The State of the Art in Automated Negotiation Models of the Behavior and Information Perspective

Ricardo Büttner

Information Systems II, Institute of Business Administration,
Faculty of Business, Economics and Social Sciences, University of Hohenheim
D-70593 Stuttgart, Germany

Abstract: The following article is a dissertation project in progress paper. It shows the results of an empirical analysis of 74 publications in the field of automated negotiations. The results show that most of the items (66) imply incomplete or uncertain information, but mainly related to the negotiation partner. Only 12 of them are related to the negotiation item. Despite the advantages of the argumentation-based negotiation [20, 45] there is no such model that implies incomplete or uncertain information related to the negotiation item. There is a need of research activities.
Keywords: automated negotiation, rationality, argumentation, incomplete information / fraught with risk

1. Problem description

Although the mathematical-normative branch of the decision-oriented approach [29] and basic works of game theory [76] assume perfect information and thus a decision situation of certainty, the majority of the organizational approaches (behavioral-decision-theory [13, 34], system-oriented approach [75], transaction-cost-theory [80], principal-agent-theory [48] and extensions of game theory [18, 26] imply an **incomplete and/or information situation of uncertainty**. The concept of **bounded rationality** by Herbert A. Simon [58, 59, 60, 61, 62] is also a basic assumption of the most microeconomic organizational approaches (extensions of game theory [49, 50, 63], behavioral-decision-theory [60, 73, 74], system-oriented approach [75], principal-agent-theory [48]). Research results in linguistics show that **arguments** play an important role in real negotiation processes [40]. In the following it will be checked how far existing automated negotiation models can handle bounded rationality, the use of arguments and incomplete or rather uncertain information situations.

2. State of the art of automated negotiations of the behavior and information perspective

In line with the analysis a systematic inquiry of the journals in Table 1 has taken place. Additionally the items [16, 42, 83, 88] were included. Overall an amount of 74 publications was researched.

Tab. 1: Journal scope of analysis

Journal	Space of time
Autonomous Agents and Multi-Agent Systems (JAAMAS)	2005 (Vol. 11, No. 2) - 1998
Group Decision and Negotiation	(Vol. 14, No. 5) - 1997
Int. Journal of Cooperative Information Systems (IJCIS)	2005 (Vol. 14, No. 4) - 1998
Wirtschaftsinformatik	2005 (Vol. 47, No. 4) - 1999
Robotics and Autonomous Systems	2005 (Vol. 53, No. 1) - 1998
Information Systems Frontiers	2005 (Vol. 7, No. 3) - 1999
Artificial Intelligence	2005 (Vol. 168, No. 1/2) - 1995
IEEE Intelligent Systems (IEEE Expert 1988-1997)	2005 (Vol. 20, No. 5) - 1988
Logic and Computation	2005 (Vol. 15, No. 5) - 1999
Data and Knowledge Engineering	2005 (Vol. 55, No. 3) - 1995
Electronic Markets	2005 (Vol. 15, No. 3) - 1999

2.1 Rationality

Since [58, 59, 60, 61, 62] (concept of bounded rationality) it is common understanding that the assumption of perfect rationality does not fit to reality because of the regularly occurring high complexity in decision problems in conjunction with human cognitive boundaries. Nevertheless **42 of the 74 researched publications assume perfect rationality**. [30] is able to represent both perfect and bounded rationality.

2.1.1 Causes-based Summary

In principle the main cause for bounded rationality in the researched papers was the limitation of resources: For instance [14, 16, 71, 77] assume the limitation of negotiation time. [28, 72, 77] restrict the computational resources. [71] assumes communication costs and [7] information costs above zero. In [9] bounded rational decision behavior results from incomplete information regarding the preferences of the negotiation partner.

Notice: This is as preprint of an article published in ITSSA, Vol. 1, No. 4, 2006, pp. 351-356.

2.1.2 Modeling-based Summary

Generally bounded rationality can modeled via simplifications: Most of the researched papers related to bounded rationality, model these through heuristics alternatively rules of thumb; for example [2, 10, 15, 24, 46, 69, 36, 51, 57, 87]. [52, 86] use heuristic search algorithms; [21, 57] heuristic (bidding-)strategies. [12] used heuristics on the basis of genetic algorithms. In [49] bounded rationality is modeled by the explicit reduction of the negotiation process by defined elements. [5] models bounded rationality through a predefined utility function. Another way to represent bounded rationality is provided by probability-based models; for example [41] by the stochastic negotiation strategy *"p-strategy"* or [77] by random numbers. Finally the fuzzy approach [85] also presents a possibility for a simplification; see [33, 78].

2.2 Argumentation

Although the argumentation-based approach is deemed to be especially effective and efficient [20] and compared to the game-theoretical and heuristical models the approach enhances the probability and quality of an agreement [45], **67 of the 74 researched articles are non-argumentative**. It can be partly explained by the fact that the argumentation-based approach is the most recent, compared to the game-theoretical and heuristical models.

[38, 42] show argumentation-based frameworks for automated negotiations. The `PARMA` protocol *(persuasive argument for multiple agents)* from [1] enables participants to rationally propose, attack, and defend actions or course of actions. The argumentation-based formalism `ODeLP` *(observation-based defeasible logic programming)* from [11] includes mechanisms for handling argumentation lines and counterarguments. [24] presents argumentation as an iterative process emerging from exchanges among agents to persuade each other and bring about a change of intentions. In [33] potential rewards are used as arguments to persuade the buyer to purchase a certain product.

2.3 Information situation

In a perfect information situation the decision takes place under certainty conditions; for example [25, 69, 88, 89]. [25], however, also includes the case of an incomplete information situation related to the negotiation partner. The majority of the researched publications (89 percent) do not assume a perfect information situation. 23 items regard the case of uncertainty or risky information. In the following the individual cases will be presented. A differentiation for the inspection subject (environment, negotiation partner and negotiation item) takes place, if indicated.

2.3.1 Incomplete described environment

The non-argumentation-based negotiation model from [12] assumes that the agents have incomplete information about the environment. The approach in [83] makes use of experiences to arrive at a list of trustworthy candidates who have negotiated the same or similar issues in the past, from whom the negotiator can learn the possible offers and counteroffers that could be made. The environment is incompletely described due to the fact that the negotiator does not know all effective (counter) offers in advance. In [1] a third party and his authoritative knowledge will be asked in order to resolve the dispute in case of a disagreement. The incompleteness of information in [91] concerns the possible search for a better alternative price amongst other bidders. The buyer does not know these prices in advance but has to ask for them. [43] takes up the problem of incomplete information related to the environment insofar as a "sufficient information model" is used to represent the relevant information. "Sufficient" in this case means that upon completion of an auction, the agent gets exactly the information he needed to evaluate any hypothetical offer ex post.

2.3.2 Fraught with risk environment

In [11] agents can act adequately in a dynamic environment fraught with risk due to real time updating of the knowledge base. [53] models risk related to the environment via a probability-based approach. The model implies that the contractors best (lowest) offer is ex ante probabilistically known by both agents (contractor and contractee), and is characterized by a probability density function. [43] proposes a statistical extrapolation of known information in order to forecast future activities. The approach of [22] is to use a fuzzy-based inference mechanism.

2.3.3 Incomplete and risky information of the environment

The multi-attribute decision support system of [10] suggests increasing the transparency of the environment fraught with risk and incomplete information, by means of additional information from a signaling-agent. However, there is no integration of the signaling-information in the decision heuristics; the user gets the information only as additional notice. [72] addresses incomplete and risky information regarding the environment through the Bayes-theorem on the basis of subjective probabilities.

2.3.4 Incomplete information about the negotiation partner

Most of the researched papers assume incomplete information related to the negotiation partner. They presume that the utility [4, 5, 14, 16, 23, 84, 90], the goals [90], the preferences [67, 81], the identity of the negotiation partner [84] or the potential negotiation partner himself [4, 54, 56] are unknown. The publications show a solution of the incomplete information situation in probability-based approaches [9, 70] or by means of a mediator component that is completely informed about the preferences of the negotiation partner [64].

2.3.5 Incomplete and risky information about the negotiation partner

In the researched publications the information situation concerns the deadline of the negotiation [17], the price limit of the negotiation partner [15, 17], the utility of the negotiation result [15], the resource constraints of the negotiation partner [15], the identity of the partner [37], his data and message formats [37], as well as his efficiency and trust values [37]. Solutions result from probability-based approaches [3, 17, 35], by fuzzy-logic [15] or through a dynamic database which contains current knowledge and information about the negotiation partner [37]. The articles [9, 66, 70] look exclusively at the risk aspect and address this aspect by means of probability-based approaches.

2.3.6 Publications related to the negotiation item

The negotiation system `FuzzyMAN` [27] was designed for the electronic labor market. `FuzzyMAN` and the model implemented therein [71] express the agent preferences related to the negotiation item (here characteristics of the employees like salary, number of working hours per week, duration of the employment, and social benefits) in fuzzy terms [85]. In the electronic trading system `AMTRAS` [8] users may specify bandwidths in the context of the search phase (e. g. risk of default or maturity). Based on this, the agents are looking for matching negotiation partners. But the situation fraught with risk is not taken into account in the actual negotiation. Instead, a perfect information situation is assumed. The negotiations support system `Negoplan` [36] also uses bandwidths in order to model risky information related to the negotiation item. In [33] such an information situation is specified by means of the fuzzy approach [85].

2.3.7 Multipurpose inspection subjects

In [28, 44, 68] an incomplete information situation related to the negotiation partner and the environment is modeled. [28] addresses the environment insofar as the potential negotiation partner is not known prior to the negotiation. An incomplete information situation or rather an information situation fraught with risk is existent regarding the deadline and the precise problem of the negotiation partner. The incomplete or rather risky information situation is solved by a probability-based approach. The parameters of the related distributions are assumed as known. The negotiation system `HOLOS` [44] addresses the problem of incomplete information situation related to the environment through the mediator component `CIM-IS`. The mediator collects all relevant information regarding the environment and provides it to the negotiating agents. The incompleteness of the information about the negotiation partner is reduced during the negotiation process by an exchange of information between the negotiating agents. The incomplete information situation in [68] is related to the negotiation partner and the environment and results from the offers of the participants not being known to all involved.

[21] researches bidding strategies for one-sided multilateral auctions. Thereby an incomplete information situation of the negotiation partner regarding his bidding behavior and utility function is taken into account. The bidding behavior is forecasted on the basis of time series. In order to model the utility function, [21] uses "negotiation decision functions" (NDF's), introduced by [14]. Additionally, an incomplete information situation related to the environment is assumed in [21] due to missing data regarding to the competitors. Finally, [21] models risky information about the negotiation partner through the definition of possibilities regarding the bidding points in time.

[71] depicts risky information about the negotiation item by means of a utility function which is based on the fuzzy approach [85]. In addition an incomplete information situation related to the negotiation partner is modeled in [71]. It refers to the unknown deadline, utility function and bidding behavior of the partner.

`Negoisst` [56] is a non-argumentative negotiation support system for B2B-applications. The system enables the representation of risky information about the environment, the negotiation partner, and the negotiation item apart from a so-called "red area", in an informal specification space called "green area". But the informal descriptions are not included in the real automated negotiation process. They are only used for information purposes.

3. Summary and the need of doing research

The analysis shows, that in about the half of the 74 researched publications perfect rationality is supposed. Only 7 publications (9 percent) are argumentation-based. 66 of the articles assume that the information circumstances are incomplete and/or fraught with risk, whereas the focus is mainly on the negotiation partner. **Just 12 works** (8 percent) **consulted consider incomplete information and/or information circumstances fraught with risk with regard to the negotiation item** (Fig. 1). But **none** of these 12 models **is argumentation-based**.

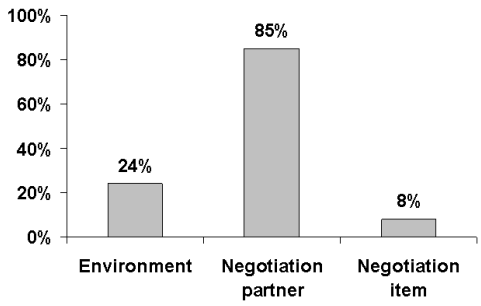

Fig. 1: Evaluation of publications with incomplete information circumstances

To summarize, the research in the field of automated negotiations is concerned with many aspects; e. g. [4, 6, 19, 32, 39, 45, 47, 65, 79]. Despite of the fact, that

imperfect information situations play an important role, most of that work focusses only on the negotiation partner. The negotiation item and the environment should be more considered. **Incomplete or uncertain information related to the negotiation item or the environment** should be a future research direction in the field of automated negotiations.

Especially, there is the need to fill the research gap of an **automated argumentation-based negotiation mechanism, that can be used on negotiation items, that are fraught with risk or alternatively incompletely specified**.

4. Corresponding research program

The object of investigation comprises the **mechanism of automated negotiations**. It should be analyzed from the perspective of **behavior- and information phenomena**. The research question is: **How to create an automated argumentation-based negotiation mechanism for a negotiation item fraught with risk?**

4.1 Goals of this study

All in all this study should make a contribution to the research area of automated negotiations. For this purpose relevant behavior- and information phenomena for automated negotiations will be identified and analyzed according to their presence in the state of the art. Based on the research gap, an analysis will take place in order to establish which modeling approaches are suitable for addressing the research gap. The modeling of the behavior mechanism in the implementation part of this study will follow.

4.2 Research concept and -methodology

At first the state of the art concerning automated negotiations was examined. For this purpose hitherto existing classification schemata were analyzed by literature investigation; e. g. [4, 6, 19, 32, 39, 45, 47, 55, 65, 79, 82].

The research of automated negotiations interacts with information technology (artificial intelligence), game theory, economics, behavioral science, law, politics and linguistics [6]. The respective research programs of these disciplines were analyzed by literature investigation with regard to which behavior- and information assumption they are based on. The aim was the formulation of an analysis pattern for behavior- and information phenomena. By systematic document analysis the journals named in Table 1 were analyzed to classify the contained publications in relation to negotiation models in the analysis pattern. The intention was to identify the need for research in this field.

To contribute to the closing process regarding the research gap, in the following course of the research initially potential modeling approaches will be compared on the basis of literature investigation. On the basis thereof, an negotiation mechanism is modeled as one part of the negotiation protocol. The negotiation protocol is described in a selected standardized specification language, based on a comparison. Finishing the negotiation strategy for evaluating arguments is shown.

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Biography of the author

Ricardo Büttner (30) has studied Computer Science, Industrial Engineering and Management at the Technical University of Ilmenau (Germany) and Business Administration at the University of Hagen (Germany). His career started at BMW Group in 2000. There he has passed several stages in Financial Controlling, Marketing and R&D. Besides he has been a PhD student at Information Systems II, Institute of Business Administration, University of Hohenheim (`buettner@uni-hohenheim.de`). His main research interests are Negotiation Systems and Automotive Software Engineering.