R_{int}, A_{ini}, A_{int}, where {Q, I, D, W, R, A} is the type of exchange (Q: information query, I: spontaneous sending, D: discussion, W: warning, R: reminder, A: auction) and {ini, int} describes the protagonists of the exchange (*ini* for the speaker and *int* for the interlocutor).

6.1.1 Automata Coming from BDIGGY

Two automata present in the BDIGGY model are reused for the negotiation: the information query automaton and the spontaneous sending automaton. Only the former is described here (Figure 1): it is only partly reused.

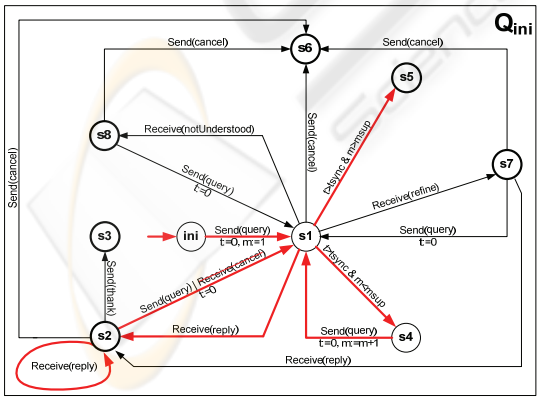

Figure 1: Information query automaton (speaker).

The transitions observed in the protocols of our application are colored in red.

6.1.2 Discussion Automata

As already said, the negotiation discussion begins either when the buyer makes an offer or when the seller asks for an offer from the buyer. Thus, the discussion exchanges were broken down into two types (*Buyer* or *Seller*) and in fact into four automata: D_{ini}Buyer, D_{int}Seller, D_{ini}Seller and D_{int}Buyer. Figure 2 shows the D_{ini}Buyer automaton used when the buyer initiates the discussion (*bid*). The seller opens the symmetric automaton D_{int}Seller.

The similar automaton D_{ini}Seller corresponds to the fact that the seller asks for an offer from the buyer. It differs only from the first performative sent (*request*). As for the buyer, he opens the D_{int}Buyer automaton.

6.2 Utterance Model

In our application, negotiations are applied to the auction of one card. It consists on specifying the seller, the buyer, the card and the number of coins exchanged. `pTrans` is a predicate that represents an auction:

```
pTrans(a1, c1, tc1, a2, c2, tc2)
```

where `a1` is the seller, `c1` the number of coins given by `a1`, `tc1` is the card that `a1` sells, `a2` is the buyer, `c2` is the number of coins given by `a2`, `tc2` is the card given by `a2`.

A message exchanged by the agents is represented by the predicate `pMessage(`A_s A_r `P O)`

where A_s is the sender, A_r is the receiver, `P` is the performative used, `O` is the object on which the performative is applied.

As for BDIGGY, each utterance is represented by a performative applied to a mental state. For example, all the directives are applied to a desire of the speaker, their general form is:

`pMessage(`A_s A_r `P pD(As,E))`

where `pD` is a desire of the agent A_s that is applied to the predicate `E` (`pTrans`).

Semantics of each performative are given by two general reduction rules (one for the sending and one for the receiving), with the pre-conditions of the sending (respectively receiving), the states of the automata from which the performative can be sent (respectively received), the new current state in the opened automaton and the updates to be done in the memory of the agent.

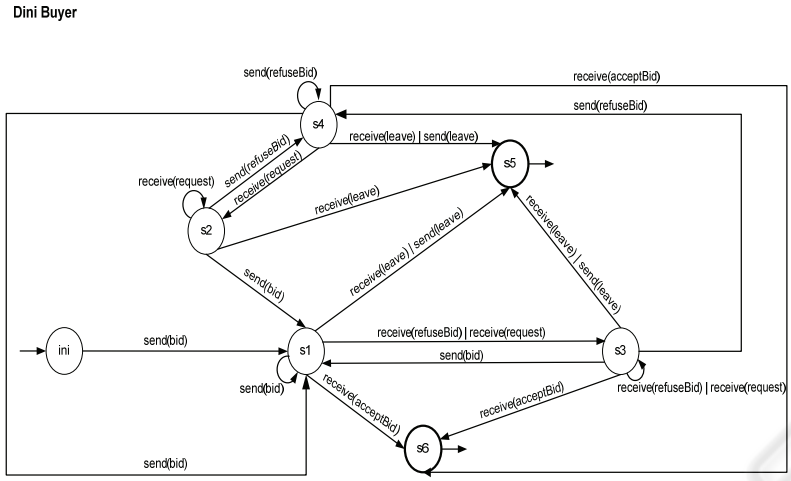

Figure 2: Discussion automaton of the buyer.

7 CONCLUSIONS AND PERSPECTIVES

The interaction model for the negotiation proposed in this article is based on the analysis of experimental logs. It aims at simulating as faithfully as possible the human processes of negotiation.

New performatives have been proposed, linked with timed automata to model the utterance level and the dialog level of interactions. This model is adaptable and enables the players to change their mind according to the situation and time. It also enables to modify the offers at any time.

However, the reasoning model is not built yet. We are currently analyzing the experimental protocols from a reasoning point of view.

The BDIGGY model is also generic enough to be re-usable for this new application (negotiation between a seller and several buyers).

When the reasoning model will be included in BDIGGY, the validation of the system will be done by comparing the set of artificial logs and the set of human logs (for example, with the use of a Turing-like test and with the use of hypothesis testing).

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