THE LOGIC BEHIND NEGOTIATION:

FROM PRE-ARGUMENT REASONING TO ARGUMENT-BASED NEGOTIATION

Luís Brito Paulo Novais José Neves
lbrito@di.uminho.pt pjon@di.uminho.pt jneves@di.uminho.pt
Universidade do Minho
Departamento de Informática
Campus de Gualtar
4710-057 Braga, Portugal
Voice: +351 253 604466/70 Fax: +351 253 604471

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ASTRACT

The use of agents in *Electronic Commerce* environments leads to the necessity to introduce some formal analysis and definitions. A 4-step method is introduced for developing EC-directed agents, which are able to take into account non-linearites such as *gratitude* and *agreement*. Negotiations that take into account a multi-step exchange of arguments provide extra information, at each step, for the intervening agents, enabling them to react accordingly. This *argument-based negotiation* among agents has much to gain from the use of *Extended Logic Programming* mechanisms. Incomplete information is common in EC scenarios; therefore arguments must also take into account the presence of statements with an *unknown* valuation.

INTRODUCTION

The amount of ambiguity present in real-life negotiations is intolerable for automatic reasoning systems. Concepts present in each intervening party of a real-life negotiation need to be objectively formalized in order for an automatic approach to be reached. Logic, and especially, Extend Logic Programming (ELP) (Baral and Gelfond, 1994) poses itself as a powerful tool to achieve both the desired formality without compromising comprehension/readability, and the ability to easily build an executable prototype for agents. Logical formulas are extremely powerful, unambiguous and possess a set of interesting advantages (McCarthy, 1959):

> *Expressing information in declarative sentences is far more modular than expressing it in segments of computer programs or in tables. Sentences can be true in a much wider context than specific programs can be used. The supplier of a fact does not have to understand much about how the receiver functions or how or whether the receiver will use it. The same fact can be used for many purposes, because the logical consequences of collections of facts can be available.*

However, in a dynamic environment such as the one found in Electronic Commerce (EC), the simple use of logical formulas is not enough. The use of non-monotonic characteristics is self-evident (which is in someway found in ELP) (Neves, 1984).

In general logic programs, negative information is provided by the *closed-world assumption* (i.e., everything that can not be proven to be *true* is *false*), however, in extended logic programs, that is not so. In ELP a query may fail due to the fact that *information is not available to support it* or, on the other hand, it may fail due to the fact that *negation* succeeds. The Knowledge Base (KB), which serves as the basis for the agent's reasoning, can be seen has an extended logic program (Π) which is a collection of rules with the form:

$L_0 \leftarrow L_1, \ldots, L_m, not\ L_{m+1}, \ldots, not\ L_n$

where L_i $(0 \leq i \leq n)$ is a *literal* (i.e., formulas of the form p or $\neg p$, where p is an atom). This general form is reduced to $L_0 \leftarrow$ (also represented as L_0) in the case of facts.

The strategy to get a consistent and sound approach for the use of agents in EC is based on (Novais et al, 2001) and is composed of a 4-step development methodology:

- **Architecture definition**: define and specify the agent's modules or functionalities, design the flow of information (e.g., *Experience-Based Mediator* (EBM) agent (Novais et al, 2000), mobile agents for virtual enterprises (Brito et al, 2000b));
- **Process quantification**: quantify each metric and/or sub-process which the agents may have to deal with. Establish the mechanisms and protocols for an efficient approach to a wide range of problems (Brito and Neves, 2000), (Brito et al, 2000a);
- **Reasoning mechanism**: each agent needs a formal (logical) set of rules that will serve as the main guidelines for the negotiation processes. The agents needs to reason about the surrounding world before it acts through argumentation (Brito et al, 2001a); and

- **Process formalization**: the process of (logical) argumentation needs to proceed via a formal specification to a consistent implementation in order to set the agents to act/react in a reasonable (logical) way. Arguing during an EC negotiation has many similarities to legal arguing (Prakken, 1993), (Sartor, 1994) and logic presents itself, once again, as a powerful specification and implementation tool.

This methodology stands as a particular case of the use of formal methods in Agent-Oriented Software Engineering (AOSE) (Wooldrige and Ciancarini, 2001).

This chapter is disposed accordingly to the proposed 4-step approach to the development of agent for EC. On section *Architecture Development,* some architectures for EC are briefly presented. On section *Process Quantification*, some examples of objective process quantifications are exposed. On the *Reasoning Formalization* section, the basic buildings blocks of the negotiation process (tools for pre-argument) such as theorem solvers, restrictions and null values are introduced, aiming at a proper formalization and the process of reasoning with incomplete information is extended to include temporality and priorities, giving way to the formalization of concepts such as delegation, gratitude and agreement. On section *Process Formalization*, the process of argumentation is formalized. Finally, on section *Conclusions*, some conclusions are drawn and future work is proposed.

The main contributions of this work are: (i) the definition of a common ground to situate the agent's reasoning mechanisms in EC environments; (ii) the use of formal tools (logic) to describe the rational behaviour of agents involved in EC; (iii) the description of a reasoning mechanism necessary for a consistent and sound development of agents for EC; (iv) the use of incomplete information in the reasoning process; (v) the bridging of legal argumentation and argument-based negotiation; and (vi) the establishment of sound syntactic and semantic tools for argument-based negotiation.

ARCHITECTURE DEVELOPMENT

The development of agent architectures for EC needs to take into account the particular reasoning characteristics to be addressed. The EBM agent (Novais et al, 2000) provides a logic-based framework (with a well-defined set of modules) for pre-argument reasoning and argument generation. However, this architecture is, in no way, the final solution. Agents oriented to price manipulation (and other econometric approaches) represent an interesting solution (although with limited reasoning capabilities).

The EBM (Experience-Based Mediator) Agent

The EBM agent is a general module-oriented architecture aiming at the development of intelligent agents for EC. Taking previous experiences as a starting point, the agent's knowledge is complemented by *general and introspective knowledge*, the former comprises information about the system itself and/or the prices and rules practiced by counterpart agents, the last embraces psychological values such as beliefs, desires, intentions and obligations. Dynamic and static knowledge are therefore embedded at this level.

An agent must be able to reason about general or even incomplete information, on the one hand, and it must also be able to explain its own behaviour or acquire new knowledge, on the other hand. But, in the present context, these procedures are not enough. The ability to deal with the market's specificities is paramount (e.g., the ability to form prices, to evaluate a good or service or to cartelise (Brito and Neves, 2000), (Brito et al, 2000a)).

Other Approaches

This is a functional approach to agent architecture in EC. Agents in EC were primarily seen as information gatherers (price gatherers) and price-adapters (through mathematical or functional techniques). The use of agents in EC scenarios has also been approached through theories of economic implication; i.e., economic models and theories condition the behaviour of an agent. As the transition towards the information economy is taking place, in (Kephart et al, 2000) proposed two kinds of agents to enable this same transition: the *pricebots* and the *shopbots*. *Shopbots* (also called *comparison shopping agents*) are the answer to intelligent price comparison of on-line providers. *Pricebots*, on the other hand, are the provider's counterpart to *shopbots*; i.e., they manipulate prices taking into account the market conditions. These two kinds of agents are a step towards the so-called "frictionless" commerce

PROCESS QUANTIFICATION

Through the *mass media* EC has been, to the eyes of the public, indisputably reduced to a Business-to-Consumer (B2C) perspective; furthermore, this short-sighted vision was reduced even more to the publicized and catalogue sales (Guttman et al, 1998).

In spite of this, the Business-to-Business (B2B) perspective is also endorsed by EC, although the lack of well-established standards and reluctance on the managerial side has hindered its success. EC can be seen under two perspectives: the Virtual Marketplaces (VMs) and the Virtual Organizations (VOs) one. VMs fall into the popular view of the subject; i.e., buying or selling in auction or non-concurrent dealings. VOs are traditionally seen as the network of commercial interests established among different businesses, in order to provide some sort of good or service. The VOs view can be extended beyond the common definition and asserts that a network of interests can be established within an organization; i.e., functional units or work areas can be found in enterprises, giving way to a network of internal interests driven by the ultimate goal of providing, with maximum quality and minimum costs and delivery time, the contracted goods or services.

The simple VM that spawns from a company that tries to sell its products on the Internet may be seen as an atomic element of a wider VO. This recursive construction is made possible by the fact that agents, being similar to their real-world counterparts, should play a mediator role; i.e., an agent is either a buyer or a seller, depending upon the pending circumstances.

The definition of a business strategy is of paramount importance for the future success of any company. Planning must rely on a series of tools that enable the elaboration of a short, medium or long-term strategy. On the real world, the main tools are *mediation*, *agreement* and *gratitude*. *Mediation* enables a company to play a dual part on the market; i.e., the experiences gathered as *buyer* may be used to extrapolate future actions as *seller* and vice-versa. *Agreement* enables a feeling of trust in an agent, either on truthful or untruthful voting scenarios (Brito and Neves, 2000). *Gratitude* is important for the creation of inter-organizational dependencies (debts) that condition future deals (Brito et al, 2000a). Typical approaches to EC are based on the assumption of one-to-one negotiation without any spurious influences on third party entities; i.e., negotiations are conducted in a one-provider to one-customer way, such that there is an absence of dialogue among providers and, therefore, all negotiations are statistically independent.

Gratitude

One can establish *gratitude* as a tacit obligation that influences the decision-making process (Brito et al, 2000a) (e.g., in the real-world, an agent may be forced to pull out from a negotiation if so requested by someone to whom it owes some *value*).

Gratitude may arise from one of two main situations: a gift of some sort is given to someone (e.g., a Christmas present) – *non-negotiable gratitude* – or, during the process to set up a settlement or agreement, an agent offers some form of compensation for the pull out of a competitor (e.g., monetary compensation for an unsure transaction) – *negotiable gratitude* (Brito et al, 2000a). The significance of this concept on VOs spawns from the fact that agents are now able to influence future decisions on the part of the other companies' counterparts; i.e., the debt of gratitude is influenced by personal standards and does not configure itself as a universal value. Gratitude may be measured marginally in the form:

$$g_m(x, y, NI)\begin{cases} value_{offer} - W_{strategy}(NI, y), NI.grt = non-negotiable \\ (1-\alpha)F_{gains}(NI), NI.grt = negotiable \\ 0, otherwise \end{cases}$$

where $g_m(x,y,NI)$, $W_{strategy}(NI,y)$, $value_{offer}$, α and $F_{gains}(NI)$ stand, respectively, for the marginal gratitude of agent *x* towards agent *y*, taking into account the negotiable information *NI*; the function that weights the influence of *NI* and agent y in the strategy of agent x; the value attributed by x to the offer that develops a gratitude debt; the percentage of the gains to offer to y as compensation for a drop-out; and the forecast of the gains taking into account *NI*. *NI* is a composite structure that includes fields such as the kind of gratitude (*grt*).

The overall agent's debt towards the community is given by:

$$G(x) = \sum_{i \in Agents \setminus \{x\}} g_m(x, i, \cdot)$$

where *G(x)* and *Agents* stand, respectively, for the aggregate gratitude debt of agent *x*, and the set of agents that represent the community. This aggregate value must be thoroughly controlled, so that an agent *x* does not enter a situation where the debt of gratitude is greater than the gains expected to be obtained in future dealings.

Agreement

Inside an organization, one may see the need for agreement, but when using *collaborative* agents, one is faced with a *truthful environment* (Brito and Neves, 2000). In these environments one is able to formalize agreements in order to provide an integrated picture of the system to the outside world. This image can be achieved by gathering all the agents' opinions on a particular subject and the use of a majority vote. The agreement strategy can, therefore, be rewritten in order to weight each agent's specificity. This may be expressed as:

$$agreement_w(value) = majority[w_1 opinion_1(value), w_2 opinion_2(value), \ldots, w_n opinion_n(value)], \quad value \in \rho. \quad \text{with } 0 \leq w_i \leq 1, \ \forall i \in Agents$$

where w_i and *Agents* stand, respectively, for the weight of agent *i* in the making of value, and the community of agents. w_i, on the other hand, may be a function of time, which can be expressed as $w_i(t)=\beta\, w_i(t-1)+(1-\beta) compliance(v_{p,i}(t),v_{r,i}(t))$ with $0 \leq \beta \leq 1$ where β, $v_{p,i}(t)$, $v_{r,i}(t)$ and $compliance(x,y)$ stand, respectively, for the weight of the historic information in the making of $w_i(t)$; the judgement of agent *i* at time *t* on the value; the value attained by agent *i* at time *t*; and a measure of the reciprocity or relation between $v_{p,i}(t)$ and $v_{r,i}(t)$.

The higher the value of β the higher the significance of historic values and smaller the influence of sporadic non-compliances. However, on an open market, one can not assume that the agents are always *truthful*; i.e., telling or expressing the truth.

For someone to reach an agreement in *untruthful* environments a round-based protocol is needed, in order to isolate the pernicious influences of untruthful voting. These protocols often rely on the existence of a minimum number of intervening factors. Typically, one must have $n \geq 3m+1$, where *n* is the number of truthful agents and *m* is the number of untruthful ones (Brito and Neves, 2000).

This natural capability to generate agreements using round-based protocols in real-world environments makes a case to *strategic planning* in inter-business relationships. One is able to form alliances among companies to forge better prices to specific products. On the other hand it makes possible the gathering of information of vital importance for the definition of market strategies, determining the limits of the common ground on which the different enterprises stand.

Strategic Planning

Every organization, in order to evolve in a sustained and sound way, must define strategic guidelines that will enable competitiveness and the definition of management goals. The concept of strategy is important in areas that range from the military to commercial organizations, either virtual or real; i.e., the necessity for a feasible and clear planning is vital in every point of the production/consumption chain. On the other hand, the companies that position themselves closer to the consumer, suffer from the impact of production defects and delivery delays, while being, at the same time, pressured by the consumers. Typical EC systems are unaware of these shortcomings; i.e., they function on a per-deal basis, which may render interesting profits on a deal but, in the long-term, may decrease the negotiable company rates. One may now formalize the difference between overall profit (spawning from strategy driven systems) and local profitability, in the form:

$$\mathrm{Pr}\,ofit(Agents) \neq \sum_{i \in Agents} \sum_{j \in Deals} profit(i, j)$$

where *Profit(Agents)* and *profit(i,j)* stand, respectively, for the overall profit obtained by the set of agents *Agents*, and the marginal profit acquired in a per-business strategy executed by agent *i* for deal *j*.

In order to define a sound strategy one must be able to gather the counterparts will and guarantee their standing on particular issues; i.e., agreement plays an important role in market placement. On the other hand one must be aware that the market evolves either within *truthful environments* (where there is agreement among the parties that make an organization) or within *untruthful* ones (this is the case where typical real-world, self-interested entities may utter conflicting opinions).

The definition of *strategic lines* must take into account punctual alliances rising from gratitude debts, which may be used in order to secure the expected behaviour from counterparts.

REASONING FORMALIZATION

Some of the most important features of pre-argument reasoning are *temporality*, *priorities*, *delegation*, *gratitude* and *agreement* (already quantified in the previous section). An agent weights its knowledge base, its temporal validity and relative priorities, and then decides if delegation is in order. As for *gratitude* and *agreement*, reasoning takes into account the quantification provided at the previous stage of the present methodology.

The general process of negotiation must be clearly distinguished from the argumentation stage (Brito et al, 2001b). The process of argumentation is tightly coupled with the process of logically founded attack on the arguments put forward by a counterpart. It deals with price-formation issues and deal finalization. On the other hand, negotiation is a wider concept that is coupled with specific forms of reasoning, dealing with the high-order, pre-arguing relationships that may be established among agents.

Right to Deal

During a negotiation process, each agent, although being able to deal with a counterpart, it may be inhibit to do so. Therefore, a distinction must be established between *capability* (i.e., an agent has the necessary expertise to do something) and *right* (i.e., an agent has the capability to do something and it can proceed that course of action) (Norman et el, 1998).

In the case of an EBM agent, it is assumed that it has the ability to deal with every product, under any scenario. However, any EBM agent has its behaviour conditioned by the *right-to-deal* premise. Consider predicates *capability-to-deal: Product, Conditions, Counterpart* → *{true,* *false}* (representing the capability to deal), and *right-to-deal: Product, Conditions, Counterpart* $\rightarrow$ *{true, false}* (representing the right to deal), where *Product, Conditions* and *Counterpart* stand, respectively, for the product to be traded, the conditions associated to that operation and, the counter-part agent involved in the deal. It may now be stated that:

$\models \forall_{\text{Product}} \forall_{\text{Conditions}} \forall_{\text{Counterpart}}$ *capability-to-deal (Product, Conditions, Counterpart)*

i.e., the capability to deal is a tautology within EBM agents. Therefore, the presence of such knowledge in the KB of an agent can be taken as implicit. Therefore, the knowledge about the right to deal (*right-to- deal: Product, Conditions, Counterpart* $\rightarrow$ *{true, false}*) rises in importance.

A logical theory (on which the KB of each agent is based upon) is now possible to define:

Definition 1 (A Logical Theory for Negotiation Agents)

A logical Theory for Negotiation Agents is defined as the quadruplet TNA= $\langle R, C, BP, \prec \rangle$ *where R, C, BP and* $\prec$ *stand, respectively, for the set of predicates on the right to deal (right-to-deal: Product, Conditions, Counterpart* $\rightarrow$ *{true, false}), the set of invariants (A:+restriction::P), the set of behavioural predicates (including the theorem proffers) and a non-circular order relation that states that if P* $\prec$ *Q, then P occurs prior Q; i.e., having precedence over Q.*

Using Incomplete Information

Typically, commerce-oriented agents (such as the EBM one) act in situations where dealing with a given agent is forbidden or, in some way, the set of conditions to be followed in a deal are not completely defined. These situations involve the use of *null values* (Analide and Neves, 2000). A special theorem solver can be developed in order to cope with this kind of information. With the use of incomplete information with *null values*, a simple 3-valued logic is set into place. Using this framework, it is now possible to assert the conditions under which a given product or service may be traded.

The use of a *null value from an unknown set of values* (Baral and Gelfond, 1994) can state the ability to deal some product with some counterpart knowing only that the set of conditions that governs such deal belongs to an unknown set of values. For this case, the KB of an agent must contain clauses such as the following:

$$
\begin{array}{ll}
exception_{rtd}(P,\ -,\ CP) \leftarrow & null_{unknown\text{-}set}(X), \\
 & right\text{-}to\text{-}deal(\ P,\ X,\ CP). \\
\neg\, right\text{-}to\text{-}deal\ (P,\ C,\ CP) \leftarrow & not\ right\text{-}to\text{-}deal(\ P,\ C,\ CP), \\
 & not\ exception_{rtd}(P\ ,C,\ CP).
\end{array}
$$

The KB of an agent must contain an instantiation of $null_{unknown\text{-}set}$ (e.g., $null_{unknown\text{-}set}$ (*cond*)) and *right-to-deal()* clauses which may use the null value (e.g., *right-to-deal(p4,cond,cp2)*).

Temporality

The concept of temporality is connected to the temporal validity of possible inferences over the KB of an agent; i.e., a fact may be valid only on a well-defined time period. Taking a non-destructive KB and a non-monotonous logic, different conclusions may be reached when the temporal validity of information is taken into account (e.g. John has the right to deal with Paul but only form 10/05/2001 to 12/05/2001) (Neves, 1984).

Taking set *R* (*right-to-deal* clauses) from logical theory *TNA*, an extension is to be made in order for these elements to encompass *temporal* validity. Therefore, an agent will reason about validity taking into account the information present at the fact level. An example of validity, for a specific clause, is shown in Figure 1.

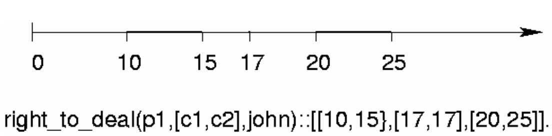

Figure 1:Example of time validity for a right-to-deal clause

Definition 2 (**Clauses with Temporality**)

A factual clause, represented as P., where P is an atomic formula, is represented, in order to encompass temporal validity, as $P::[i_1,i_2,...,i_n].$*, where* $i_j=[t_a, t_b]$ *is one of the following elements:*

1. *temporal instant*
   $t_a= t_b,\ t_a,\ t_b \geq 0$ with $t_a,\ t_b \in TD$.
   $TD = \{t|t \in N_o\} \cup \{forever\}$, where *forever* represents the *end of times*.
2. *temporal interval*
   $t_a< t_b,\ t_a \geq 0$ with $t_a,\ t_b \in TD$.
   $TD= \{t|t \in N_o\} \cup \{forever\}$, where *forever* represents the *end of times*.

In the case where positive and negative information is present in the KB, set *R* of theory *TNA* should be consistent; i.e., the following condition should be verified:

$$\exists P :: T_1 \wedge \exists P :: T_2 \rightarrow T_1 \cap T_2 = \emptyset$$

Priorities

In logic programming languages, such as Prolog, some priority is established through the ordering of clauses. However, this kind of priority is too weak, giving way to the definition of new priority rules with well-specified semantics.

The necessity to establish priorities, within the set of clauses that compose an agent's KB, arises either from computational reasons or from the necessity of establishing new semantics. The solution, for a feasible priority treatment, lies in the embedding of priority rules in the KB of each agent (Brito et al, 2001a), (Brito et al, 2001b). Therefore, logical theory *TNA* is to be changed into a new logical theory *(TNAP)* in which the organization of factual clauses is given by the semantics of *priority rules*.

Definition 3 (**A Logical Theory for Negotiation Agents with Priorities**)

The logical Theory for Negotiation Agents with Priorities is defined as $TNAP=\langle R,C,BP,PR \prec \rangle$ *where, R, C, BP, PR and* $\prec$ *stand, respectively, for the set of predicates on the right to deal (right-to-deal:Product,Conditions,Counterpart* $\rightarrow$ *{true, false, unknown}), the set of assertion restrictions/invariants (A:+restriction::P.), the set of behavioural predicates (including all demonstrators/theorem solvers), the set of embedded priority rules and the non-circular order relation established among the different clauses in a KB that derives from the time of their insertion. Relation* $\prec$ *determines, in the case of* $P \prec Q$*,* *that P is earlier than Q, thus ordering the set of clauses, providing for a fail-safe priority mechanism under the one provided by the set PR.*

Although priorities can be established between single clauses, it is usual, at least as a first-level approach, to consider priorities among *bodies of knowledge* (e.g. information about *mary* as priority over information about *john*). These *bodies of knowledge* are nothing more than a high-level classification of factual clauses (e.g., $ag_y : bk_1 : right\text{-}to\text{-}deal(p2,[c5], cp4) :: [[0, 10]].$). Notice, however, that this classification has variable *granularity*, giving way to a per-clause priority if so needed (with the consequent increase in complexity).

The previous definitions on the use of incomplete information, temporal information and priorities culminate in the creation of a theorem solver that enables reasoning pre-argumentative reasoning.

Definition 4 (A LP Theorem Solver for Incomplete and Temporal Information with Priorities)

Taking factual clauses with temporal validity and body of knowledge classification (represented by $BK::P::[i_1,i_2,...,i_n].$*) and rule clauses (represented by* $P \leftarrow Q.$ *and being read as "P if Q") as the components of the KB present in each agent, the predicate* $demo_{LPITP}:T,CT,V \rightarrow \{true, false\}$*, where T, CT, V and {true, false} stands, respectively, for a logical theorem, the current time, the theorem valuation (true, false or unknown) and the possible valuations for the* $demo_{LPITP}$ *predicate, represents the LP theorem solver for incomplete and temporal information over the KB, governed by the following set of rules:*

$$
\begin{array}{ll}
demo_{LPITP}(P, CT, true) \leftarrow & priority(BK_1, BK_2), \\
 & test_{priority}(BK_1, BK_2, P,T), \\
 & in_{time}(CT, T). \\
demo_{LPITP}(P, CT, false) \leftarrow & priority(BK_1, BK_2), \\
 & test_{priority}(BK_1, BK_2, P,T), \\
 & \neg in_{time}(CT, T). \\
demo_{LPITP}(P, CT, false) \leftarrow & priority(BK_1, BK_2), \\
 & ntest_{priority}(BK_1, BK_2, P,T), \\
 & in_{time}(CT, T). \\
demo_{LPITP}(P, -, unknown) \leftarrow & priority(BK_1, BK_2), \\
 & not\ test_{priority}(BK_1, BK_2, P,-), \\
 & not\ \ ntest_{priority}(BK_1, BK_2, P,-). \\
test_{priority}(BK_1, -, P,T) \leftarrow & (BK_1::P::T). \\
test_{priority}(-, BK_2,, P,T) \leftarrow & (BK_2::P::T). \\
ntest_{priority}(BK_1, -, P,T) \leftarrow & \neg\, (BK_1::P::T). \\
ntest_{priority}(-, BK_2, P,T) \leftarrow & \neg\, (BK_2::P::T).
\end{array}
$$

where predicates in_{time}*: CT, LT→{true, false},* $test_{priority}$*:* BK_a*,* BK_b*, P, T→{true, false} and* $ntest_{priority}$*:* BK_a*,* BK_b*, P, T→{true, false} stand, respectively for the verification of presence of time CT in the list of validity intervals LT, the prioritised demonstration of theorem P for the bodies of knowledge* BK_a *and* BK_b *and the prioritised demonstration of theorem P through negative information for the bodies of knowledge* BK_a *and* BK_b*.*

Delegation

Delegation can be seen as the delivery (assimilation) of a valid negotiation from one agent to another. Negotiation tasks may only be delivered to a third party if there is sufficient knowledge relating to the *right to deal* with that same agent.

Delegation acts as a way to undertake indirect negotiations; i.e., use a proxy agent taking advantage of its particular characteristics, such as gratitude debts and agreements established amongst the proxy and the other agents (Brito et al, 2000a). Therefore, formalizing the delegation process is equivalent to formalizing the generation of a "middle-man" approach to business. A logical perspective is given by considering that, the act of delegating deals that involve product *P*, conditions *C* and counterpart *CP* to agent *Y* (considering time *CT*), is only possible if: the delegating agent is able to deal the product with the final counterpart (valid for the present view over delegation); the delegating agent is able to deal with the proxy agent; and the proxy agent is able to deal with the final counterpart by itself. Formally:

ag_x *: delegate(P,C,CP,Y,CT)←*
    ag_x *:* $demo_{LPITP}$*(right-to-deal(P,C,CP), CT, true),*
    ag_x *:* $demo_{LPITP}$*(right-to-deal(P,-,Y), CT, true),*
    Y: $valid_{assimilation}$*(Y: right-to-deal(P,C,CP), CT).*

Gratitude

Although gratitude quantification is possible and even desirable in order to enable computational manipulation, it is still a subjective element, and a non-linearity that has decisive influence in the outcome of many business strategies (e.g., in strategic planning) (Brito et al, 2000a). A quantified characterization of the *marginal gratitude* concept is depicted in section *Process Quantification*.

Analysing the two gratitude situations it can be seen that the first one (*non-negotiable gratitude*) occurs with gratitude value (*Value*) when, taking into account the negotiation information (*NI*), the counterpart agent (*Y*) and the reasoning time (*CT*), a specific offer (e.g. gift) from the counterpart agent takes place. Dealing with that counterpart is authorized and the “subjective” (although quantified) value of the offer is taken into account when updating the negotiation information through which a strategic evaluation (conditioning further action) is made. The next situation (*negotiable gratitude*) is viable when it is possible to deal with a specific counterpart agent, which in turn, states in its own KB that the agent is able to drop a specific negotiation (probably a competitive negotiation) in exchange for some compensation (reflected in terms of gratitude). Formally:

$$
\begin{aligned}
& ag_x{:}gratitude(Value,NI,Y,CT) \leftarrow \\
& \quad ag_x{:}offer(Y,Description), \\
& \quad ag_x{:}demo_{LPITP}(right\text{-}to\text{-}deal(\text{-},\text{-},Y),CT,true), \\
& \quad ag_x{:}evaluate_{offer}(Y,Description,CT,Value_{offer}), \\
& \quad ag_x{:}update(NI,Y,Description,Value_{offer},CT,NNI), \\
& \quad ag_x{:}evaluate_{strategy}(NNI,Y,CT,S,S_{weight}), \\
& \quad ag_x{:}gratitude_{marginal}(NNI,[Value_{offer},S_{weight}],Value), \\
& \quad Value>0.
\end{aligned}
$$

$$
\begin{aligned}
& ag_x{:}gratitude(Value,NI,Y,CT) \leftarrow \\
& \quad ag_x{:}demo_{LPITP}(right\text{-}to\text{-}deal(\text{-},\text{-},Y),CT,true), \\
& \quad Y{:}drop_{compensation}(ag_x,NI,CT,\alpha), \\
& \quad ag_x{:}forecast_{gains}(Y,NI,CT,F), \\
& \quad ag_x{:}gratitude_{marginal}(NI,[\alpha,F],Value), \\
& \quad Value>0.
\end{aligned}
$$

Agreement

Like gratitude, agreement can be seen, in many cases, as a subjective element that introduces non-linearities in the negotiation process (Brito and Neves, 2000), (Brito et al, 2000a). The simplest case of agreement is reached through the use of a majority of votes. This democratic approach relies on the existence of fully veridic agents; i.e., agents that convey their opinion in a consistent manner to their peers. This majority approach is quantified in section *Process Quantification.*

In logical terms, an agreement can only be reached among agents that are able to deal with each other; i.e., if an agent is unable to assert the right to deal with other agents, it can never establish some sort of commitment (agreement). An agreement is reached on a specific subject (*S*), among a set of entities (*E*) with a set of opinions (*O*) at a specific time (*CT*). By definition, an agent is in agreement with itself in every subject. As for the other counterparts, an agreement with them is reached if the agent is authorized to deal with every one of them, their opinions gathered and, finally, a summary is produced, i.e., it is possible to establish an agreement situation weighing the set of opinions. Formally:

ag_x*:agreement(-,[*ag_x*],-,-).*
ag_x*:agreement(S,E,O,CT)* ←
  ag_x*:can-deal-with(E,CT),*
  ag_x*:*$gather_{opinions}$*(S,E,CT,LO),*
  ag_x*:summarize(S,O,LO,CT).*

ag_x*:can-deal-with([A],CT)* ←
  ag_x*:*$demo_{LPITP}$*(right-do-deal(-,-,A),CT,true).*
ag_x*:can-deal-with([A|T],CT)* ←
  ag_x*:*$demo_{LPITP}$*(right-do-deal(-,-,A),CT,true),*
  ag_x*:can-deal-with(T,CT).*

Example

Assume the following KB, defined according to the non-circular theory *TNAP*. Reasoning about *delegation* will now involve the set of restrictions embedded into the KBs. The clauses are:

ag_x *:* bk_1 *: right-to-deal(p1,[c1], cp2):: [[0, forever]].*
ag_x *:* bk_2 *: right-to-deal(p2,[c3, c4], cp3):: [[0, 50]].*
% exceptions ag_x
% theorem proffers ag_x
% priorities
$ag_{x:}$ *priorities(*$bk_{1,}$ bk_2*).*

ag_y : bk_1 : right-to-deal(p2,[c3, c4], cp3):: [[0, 60]].
ag_y : bk_1 : right-to-deal(p2,[c5], cp4):: [[0, 10]].
ag_y :money(900).
% exceptions ag_y
% theorem proffers ag_y
% priorities
ag_y: priority(bk_1, bk_2).

Agent ag_x is able to negotiate product *p1*, taking conditions *[c1]* with counter-part agent ag_y permanently. In the case of product *p2*, conditions *[c3, c4]* are established for counter-part agent *cp3*, but only for interval *[0,50]*. The knowledge about the right to deal with ag_y overpowers the knowledge about *cp3*. Agent ag_y is able to negotiate product *p2*, taking conditions *[c3, c4]* with counter-part agent *cp3*, but only on interval *[0,60]*. Furthermore, it is able to negotiate product *p2*, taking conditions *[c5]* with counter-part agent *cp4*, but only on interval *[0,10]*. Agent ag_y has *900* monetary units expressed in its KB and a new assertion is conditioned to the existence of 1000 monetary units (due to an assertion restriction). Priority rules establish that the knowledge about *cp3* overpowers that of *cp4*.

The KB can be queried in order to determine the validity of a delegation process:

?ag_x: delegate(p1,[c1],cp2, ag_y,10).	*false*
? ag_x: delegate(P,C,cp2, ag_y, 10).	*P={p1},* *C={[c1]}*

The second column expresses possible variable valuations or the valuation for the query itself. In the first query, although the right to deal is well established in agent ag_x, it is impossible to assert the necessary knowledge in the proxy agent (ag_y) due to the assertion restriction. In the second query, the delegation on agent ag_y for a negotiation with *cp2*, at time instant 10, is only possible for product *p1* and conditions *[c1]*.

PROCESS FORMALIZATION

Argument-based Negotiation

The use of logic for the formalization of argument-based negotiation does not aim at the definition of the best dealing strategies (although the construction of problem-solving methods for that purpose may turn out to be more stable, taking into account the concepts stated in the formal theory). There are two main objectives: offers and counter-offers are logically justified and, the definition of conflict/attack among opposing parties is clearer. Without arguments, each agent has no way of ascertaining why their proposals/counter-proposals are accepted or rejected, due to the limited amount of exchanged information (Jennings et al, 1998).

Global vs. Local Knowledge

Each element that composes an argument may come from one of two main sources: *global* or *local knowledge*. Global knowledge is shared by the intervening entities and is, therefore, independent of a particular experience or local state. Local knowledge derives from sources that are not common to every agent, giving way to the possibility of contradictory conclusions upon confrontation.

Contrary to the definitions found in logical formalizations in Law (Prakken, 1993), the KB embedded in each agent may be quite different. The use of global or local knowledge conditions the capacity to determine the winner of a confrontation. As expected, local knowledge is not the best starting-point for a premise denial attack (e.g., a claim such as "my experience tells me I sold item X for Y monetary units" is difficult to be stated as false by a the counterpart agent, because he can not say what are the particular experiences of the other agent). In many Business-to-Business (B2B) or Business-to-Consumer (B2C) argumentations there is often no winner or loser, however, the exchange of arguments among agents is essential so an acceptable situation for both parties is reached (even if an agent decides to drop, at any time, the negotiation). *Local* knowledge is important for an agent to reach another agent's acceptability region faster (Jennings et al, 1998).

Negotiation Arguments

After a theory and a language have been established, in order to represent each agent's knowledge/information (from which it will draw the justification for each offer/counter-offer), a definition for *argument* must be reached. An argument is to be constructed progressively, being the antecedent of each rule composed by the consequents of previous rules. This definition is, perhaps, the most important one in the logical formalization of argument-based negotiation.

Definition 5 (**negotiation argument with an implicit meta theorem-solver**)

Taking ordered theory TNAP, a negotiation argument is a finite, non-empty sequence of rules $\langle r_1,\ldots,demo(r_i,V_i),\ldots,r_n\rangle$ *such that, for each sequence rule* r_j *with P as a part of the antecedent, there is a sequence rule* r_i $(i<j)$ *on which the consequent is P.*

The use of such arguments, extended by a three-fold logic, is important due to their informative nature; i.e., one of the advantages of using argument-based negotiation lyes in the fact that information is conveyed in such a way that the counterpart agents are able to evolve their counter-arguments in a parallel way (reaching a cooperative usage of knowledge) (Brito et al, 2001b), (Jennings et al, 1998).

The conclusion of an argument relates to the consequent of the last rule used in that same argument. Formally:

Definition 6 (**argument conclusion**)

The conclusion of an argument $A_1=\langle r_1,\ldots,r_n\rangle$*, conc*$(A_1)$*, is the consequent of the last rule* (r_n)*.*

Has it has been stated, the nature of the knowledge each agent has (local/global) is relevant for arguments and counter-arguments. By composing an argument with rules or facts that spawn from local knowledge (e.g., previous experiences), the attack or counter-argument launched by the opposing agent during its *round* is conditioned (due to the fact that local knowledge is hard to deny).

Taking into account the two forms of argument attack (*conclusion denial* and *premise denial*), a conflict amongst two opposing agents (e.g., buyer/seller) can be formally specified:

Definition 7 (conflict/attack over negotiation arguments)

Let $A_1=\langle r_{1,1},\ldots,r_{1,n}\rangle$ be the argument of agent 1 and $A_2=\langle r_{2,1},\ldots,r_{2,m}\rangle$ be the argument of agent 2. Then,

(1) if $r_{1,i} \in A_1$ or $r_{2,j} \in A_2$ are local, the arguments are said to be in "probable conflict";
(2) A_1 attacks A_2 iff A_1 executes a conclusion denial attack or a premise denial attack over A_2;
(3) A_1 executes a conclusion denial attack over A_2 iff there is no local knowledge involved and conc(A_1) is contrary to conc(A_2);
(4) A_1 executes a premise denial attack over A_2 iff there is no local knowledge involved and conc(A_1) is contrary to some $r_{2,j} \in A_2$.

Having in mind the use of rational agents (i.e., those that do not undermine their own actions and are able to formulate coherent arguments), a proper definition of coherency must be formulated:

Definition 8 (argument coherency)

An argument $A_1=\langle r_1,\ldots,r_n\rangle$ is said to be "coherent" iff $\neg\exists_{ai,aj}\ a_i,aj \in subarguments(A) \wedge i\neq j : a_i$ attacks a_j.

Taking into account the definition of conflict/attack and the concept of round it is possible to logically define the victory/defeat pair.

Definition 18 (victory/defeat of negotiation arguments)

Let $A_1=\langle r_{1,1},\ldots,r_{1,n}\rangle$ be the argument of agent 1 and $A_2=\langle r_{2,1},\ldots,r_{2,m}\rangle$ be the argument of agent 2 and A_2 is presented at a later "round" than A_1. Then, A_1 is defeated by A_2 (or A_2 is victorious over A_1) iff

(1) A_2 is coherent and A_1 is incoherent;
(2) A_2 is coherent, executes a conclusion denial attack over A_1 (coherent) and the conclusion rule of A_2 is prioritary (taking into account the TNAP theory) over A_1;
(3) A_2 is coherent, executes a premise denial attack over A_1 (coherent) and the conclusion rule of A_2 is prioritary (taking into account the TNAP theory) over A_1.

Example

Some examples may be presented to illustrate the previous definitions. Let agents E and F be engaged in the process of buying/selling product p1 in an environment with priority rules embedded in the KBs. Agents E and F share general knowledge, market knowledge and the set of priority rules.

Agent E:
PE : r_5 : price(p1,143). *%(experience) price for p1 is 143*
MK : r_7 : price(p1,147). *%(market) price for p1 is 147*
GK : r_1 : price(p1,150). *%(global) price for p1 is 150*
PRIO : r_4 : priority(PE,GK). *%(priority) PE overpowers GK*
PRIO : r_6 : priority(MK,PE). *%(priority) PE overpowers GK*

Agent F:
MK : r_7 : price(p1,147). *%(market) price for p1 is 147*
GK : r_1 : price(p1,150). *%(global) price for p1 is 150*
PRIO : r_4 : priority(PE,GK). *%(priority) PE overpowers GK*
PRIO : r_6 : priority(MK,PE). *%(priority) MK overpowers PE*

The argument given by agent E might be $A_E = \langle r_4, r_5 \rangle$, however, agent F might argue with $A_F = \langle r_6, r_7 \rangle$, representing a conclusion denial attack taking into account the priority rules shared by the community. Agent F is considered the winner due to the fact it uses an higher priority rule on the set of priority rules.

CONCLUSIONS

As previously stated logic stands as an important tool for formalizing approaches to the development of agent-based software. Logic provides a way to eliminate (or at least reduce) ambiguity and, in the particular case of ELP, is close to a working prototype.

EC is an area posing particular problems to the use of agent-based software. Though applications in this area are particularly suited to be solved by agents, no formal development process has it been devised for such field of expertise. However, as previously seen, building agents for EC purposes can be seen as a 4-step approach. Starting with the definition of an agent architecture, the processes which take place within and among agents are to be quantified, the reasoning mechanisms formally stated and the flow of knowledge must be stated.

The processes involved in EC, which are difficult to assimilate into traditional systems, revolve around subjective business parameters. Parameters such as gratitude and agreement among parties are non-linearities, which need to be considered in order to develop a feasible EC system. This information is to be taken into account when drawing up a strategic plan of action. However, once subjective parameters have been quantified, some reasoning must take place before any argument is exchanged with potential counterparts. This stage, which has been called "pre-negotiation reasoning" deals with the existence of incomplete information and delineates logical conclusions upon an agent's KB (e.g. is agent A able to deal product P with agent B at time T). The exchange of arguments among agents serves the main purpose of information exchange. Exchanging justified information provides an agent's counterpart with enough knowledge to try and reach a common understanding much faster. Formalizing the ways an agent can attack an argument (and which knowledge to use for an effective "victory") culminates the most important steps in the development of EC-directed agent software.

REFERENCES

Analide, C., Neves, J. (2000). *Representation of Incomplete Information*, in CAPSI, Conferência da Associação Portuguesa de Sistemas de Informação, Universidade do Minho, Guimarães, Portugal.

Baral, C., Gelfond, M. (1994). *Logic Programming and Knowledge Representation*, Journal of Logic Programming, 19,20:73-148.

Brito, L., Neves, J. (2000). *Agreement and Coalition Formation in Multiagent-Based Virtual Marketplaces*, proceedings of the IEA/AIE-2000: The 13th International Conference on Industrial & Engineering Applications of Artificial Intelligence & Expert Systems, New Orleans, Louisiana, USA, 2000.

Brito, L., Novais, P., Neves, J. (2000a). *Mediation, Agreement and Gratitude in Strategic Planning for Virtual Organisations*, proceedings of the ICEIS2000 - 2nd International Conference on Enterprise Information Systems, Stafford, UK.

Brito, L., Neves, J., Moura, F. (2000b). *A Mobile-Agent Based Architecture for Virtual Enterprises,* proceedings of the PRO-VE 2000 – 2nd IFIP/Massyve Working Conference on Infrastructures for Virtual Enterprises, Florianópolis, Brasil.

Brito, L., Novais, P., Neves, J. (2001a). *Temporality, Priorities and Delegation in an E-Commerce Environment,* proceedings of the 14th Bled Electronic Commerce Conference, Bled, Slovenia.

Brito, L., Novais, P., Neves, J. (2001b). *On the Logical Aspects of Argument-based Negotiation among Agents*, proceedings of the CIA 2001 – Fifth International Workshop on Cooperative Information Agents, Modena, Italy.

Guttman, R., Moukas, A., Maes, P. (1998). *Agent-mediated Electronic Commerce: A Survey,* Knowledge Engineering Review.

Jennings, N.R., Parsons, S., Noriega, P., Sierra, C. (1998). *On Argumentation-Based Negotiation,* proceedings of the International Workshop on Multi-Agent systems, Boston, USA.

Kephart, J., Hanson, J., Greenwald, A., (2000). Dynamic Pricing by Software Agents, in Computer Networks.

McCarthy, J. (1959). *Programs with Common Sense*, proceedings of the Teddington Conference on the Mechanization of Thought Processes, 75-91, London.

Norman, T., Sierra, C., Jennings, N. (1998). *Rights and Commitment in Multi-Agent Agreements*, proceedings of the 3rd International Conference on Multi-Agent Systems (ICMAS-98), Paris, France, 222-229.

Neves, J. (1984). *A Logic Interpreter to handle time and negation in logic data bases*, proceedings of the ACM 1984 Annual Conference, pages 50-54, San Francisco, California, USA.

Novais, P., Brito, L., Neves, J. (2000). *Experience-Based Mediator Agents as the Basis of an Electronic Commerce System*, proceedings of the Workshop 2000 - Agent-Based Simulation, Passau, Germany.

Novais, P., Brito, L., Neves, J. (2001). *Developing Agents for Electronic Commerce – A Constructive Approach*, proceedings of the SCI 2001 - 5th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, USA.

Prakken, H. (1993). *Logical Tools for Modelling Legal Argument*, Doctoral Dissertation, Free University, Amsterdam.

Sartor, G. (1994). *A Formal Model of Legal Argumentation*, Ratio Juris 7, 212-226.

Wooldrige, M., Ciancarini, P. (2001). *Agent-Oriented Software Engineering: The State of the Art*, Agent-Oriented Software Engineering, Springer-Verlag Lecture Notes in AI Volume 1957.