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Towards a Structured Design of Electronic Negotiations

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Global communication networks and advances in information technology enable the design of information systems facilitating effective formulation and efficient resolution of negotiation problems. Increasingly, these systems guide negotiators in clarifying the relevant issues, provide media for offer formulation and exchange, and help in achieving an agreement. In practice, the task of analysing, modelling, designing and implementing electronic negotiation media demands a systematic, traceable and reproducible approach. An engineering approach to media specification and construction has these characteristics. In this paper, we provide a rationale for the engineering approach that allows pragmatic adoption of economic and social sciences perspectives on negotiated decisions for the purpose of supporting and undertaking electronic negotiations. Similarities and differences of different theories that underlie on-going studies of electronic negotiations are identified. This provides a basis for integration of different theories and approaches for the specific purpose of the design of effective electronic negotiations. Drawing on diverse streams of literature in different fields such as economics, management, computer, and behavioural sciences, we present an example of an integration of three significant streams of theoretical and applied research involving negotiations, traditional auctions and on-line auctions.

Keywords: electronic negotiations, electronic auctions, negotiation protocols, negotiation engineering, negotiation support systems, electronic negotiation media

1. Introduction

Negotiation is the key decision-making approach used to reach consensus whenever a person, organization or another entity cannot achieve its goals unilaterally. Negotiations appear in a multitude of forms, take place in very different situations and are influenced by ethical, cultural and social circumstances. The variety and diversity of roles of negotiators and negotiation situations challenge researchers from many disciplines including anthropology (Gulliver 1979), psychology and sociology (Druckman 1977; Pruitt 1981), political sciences (Ury 1993; Fisher, Kopelman et al. 1994), economics (Young 1975; Roth 1995), law (Wetlaufer 1996), and applied mathematics (Harsanyi 1997). Negotiations have been investigated from descriptive, prescriptive and normative perspectives and under different assumptions leading to a diversity of theories, models and negotiations procedures.

The variety of involved disciplines and perspectives has created different terminologies, definitions, notations, concepts and formulations. As a result, interdisciplinary cooperation among concerned fields of study suffers from inconsistencies and contradictions (Gulliver 1979). Yet, negotiations require an interdisciplinary approach because of their psychological, social and cultural character; economic, legal and political considerations; quantitative and qualitative aspects; and strategic, tactical and managerial perspectives. Clearly, interdisciplinary approaches provide richer and more comprehensive models of negotiators and negotiations.

A schematic representation of the different perspectives and influences on negotiations research is presented in Figure 1. Law and social sciences are the main contributors to the prescriptive and descriptive models, heuristics and qualitative studies of negotiations processes and negotiators' behaviour (Pruitt 1981; Bell, Raiffa et al. 1991). Economics and management science concentrated on the construction of formal models and procedures of negotiations, rational strategies and the prediction of outcomes (Nash 1950; Roth 1979). Computer science and information systems contributions include construction of electronic negotiation tables, decision and negotiation support systems (DSS, NSS), artificial negotiating software agents (NSA) and software platforms for bidding and auctioning (Rosenschein and Zlotkin 1994; Kersten 1997; Holsapple, Lai et al. 1998; Maes, Guttman et al. 1999).

The four arrows depicted in Figure 1 connect areas of studies with results. The bi-directional arrow indicates that the negotiation systems, agents and platforms are often based on the results of the studies in economic and social sciences (Kersten 1985; Teich, Wallenius et al. 1994; Hamalainen 1995; Raiffa 1996; Bui, Yen et al. 2001), and also that, increasingly, computational models and systems

influence the construction of negotiation techniques, models and procedures (Sycara 1993; Guttman 1998; Kumar and Feldman 1998; Pennock, Horvitz et al. 2000). The latter marks a fairly recent development in negotiation research: increased computing and networking power provides new flexibility in designing negotiations, while at the same time the findings from computer science and information systems feed back into models and procedures of negotiations.

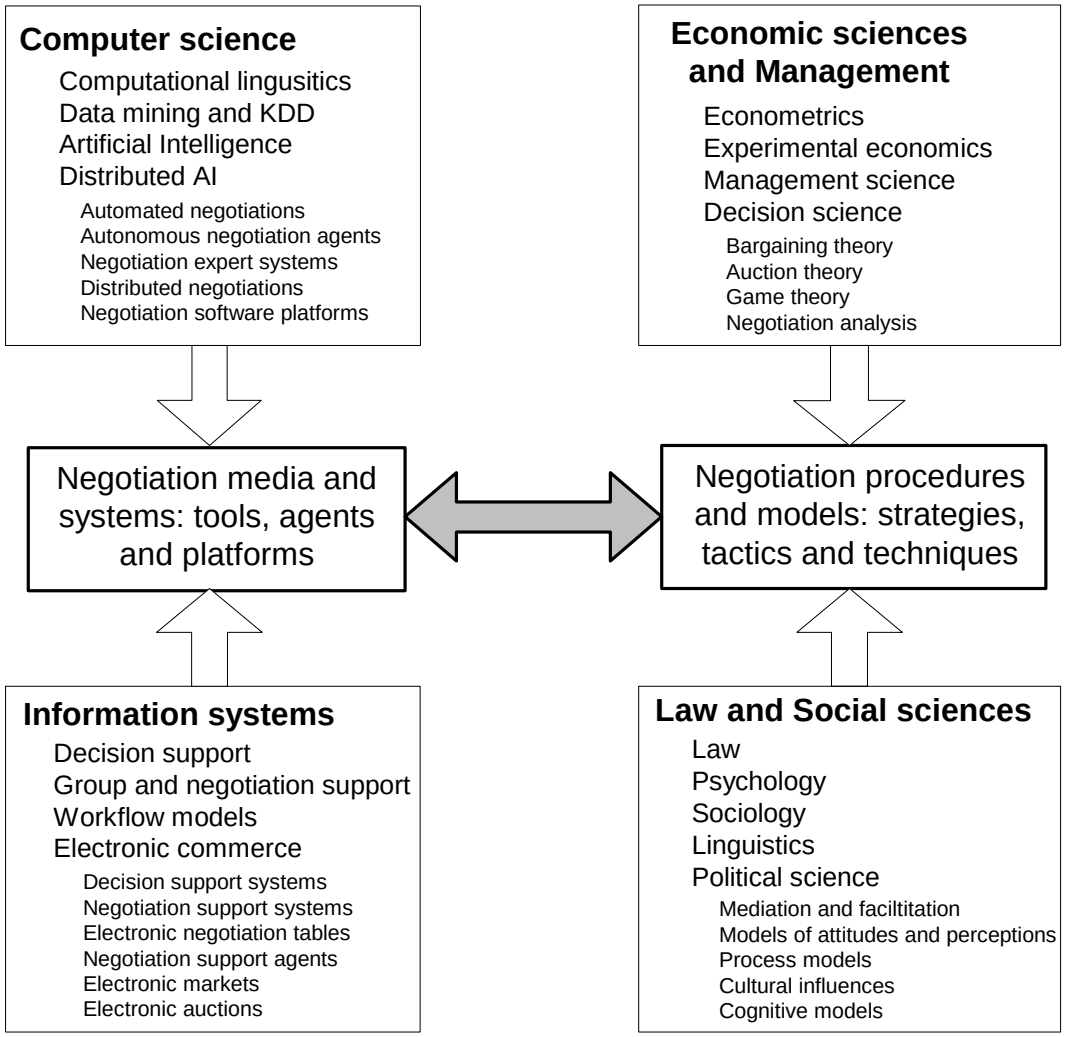

Figure 1. Negotiation research areas, their results and key influences

Most traditional negotiations have been conducted face-to-face; others have been conducted using mail, fax and telephone. Mail-based and email-based negotiations share many similarities in that they are difficult to manage, are time consuming, and prone to misunderstanding (Thompson 2001). Yet, the impact of information technologies on negotiations is not limited to the use of electronic communication. Information technology changes the way a negotiation problem can be represented and a

negotiation process structured. The use of Internet-based information systems allows for many more activities undertaken in negotiations, including, efficient matching of potential negotiators; exchange, comparison and categorization of rich data; and the use of tools for data collection, problem structuring and analysis, and interpretation of offers.

These new possibilities have led to the emergence of formal negotiation procedures and protocols, which are necessary for the use of rich and expressive information technologies in various stages of negotiation processes rather than solely for the exchange of messages. Initiated by the commercial exploration of the Internet as a global communication and "negotiation" infrastructure (see e. g. Raisch 2000), electronic varieties of negotiations have started to gain momentum in manifold shapes—from web-based NSS (Shim and Hsiao 1999), to on-line auctions (Vakali, Angelis et al. 2001), to automated agent-based negotiations (Jennings, Faratin et al. 2001), in both research studies and business applications (Edwards 2001). Examples of new negotiation protocols include auction protocols with combinatorial bids on product bundles (Rassenti, Smith et al. 1982; Rothkopf and Pekec 1998; Parkes 1999), supply curve bids in a volume discount auction (Davenport and Kalagnanam 2000), multi-attribute auctions (Che 1993; Teich, Wallenius et al. 1999; Bichler 2001), iterative double auctions (Preist 1999), automated negotiations among software agents (Rosenschein and Zlotkin 1994; Guttman, Moukas et al. 1998; Wurman, Wellman et al. 1998; Sandholm 1999) as well as protocols supporting bi- and multilateral negotiations among human negotiators (Kersten and Szpakowicz 1998; Teich, Wallenius et al. 2001; Stroebel 2002).

The computerization of negotiation processes increasingly affects the way organizations (and individuals) interact with each other. Electronic negotiations promise higher levels of process efficiency and effectiveness, and most importantly, a higher quality and faster emergence of agreements. The potential monetary impact leads to an increased demand for appropriate electronic negotiations for specific negotiation situations (e. g. electronic tenders for electronic procurement). Yet, both the design of suitable electronic negotiation protocols and the implementation of germane electronic negotiation media largely lack systematic, traceable and reproducible approaches and thus they remain more an art than a science.

Recent developments created an opportunity for mutual fertilization of research studies and approaches, and for integration of different perspectives on negotiations into an interdisciplinary research effort to develop an engineering approach to electronic negotiations, similar to, for example, system or process engineering which brings together the findings about negotiators and negotiation processes from the different research areas.

The phenomenal growth in computer science and information systems led to the design of models and systems that often use little from the behavioural and economic body of knowledge. In effect, systems were developed that are appealing, easy to use and allowing users to delegate many complex decision and negotiation tasks but with not sufficient concern of the users' needs and expectations in particular of qualitative nature, and their cognitive capabilities and limitations. More importantly, people biases, misconceptions and misunderstanding that have been shown to occur very often are not considered and countered with a sound decision and negotiation methodology embed in the system.

There is thus a strong need to consider the many results of economic and social sciences for the design and development of negotiation media and systems. However, both the new methods for data processing, representation and presentation, and many pragmatic approaches to provide user-oriented support that have been proposed by computer science and information systems should not be discarded by social scientists. Hence, there should be, as shown in Figure 1, a feedback between results of the two groups of negotiation research areas, that is, between the negotiation media and systems, and the models and procedures. To achieve this a multidisciplinary approach towards the emerging field of electronic negotiations is necessary, one which is much broader and more encompassing than often implemented.

The design and implementation of electronic negotiation media requires the consideration of insights from multiple relevant research areas in order to fulfil its promises and represent the richness and complexity of real negotiation scenarios in electronic commerce. To this end, we motivate "electronic negotiations" and propose comprehensive definitions of important terms as a first step towards a common framework on the subject. We identify a lack of principles and guidelines required for the construction of electronic negotiation media in a particular environment: How should a negotiation designer choose among negotiation protocols for a given application domain and which criteria exist for the customisation of a particular protocol? Which methods assist him in choosing alternative protocols and in assessing their relative merits? Currently designing and implementing electronic negotiations media remains a laborious trial-and-error process. The intention of this paper is to provide the rationale for a structured design of negotiation systems and engineering approach to electronic negotiation media.

In the next section, we propose a comprehensive definition of negotiation and associated terms, and demonstrate the convergence of negotiations and auctions under the impact of information technology. In Section 3, we extend our definition to embrace negotiations as well as auctions, and introduce two main types of information systems implementing electronic negotiations: support systems and elec-

tronic negotiation media. In Section 4, we give a brief overview of modelling approaches and solution concepts underlying electronic negotiation media and associated protocols in preparation of our outline of an engineering of electronic negotiations in Section 5. Questions and directions for further research conclude the paper.

2. Negotiations and auctions

2.1 Negotiation processes

Negotiation research has developed many different meanings for the term "negotiation", from restricted and rigorous formal definitions to behavioural and broad concepts. In the economic literature, especially in game- and auction-theoretic streams, the term "negotiation" is sometimes used synonymously with bilateral bargaining and contrasted with auctions (Bulow and Klemperer 1995). The popularity of auctions in electronic commerce (Ebay, Yahoo!, Amazon, Onsale) has created an "auction-centric perspective" on negotiations in which every structured message exchange used in negotiation is regarded as an auction (Wurman, Wellman et al. 2001).

A different perspective on negotiations was proposed in negotiation analysis (Young 1991; Sebenius 1992) which focuses on the progressive process; the process that is initiated with an inefficient offer and leads to an efficient (Pareto-optimal) compromise. Negotiation analysis emphasises practical issues such as the parties' not fully rational behaviour, non-binding commitments, and incomplete information.

Behavioural studies focus on the negotiation process as the process of interpersonal communication for the purpose of forming and modifying perceptions and attitudes. Negotiation is every process of social interaction and communication involving distribution and redistribution of power, resources, and commitments (Pruitt 1981). A significant contribution of behavioural research is in numerous heuristics and qualitative models that have been shown to be useful in negotiation practice.

Most of the existing research concentrates on two directions: (1) traditional, face-to-face negotiations that rely on human expertise but little, if at all, on the information systems, and (2) formal models of idealized negotiators involved in complex strategic encounters. Electronic negotiations and processes that involve information systems as actively participants, negotiations among both human and artificial agents who use distributed knowledge and information require consideration of approaches from areas that traditionally were "foreign to each other." We need to continue integrating concepts and approaches proposed in law and social science with those proposed in economic science and manage-

ment. We also now need to seek how these concepts and models can support, complement and enrich those proposed in computer science and information systems.

In order to establish a common terminology and to facilitate multidisciplinary research, we propose to define negotiations in such a way that it is possible to include the various existing negotiation situations and approaches.

We describe *negotiation* as an iterative communication and decision making process between two or more agents (parties or their representatives) who:

1. Cannot achieve their objectives through unilateral actions;
2. Exchange information comprising offers, counter-offers and arguments;
3. Deal with interdependent tasks; and
4. Search for a consensus which is a compromise decision.

The *outcome* of a negotiation can be a compromise (an allocation) or a disagreement. *Negotiation arena* is the accepted place where the negotiators communicate. The *agenda* specifies the negotiation framework, including the specification of the negotiated issues and format in which they are presented (e.g., sequentially or simultaneously). *Decision-making rules* are used to determine, analyse and select decision alternatives and concessions. *Rules of communication* determine the way offers and messages (arguments) are exchanged. Most negotiations follow certain rules; in negotiations in which software carries out some tasks, rules need to be explicitly specified allowing, among others, a distinction between tasks undertaken by a system and by people.

The process may be enforced by rules defining the arena and agenda, and describing permissible decision-making and communication activities. A *negotiation protocol* includes all rules that define the negotiation arena, agenda and permissible decision-making and communication activities of the negotiators. The protocol may specify possible actions and their sequence, allowable offers and messages, timing of offers and messages. It may also specify the syntax and semantics of the messages, and mechanisms in which alternatives are determined and assessed, offers are constructed, and concessions are made. Depending on the protocol we can distinguish different levels of negotiation structuring.

1. *Unstructured negotiations* do not follow any protocol allowing for exchanges that do not conform to any rules (example: face to face negotiations).

2. *Semi-structured negotiations* follow certain rules but the protocol is not fully defined so that the participants have some flexibility in their decision making and information exchange ac-

tivities (example: negotiations supported by NSS).

3. *Structured negotiations*, follow a set of rules which fully defines the parties' decision-making and allowable activities (example: auctions).

Completely unstructured negotiations are rare. Even if the parties engage in a free-form exchange without any clearly defined rules, they often may accept certain implicit rules, for example, that no one would make a reverse concession or that a hand-shake is the agreement confirmation. Most of negotiations among people is semi-structured with both explicit and implicit rules.

2.2 Negotiation and auction characteristics

The recent appearance of new negotiation protocols in electronic commerce has initiated a controversial discussion about the relation between the concepts of negotiations and auctions (Kersten, Noronha et al. 2000; Lomuscio, Wooldridge et al. 2000; Vakali, Angelis et al. 2001; Wurman, Wellman et al. 2001) and has rendered a wide-spread view on negotiations and auctions as two contradicting types of decision making invalid. Kersten et. al. (2000) note that "[t]he presence of two and more issues [in auction protocols] begins to blur the difference between auctions and negotiations" because recent auction protocols introduce traditional negotiation techniques (e. g. utility as a measure of preference instead of price, trade-offs, logrolling, simultaneous improvement) and enable integrative negotiations. As a consequence, decision making processes, which in the past were not regarded as negotiations, now share many similarities with the traditional notion of negotiation. In Table 1 a comparison traditional negotiations and auctions, and on-line is given.

Negotiations and auctions have traditionally exhibited different characteristics, as this is shown in Table 1. *Traditional auctions* are resource allocation mechanisms based on a competitive bidding process over a single issue (i. e. price) of a single, well-defined object and involve "a set of auction rules that specify how the winner is determined and how much he has to pay" (Wolfstetter 1996). In essence, traditional auctions are market institutions "with an explicit set of rules determining resource allocation and prices on the basis of bids from the market agents" (McAfee and McMillan 1987) while the bids indicate the bidder's willingness-to-pay for the object (Milgrom 1989). Thus traditional auctions represent distributive, multi-bilateral negotiation processes based upon a fixed pie assumption (Kersten, Noronha et al. 2000) which prohibit integrative negotiation techniques (Kersten and Noronha 2000). The two basic types of traditional auctions are single and double-sided auctions. Single sided auctions comprise the ascending-bid auction (also called the open, oral, or English auction), the descending-bid auction (or Dutch auction), the first-price and the second-price sealed-bid auction (also

called the Vickrey auction), among others. Double sided auctions admit multiple buyers and multiple sellers at once and are favoured market institutions for trading financial instruments at stock exchanges.

Table 1. Characteristics of negotiations and auctions

Characteristic	Traditional auctions	Traditional negotiations	On-line auctions
1. Number of participants	Multi-bilateral, single or double-sided	Bilateral, multilateral or multi-bilateral; arbitrary number of sides	Multi-bilateral, single or double sided
2. Participation	Open or restricted	Restricted	Open, restricted or rule-defined
3. Consensus required	Bid-taker and selected bidder	Selected or for all participants	Selected participants
4. Number of objects	Single, homogenous	Single or multiple, homo- or heterogeneous	Single or multiple, homo- or heterogeneous
5. Number of issues	Single	Single or multiple	Single or multiple
6. Issues structure	Well-defined	Well-defined, partially, or ill-defined	Well-defined
7. Offer space	Fixed	May be unknown and modified	Fixed
8. Exchange and knowledge of offers and concession-making	Yes	Yes	Yes
9. Logrolling (conditional concessions)	No	Yes	Yes
10. Knowledge of offers and concessions	Public or private	Private (rarely public)	Public or private
11. Exchange of opinions, arguments, threats	No	Yes	No
12. Interdependence	Between bid-taker and bidders (single sided) or between but not within sides (double-sided)	Full interdependence except multi-bilateral negotiations	Between bid-taker and bidders (single-sided) or between but not within sides (double-sided)
13. Protocol	A priori defined, explicit and fixed	Well-defined or partially defined; explicit or implicit.	A priori defined, explicit and fixed
14. Competition versus Cooperation	Competition among bidders on at least one of the possibly two sides; cooperation prohibited	Competition or cooperation among the agents	Competition among bidders on at least one of possibly the two sides; cooperation prohibited
15. Process control	Defined a priori	Ill-defined, modifiable by participants	Defined a priori

Traditional negotiations are based on bilateral, multilateral or multi-bilateral negotiation processes over a single or multiple issue/s of one or more well-, partially, or ill-defined objects and involve co-operation and/or competition among the negotiating agents (see Table 1). The processes focuses on underlying objectives instead of price as an indicator of preference and may include integrative techniques such as trade-offs, logrolling and simultaneous improvement. Traditional negotiations are rarely completely structured and comprise negotiation situations in which haggling, bartering and tendering take place. One of the most popular traditional negotiations is bilateral bargaining that involves two parties who compete and/or cooperate in order to achieve a compromise. One party may engage in multi-bilateral negotiations with selected counterparts. The selection of the counterparts may be arbitrary or defined by a rule, for example, proximity. More complex are multi-bilateral negotiations which are common in business, for example, in sales and procurement. In multi-bilateral processes one person is simultaneously engaged in negotiations with many other parties (e.g., buyers or sellers).

Over the past few years, researchers have been investigating new kinds of auction protocols based on new technological possibilities in order to extend the framework of traditional auctions and to apply auctions to more complex negotiation situations. *On-line auctions* are resource allocation mechanisms based on a multi-bilateral, competitive bidding process over a single or multiple issue/s of one or more well-defined objects (see Sec. 4.4). Thus, on-line auctions possess important characteristics similar to traditional negotiations: They introduce competitive bidding over multiple, homo- or heterogeneous objects and allow for competitive bidding over multiple issues employing utility as a measure of preference instead of price (multi-issue/multi-attribute auctions). This new type of auctions plays an important role in e-commerce. Innovative protocols are likely to be proposed extending auctions' capability in handling complex negotiation situations.

3. Electronic negotiations

3.1 E-negotiations, media and support

In the previous section, we have discussed the similarities between on-line auctions and traditional negotiations, in particular, the ability of on-line auctions to include multiple issues and objects. This is possible through the use of information and communication technologies while traditional negotiations are typically conducted face-to-face. An increasing number of traditional negotiations are now moved on-line, leading to their convergence with on-line auctions and to the concept of the electronic negotiation:

Electronic negotiation, or *e-negotiation*, is the negotiation process (defined in Sec. 2.1) in

which the information is exchanged via electronic media.

This definition covers a whole spectrum of negotiations ranging from unstructured exchange of messages using email and chat systems, to partially structured e-negotiations supported by NSS, NSA or on-line auctioning platforms used for selected tasks, to completely structured negotiations conducted autonomously by computer systems.

In e-negotiations, all communication is performed using an *electronic medium* with electronic (or digital) channels that transport data. Stroebel and Weinhardt (2002) use the media reference model (Lechner and Schmid 1999) to propose e-negotiation media (Lechner and Schmid 1999), i. e. platforms where transactions are coordinated through agent interaction (Stroebel and Weinhardt 2002). The consideration of a medium as a space (physical or virtual) where the negotiation is being conducted and the agents who interact in this space allows distinguishing between three categories of information systems used in e-negotiations:

1. *Negotiation support tools*, such as DSSs and NSSs, assist a decision maker with communication or decision tasks in a negotiation process, e. g. with information gathering, problem structuring, or generation of alternatives.

2. *Negotiation software agents* (NSAs) replace human negotiators in all their decision-making, communication and other negotiating activities. The agents may represent others, e.g., people, or they may engage in negotiations on their own behalf, e.g., a software agent that is responsible for a cluster of printers may negotiate with a number of computers requesting printing services.

3. *E-negotiation media* are information systems comprising electronic channels that process and transport data among the participants involved in a negotiation and provide a platform where transactions are coordinated through agent interaction. They implement the rules of communication in a negotiation protocol.

The distinction reflects the fact that negotiations involve exchange of information and therefore the use of a medium is necessary (e.g., face-to-face, telephone, electronic channels). In an e-negotiation, the medium also defines the virtual space in which the negotiation takes place (Stroebel 2002). Notwithstanding the medium, the negotiators may use certain tools to make better decisions and achieve a better compromise.

The difference between media and support tools is illustrated in Figure 2. The negotiator has to use a

medium (e-market) but may use services of advisors and experts (human or artificial), and DSS and NSS. Negotiator 1 uses these additional services while Negotiator 2 uses only the e-marketplace. The four cascading concepts depicted in Figure 2 for the e-marketplace correspond to the four phases of interactions identified in the media reference model (Lechner and Schmid 1999; Stroebel 2001).

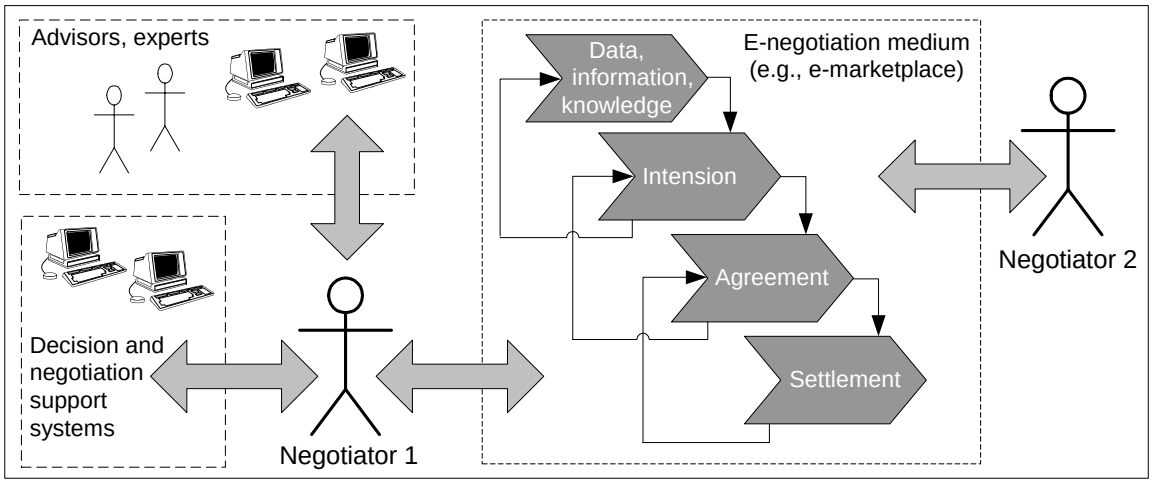

Figure 2. E-negotiations and two categories of systems: media and support

Based on the two types of systems we distinguish three types of e-negotiations:

1. *Unsupported e-negotiations* involve people who control the process and undertake all tasks without support or advice from an information system.

2. *Supported e-negotiations* involve people who control the process and delegate certain decision-making and negotiation tasks to information systems.

3. *Automated e-negotiations* involve software agents that make decisions and control the entire process, including the specification of offers and concessions, and the final decision about agreement or disagreement.

The level of negotiation structuring is related to the above three types of e-negotiations (see Sec. 2.1). Unsupported e-negotiations are typically unstructured, for example those conducted via email or online chat. Supported negotiations must be at least partially structured to allow delegation of some tasks to information systems. Rarely would they be completely structured because of the imposition of strict rules of conduct on the negotiators. Automated negotiations need to be structured so that software agents can conduct them autonomously. Protocols play key role in the automated and, to a lesser degree, supported negotiations. This is because a protocol is used to structure the process and impose

rules of permissible behaviour on the participants.

The above definitions allow for the consideration of different ways of implementation of negotiation activities in e-negotiation media and systems. E-negotiation media comprise the negotiation arena or electronic bargaining table, but they may also provide additional services. In future, the distinction between media and support tools may be defined by ownership rather than by technology and purpose. That is, an e-negotiation medium may provide a wide range of services including those traditionally provided by DSS and NSS but they will be accessible to the negotiators (who may have to pay for them). In contrast, e-negotiation systems are those that are owned or hired by the negotiators to help them, represent their interests, and act on their behalf; or they are the negotiation software agents, that is the negotiators themselves.

3.2 A rationale for electronic negotiation

The computerization of negotiation processes increasingly affects the way businesses interact with their customers, suppliers, and other business partners. Traditionally, firms conducted negotiations with a counterpart in a bilateral manner: face-to-face, in writing, or via telephone and facsimile. Such negotiations are difficult to manage, time consuming, prone to misunderstanding, and require significant cognitive efforts (Thompson 2001). Traditional negotiations suffer from limited transparency of the negotiated issues (e. g. price transparency), meagre liquidity (i. e. a shortage of offers and counter-offers), an ex ante restricted number of potential counterparts (since, for example, the human capacity of handling multiple telephone calls simultaneously is limited) and high transaction costs (i. e. implicit transaction costs such as large bid-offer spreads and explicit transaction costs such as labour and equipment) (Weinhardt and Gomber 1999). Those negotiation processes are rarely efficient and often lead to inefficient compromises (Kersten and Mallory 1999).

The rationale for e-negotiations is, therefore, the promise of higher levels of process efficiency and effectiveness, including the exchange of quantitatively and qualitatively improved information during the negotiation process. Most importantly, e-negotiations promise a higher quality and faster emergence of negotiated agreements. This is because the participants can use negotiation support tools capable of providing support and advice to negotiators and mediators who then can make more informed decisions throughout the negotiation process. In traditional negotiations, the use of negotiation support tools is difficult and awkward because all information exchanged face-to-face must be entered manually during the process.

The design of e-negotiation media, support systems and software agents that matches the diversity of

users, and the richness and complexity of negotiation situations requires categorization and structuring of the latter, and also specification of concepts and constructs. This effort led to the creation of a taxonomy of electronic negotiations comprising types of processes and terms used to describe different types in detail. Raiffa in his seminal work discourages “devising a taxonomy of disputes, in which the listing would be reasonably exhaustive and in which overlaps among categories would be rare. This was possible, I found, only after developing a host of abstract constructs — and even then the taxonomy was not very useful” (Raiffa 1982).

Noting this caveat, we argue that such efforts need to be made. This is because new information technologies are increasingly being used to construct media for engagement in social and economic processes such as negotiation in parallel and independently of the behavioural and normative models of these processes. Results of social sciences should be taken into account in the design of these media and as well as their implications for the processes themselves. In addition, a taxonomy allows for the establishment of a common, unique terminology across disciplines; classification of models and systems; identification of their possible extensions; and for the identification of new constructs and negotiation protocols.

Raiffa (1982) and others point out to the “science and art of negotiations”. The scientific aspects, that is, applications of mathematics to negotiation modelling, are discussed in Section 4.

3.3 A brief review of electronic negotiations

In recent years, a number of information systems and media have been designed, implemented and applied to various negotiation situations. Shim and Hsiao (1999) provide an overview of several web-based NSS. Klein (1997), Beam and Segev (1996), Kumar and Feldman (1998) and Turban (1997) discuss different on-line auction systems. Multi-agent systems in the context of automated negotiations are discussed by Vakali et. al. (2001), and Sandholm (1999) presents an introduction to automated negotiations. The application of multi-agent systems to automated negotiations has been discussed by numerous authors (see e. g. Jennings, Faratin et al. 2001). Recent software frameworks for the design and implementation of e-negotiation media and support tools include DynamiCS (Tu, Seebode et al. 2001), INSULA (Benyoucef, Alj et al. 2001), MAP (Bichler and Kalagnamam 2002), SilkRoad (Stroebel 2000), SMACE (Cardoso and Oliveira 2000), RETSINA (Sycara, Paolucci et al. Forthcoming, 2002), NOMAD (Sandholm and Huai 2000). Examples of e-negotiation media in B2C e-commerce include Kasbah (Chavez and Maes 1996), Tete-a-Tete (Maes, Guttman et al. 1999), COALA (Tsvetovat and Sycara 2000), and SARDINE (Morris and Maes 2000). Kersten (Kersten

1999) and Kersten and Lo (Kersten and Lo 2002) discuss general applications of software agents to web-based NSS and present a NSA. General purpose e-negotiation media are, for example, AuctionBot (Wurman, Wellman et al. 1998), eMediator (Sandholm 2000), and CNSS (Benyoucef, Hakim et al. 2001).

Although, this enumeration is by far not exhaustive it should illustrate the breadth of approaches. Systems like AuctionBot, and SilkRoad fulfil many functions of an e-negotiation medium. They disseminate information, enforce the rules for the message exchange, and provide scheduling and allocation of offerings. The task of resource allocation itself, however, can already be see as a form of decision support. For example, the MAP platform provides winner determination algorithms for various types of offers, which support the evaluation of bids for the bid taker. InterNeg provides decision support for the negotiators in an even broader sense (Kersten 1999).

Commercial vendors also market and offer e-negotiation media. One strand of current software offerings runs under the label “Electronic Procurement” and refers to e-negotiation media which attempt to automate a request for quotation (RFQ) and similar procurement processes in B2B e-commerce. A prominent example is Moai (Raisch 2000), which is marketed as a multi-issue, multiple phase e-negotiation system with an auction and several bilateral negotiation components. Moai allows a negotiation owner to switch from an auction protocol to one or more bilateral negotiations (Neumann and Benyoucef 2002). Perfect Commerce Inc. advertises a system which implements filtering techniques as well as preference ordering and optimisation methods to enable RFQ processes that closely resemble their non-electronic counterparts (Milgrom 2000).

4. Modelling approaches and solution concepts

One reason for the variety of implementation concepts lies in the many approaches and concepts for their study (see Figure 1). In this section we briefly review four key formal approaches negotiation modelling because: (1) the presented approaches have already been utilized in e-negotiation media; and (2) they provide a basis for e-negotiation protocols and media that integrate several approaches. Further work is needed regarding the comparison and categorization of numerous results from the behavioural research which concentrated on such issues as the relationships between the social and individual context and the negotiation process and its outcomes, the communication patterns, cognitive biases, interpretations and misinterpretations, and the relationships between individual characteristics and the process.

Behavioural issues are critical for the adoption of e-negotiations. In the past,they were largely ignored in NSSs and DSSs, which are based on the formal approaches because these systems were designed for the analysts and experts rather than negotiators themselves. E-negotiation media and support systems necessitate integration of the results of behavioural studies in models proposed in decision theory, game theory, negotiation analysis, and auction theory, which we discuss here.

4.1 Decision theory

Negotiations require that the participants make many decisions. The offers, counter-offers and concessions they make in an effort to search for an agreement result from the individual decisions they make. The issues of formulating and solving decision problems, including the specification of feasible alternatives, formulation of decision criteria and preferences, are subject of decision theory. There is vast literature on decision theory, rationality and decision making.

One of the central tenets of decision theory is rationality and its use in the assessment of decision alternatives and choice. It is well known that people often do not conform to the rationality principles even if they are aware of breaking the axioms (Kahneman, Slovic et al. 1982; Nozick 1993; Sethi and Somanathan 2001). Decision theorists' assert that even if full rationality is not attainable, instrumental rationality is, which requires a rigorous approach to gathering and using information about the problem and about the decision-maker (von Winterfeldt and Edwards 1986; Bell, Raiffa et al. 1991; French 1998). This is perhaps one of the most important contributions of decision theory which also is directly applicable to negotiations.

The three central topics of decision theory are: (1) decision alternatives, (2) multiple conflicting objectives, and (3) uncertainty of the decision outcomes (von Winterfeldt and Edwards 1986). Uncertainty of decision outcomes is an important issue which needs to be considered in every decision problem, including negotiations. With the exception of the participants having a different opinion about uncertainty, it is an issue that is inherent to the problem and not subject to negotiation.

The specification of decision alternatives, either implicitly (i.e., with the use of constraints) or explicitly, is performed during the structuring of the decision problem. The development of the problem analytic structure involves the consideration of decision attributes and objectives. The attributes, objectives and alternatives are key aspects of negotiations; decision theory provides a number of well-defined approaches for structuring (Keeney 1992) as well as specific techniques, including decision trees, influence diagrams, and decision tables.

Many decisions are difficult because the decision maker has multiple and conflicting objectives. The contribution of decision theory is to use a preference elicitation scheme and a function which is defined on the objectives and preferences (Keeney and Raiffa 1976; French 1998). This function, under rationality conditions, determines the subjective value of a decision alternative in the case of certainty or the utility—in the case of uncertainty. This function is a measurement function defined on the set of alternatives.

The measurement of alternatives, even if tentative, allows for their precise evaluation and comparison. In negotiations it allows to compare offers and counter-offers, determine differences among them and select concessions that may increase the utility for the counterpart while limiting the decrease of one's own utility. The use of utility functions allows for the achievement of efficient compromises providing that the participants or a third party knows these functions and the set of feasible alternatives.

Given the set of feasible alternatives, it is the utility function that assigns a unique value to each alternative, making the choice of the optimal alternative automatic. Because of the importance of utility, decision analysts propose that this function be constructed carefully and with the help of experts. They apply a preference elicitation and utility construction approach so that the assumptions underlying the multi-attribute utility theory (MAUT) are met. The strict requirements of MAUT and difficulties in utility construction directly by decision makers led to the use of proxy functions without regard for the rationality principles. Such functions as, for example, linear functions of score-weighted attributes, are simple and may be powerful provided that it is not suggested that they meet assumptions of MAUT and the decision-makers realize their tentative and imprecise nature.

4.2 Game theory

Game theory builds on decision theory in that it is not concerned how alternatives and utility values are obtained but what alternatives should be selected in the case of multiple decision makers. Game theory has been used to analyse strategic decisions in such bilateral bargaining decisions and auctions, which would predict particular outcomes for a certain situation.

Nash (1950; 1953) initiated two related, influential approaches. In his 1950 paper, he proposed a model, which defined a rational outcome of bargaining based on information about the participants' expected utility functions over a set of feasible agreements and the outcome. Nash described a two-person multi-item problem with complete information and used the utility theory of von Neumann and Morgenstern (1944). Nash's approach to analysing bargaining, using abstract models, which focus on outcomes, in the spirit of "cooperative" game theory, and more detailed strategic models, in the spirit

of “non-cooperative” game theory, has influenced many researchers.

Harsanyi and Selten (1972) extended Nash’s theory of two-person bargaining games with complete information to bargaining situations with incomplete information and found several equilibria. In dynamic, i. e. sequential games, the players do not bid at the same time, but one player moves and then the other player responds. These dynamic games are more difficult to solve than the static ones. Rubinstein (1982) calculated perfect equilibrium in a bargaining model which involved a pie, two players, and sequential alternating offers of how to split the pie. Vickrey (1961) provided the first formalization of “auctions”. A multitude of advances have been made since then, including Wilson and Kreps (1982), Fudenberg and Tirole (1991), or Chatterjee and Samuelson (1987), but more detailed treatment is outside the scope of this paper.

Game theory is the most rigorous approach towards conflict resolution and allows for formal problem analysis and the specification of well-defined solutions. Game-theoretical bargaining models assume rationality of agents assuming that each agent’s choice can be uniquely described by a utility function. Linhart et al. (1992) summarize several restrictions regarding game-theoretical models of bargaining. For example, human agents are often constrained by the bounds of rationality, which is one reason why game-theoretic models of bargaining are limited in explaining real human negotiating behaviour. Yet, game-theoretic models of bargaining are seen as potential candidates for automated negotiations among software agents.

4.3 Negotiation analysis

The limitations of game theory are well known and rooted in its normative orientation caused mainly by the strict rationality assumptions that are not met in reality Therefore, game theoretic models do not allow for prescriptive advice that is sought by negotiators and their advisers. From the analysts’ perspective it may be reasonable to assume that the negotiator whom the analyst advises is rational, however it is not reasonable to assume the same about the opponent. This observation together with a weakened rationality assumptions provided the basis for negotiation analysis (Sebenius 1992). With the objective of providing advice to one party, negotiation analysis takes prescriptive/descriptive orientation in that it assumes rationality of one party but not necessarily of the other (Young 1991).

Negotiation analysis integrates decision analysis and game theory in order to provide formal and meaningful support. The goal of negotiation analysis is to bridge the gap between descriptive qualitative models and normative game-theoretic models of bargaining. It adopted a number of behavioural concepts (e.g., reservation values, BATNA, integrative/distributive negotiations and principled nego-

tiations) and incorporated them in quantitative models. This way it significantly extended the expressiveness of the models and their capability of describing various negotiation situations. It also allowed analysts and advisors to conduct formal analysis of negotiations and to provide support.

Negotiation analysis tends to downplay the application of game-theoretical solution concepts or efforts to find unique equilibrium outcomes. Instead, negotiation analysts generally focus on changes in perceptions in the zone of possible agreement and the distribution of possible negotiated outcomes, conditional on various actions (Sebenius 1992; Clyman 1995).

The contributions of negotiation analysis include: (1) a subjective perspective on the process and outcomes, (2) concentration on the possible agreements rather than search for one equilibrium point, and (3) acceptance of goal-seeking rather than game-theoretic rationality. This makes an asymmetric perspective possible (Raiffa 1982; Young 1991). Other approaches have a symmetrical orientation: behavioural studies focus on descriptions of the parties and their interactions, game theory and optimisation assume that the parties are rational hence they have symmetrically prescriptive orientation. In contrast, negotiation analysis is used to generate prescriptive advice to the supported party given a descriptive assessment of the opposing parties. In other words, negotiation analysis reconciled several important concepts of behavioural research and game theory.

The purpose of negotiation analysis is to help negotiation analysts and advisors. Therefore its perspective is external to the negotiator and negotiations. Furthermore, the assumption underlying the approach is that the analysts possess knowledge that is not embedded in the model. These are the key reasons for strong impact of negotiation analysis on the academic community and negotiation teaching (Young 1991; Thompson 2001) but much less on the construction of models and design of NSSs, including those discussed in Section 3.3.

The purpose of NSSs is to support the negotiators themselves rather than analysts but negotiation analysis is concerned with the analyst's work. A related difficulty in applying negotiation analysis is the assumption that the negotiator conforms to the rationality principles. We mentioned in Section 4.1 that this is rarely the case and therefore NSS and NSA designers seek models that are easy to use and capable of providing support irrespectively of violation of rationality assumptions. We need to add, however, that the interest of the negotiation analysis proponents in the real-life situations and processes and their success in relating concepts proposed in behavioural studies to formal constructs (e. g., BATNA) had a strong and lasting impact on decision and negotiation support research.

4.4 New directions in auction theory

Auction design and strategies have been a focus of researchers in game theory; over the years scholars

in the field have developed a thorough classification and terminology. Early contributions were made by Vickrey (1961). Many game theorists and experimental economists have been analysing strategic aspects of both single-sided and double-sided auction institutions thereafter (Wolfstetter 1996). As already discussed, traditional auction games are restricted to price-only negotiations however; new approaches to auctions enable structured negotiations over both price and other attributes.

A fairly wide-spread extension to price-only auctions are multi-unit auctions in which bidders submit both the number of units of an item they wish to buy and how much they are willing to bid for the overall quantity. Volume-discount auctions are an interesting extension of multi-unit auctions (Tenorio 1993). These auctions can be used in a procurement context where bidders are allowed to specify the price they charge for an item as a function of order quantity. Bids take the form of supply curves that specify the price to be charged per unit of item when the quantity of items being purchased lies within a particular quantity interval (Kalagnanam, Davenport et al. 2001).

Combinatorial auctions (also referred to as multi-item or bundle auctions) are an approach to achieving efficient allocations in situations where bidders are allowed to place bids on combinations of possibly heterogeneous goods or services (Rothkopf and Pekec 1998; Sandholm 1999). An example is a bid on a group of adjacent real estate properties or a bid on connected shipping lanes (bundle bidding). A winning bid on a shipping lane between two production plants is of higher value for a shipping company if she also wins the lane in the opposite direction, i. e. the bids for a combinatorial bid on the two shipping lanes are higher than the bids on the individual lanes. A well-known example is the new design for the US FCC spectrum auctions, where bidders, comprised of US telecommunication companies, cellular telephone companies, and cable-television companies, compete to win various spectrum licenses for different geographical areas. The synergies arising from owning licenses in adjoining geographical areas create dependencies in (some) bidders' valuations for individual licenses (Cybernomics 2000).

Another interesting auction type is the multi-attribute auction (Bichler 2001) where bidders are allowed to submit multi-attribute bids and therefore negotiate not just on price but quantity and qualitative attributes. Usually, multi-attribute auctions describe bids as a set of attribute-value pairs. Extensions thereof allow also for configurable offers and/or multiple sourcing (Bichler and Kalagnamam 2002). The various extensions to traditional auction theory are sometimes called multidimensional auctions. They allow more degrees of flexibility in a negotiation through the efficient exchange of rich offer information.

Often, however, multidimensional auctions face the limitations of computability when their rules require the solution to NP-hard optimisation problems. The complexity of such allocation problems has attracted the attention of computer scientists and mathematicians. With richer bid data, also other problems need to be solved. For example, topics like information revelation needs a more thorough analysis, as the amount of information revealed during the bidding process might reveal unwanted private information about a bidder (Beil and Wein 2001). Yet another issue is preference elicitation (Conen and Sandholm 2001). The bid taker's preference in a traditional auction is easy to identify, but having an accurate model of a buyer's preference has shown to be a key issue for multidimensional auctions.

But even a computationally efficient auction design, implementing a theoretically well-understood economic design, may not lead to the predicted outcome. Indeed, human participants may show limited rational behaviour, or base their decisions on exogenous criteria. Laboratory experiments provide an excellent means to analyse new mechanisms with human participants. Unfortunately, at this point in time the experimental literature on multidimensional auctions is still scarce.

5. Towards an electronic negotiation engineering

As we have already pointed out, designing negotiation protocols and associated e-negotiation media has become an important issue for electronic commerce. Although, there are many scientific approaches to analysing and designing certain negotiation protocols and related decision support components, a solid engineering practice for e-negotiation media has not yet emerged. In practice, the development of e-negotiation media is still more of an art than a science, and depends largely on the creativity and know-how of a certain engineer. There is little knowledge about what to consider during the analysis, which protocols are suitable for a certain negotiation situation and how to evaluate the outcome of a negotiation.

5.1 Electronic negotiation protocols

The implementation of every model in an information system brings forth certain rules of interaction that those who use this medium must follow. These rules need to be specified so that agents (human or artificial) know the permissible set of actions. An *e-negotiation protocol* is a model of the negotiation process in which at least some activities are supported or performed by information systems and the negotiations are conducted with an electronic medium.

The e-negotiation protocol may be complex and with many rules governing the parties as they move

through different stages and phases of the negotiation process. For example, an e-negotiation may begin with an auction and, after three winning bidders have been identified, move on to a bilateral bargaining protocol among the three winners.

Typically, designers try to achieve certain goals for the outcome of a negotiation and for the negotiation process itself, such as, Pareto optimality of the result, maximization of the bid taker's revenue/utility, stability, and speed of convergence (Jackson 2000). These objectives are achieved through:

1. Specification of the structure of the negotiation problem and process
2. Specification of rules of feasible activities, and their sequencing and timing; and
3. Imposition of limitations on the form and content of information exchange

Every e-negotiation protocol restricts the negotiators' freedom in order to meet one or more of the above objectives. A *closed e-negotiation protocol* is one that is defined and fixed prior the negotiation process so that new rules cannot be added throughout the negotiation. A closed negotiation protocol can cover various negotiation situations but the set of rules is fixed and the rules cannot be modified. Implementations of traditional auction formats such as the Dutch or English auction are good examples of a closed e-negotiation protocol.

An *open e-negotiation protocol* does not contain all rules required for the negotiation; they may be constructed by the participants or by mechanisms during the negotiation process. In both cases, this involves learning about the participants, problem and process; the results of learning are new rules that were not present prior to the e-negotiation.

Complex electronic negotiation protocols often involve a combination of two or more different classes of negotiation protocols and thus exhibit the characteristics of multiple negotiation models in either sequential or parallel execution. For example, in financial markets continuous double auction protocols have been combined with bilateral chat markets (Budimir and Holtmann 2001) where a trader can select an offer and engage in a bilateral chat with the respective counterpart.

5.2 A pattern language of electronic negotiations

As we have seen, many academic disciplines provide valuable contributions to the overall design of e-negotiation systems, and researchers are now in a position to combine the different techniques and support or automate a variety of complex negotiation situations. During the past couple of years a number of promising prototypes has been developed (see Sec. 3.3). Some of these e-negotiation media use behavioural or decision theoretic models to implement negotiating agents. Others extend tradi-

tional auction theory to other types of negotiations. Some of these protocols have been tested in the laboratory; others have been deployed in the field.

Unfortunately, there is still little guidance for a systems engineer, who needs to develop an e-negotiation medium for a particular environment. Of course, once a negotiation protocol has been selected traditional software engineering methods can be used to design and implement an appropriate information system, but currently, there is little help in either selecting or adapting such an e-negotiation protocol. In many cases traditional price-only auctions are used as the protocol of choice, simply because they are well known and easy to implement. A thorough analysis of the particular negotiation situation is missing, ignoring the benefits alternative negotiation protocols such as combinatorial auctions or bilateral NSS can achieve. In other words, the *requirements analysis* is often a weak point throughout the development of e-negotiation media.

As in every engineering project, the software engineer needs to have a clear understanding of the environment, the goals of the system, and the alternative negotiation protocols that are available. This understanding includes (see Section 5.1):

- Characteristics of the negotiation objects in question. These objects might be characterized by price, quantity, and/or qualitative attributes.

- Characteristics of the participating agents such as computational power, rationality, or risk attitude. In addition, agents might have private values for an object or the object has some common value or resale value for all agents.

- Properties of the alternative e-negotiation protocols, such as incentive compatibility, convergence towards an equilibrium, or speed of such a convergence.

- Properties of a solution to an e-negotiation protocol, such as Pareto efficiency, revenue maximization, or stability.

All of these aspects need to be considered in a systematic way when designing e-negotiation media. The software engineering community has developed a number of techniques to support the analysis and design of complex systems. *Design patterns* have become a wide-spread means to transfer knowledge about successful designs. They are more or less formalized descriptions of solutions to certain problem classes, and are well suited to establish a body of knowledge for a particular application domain (Fowler 1996).

The term “negotiation” covers a huge, unstructured domain of coordination problems. There is little knowledge about the different negotiation situations and the various protocols and algorithms which can be used to get to a compromise. This includes different techniques to elicit preferences, evaluate offers, and calculate settlement prices. A pattern language of negotiations could establish successful solutions to particular problem instances, i. e. negotiation situations, and at the same time establish a language to communicate about and name successful designs. A *negotiation pattern* can describe

- Possible rules of the message exchange
- Suitable algorithms for preference elicitation and bid evaluation
- Roles and strategies for participating agents

Scientific and practical advances will continually produce new tools, algorithms and protocols to support negotiations. Together with the results from laboratory and field experiments, a pattern library could be a helpful tool for a more thorough discussion about new designs and their use in practice.

5.3 Engineering of electronic negotiation media

Requirements analysis and design are only two of the steps throughout the software engineering lifecycle. We believe that there are several aspects of negotiation media, which require special attention throughout the development process.

- Negotiation media are based on a set of algorithms for tasks like preference elicitation, bid optimization, bid evaluation and allocation throughout the negotiation process, very much like database engineering is based on a number of algorithms for storing and searching data. The characteristics of these algorithms impact the design of the overall protocol and therefore need special treatment.

- There are additional requirements concerning the *testing and evaluation* of negotiation media, due to the behavioural characteristics of the negotiators, the stochastic nature of the input and the strategic aspects of the message exchange. The evaluation of negotiation media has to include properties of negotiation protocols such as allocative efficiency and speed of convergence. Numerical simulations and experimental methods will therefore be an integral part of the development lifecycle.

- E-negotiation media are inter-organizational information systems; many people and from different organizations may participate in their design.

We believe that an engineering approach towards the development of e-negotiation media is not only possible but highly desirable because it may contribute to the improvement of the quality of real-world negotiation media. The above features require the development of new methods and algorithms, which are not yet part of the traditional software engineering literature. For a further advancement of the field, we need to add analytical techniques from economics and applied mathematics and the qualitative and quantitative approaches from behavioural sciences and experimental economics. It requires a structured process to combine these methods in a meaningful way and design systems, which consider the variety of computational, social and economic aspects of real-world negotiations.

6. Summary

In this paper, we describe the emerging field of electronic negotiations and argue for the need to engineer e-negotiation media. We sketch out an engineering approach towards developing electronic negotiations and argue in favour of an interdisciplinary engineering approach to promote an increased understanding of the variety of contributing factors to understanding, modelling and designing negotiations.

As a starting point for multidisciplinary research efforts, we provide a common framework of terms and concepts which, in addition to formal approaches, facilitates an incorporation of results of multiple disciplines and especially of behavioural studies into an engineering approach. Based on the proposed terms and concepts, suggestions for the integration of relevant approaches to negotiation representations are formulated and numerous references to existing works from many different fields of studies are given.

Several questions arise in this context: Which assumptions can we make about negotiators, both in terms of rationality and computational capabilities? Besides, how should we treat the issues of culture, ego and pride? These issues certainly play an important role in many real-world negotiations. Where do we need to take these issues into account? Is it better to rule out these issues? For example, in a procurement negotiation one could argue that the outcome of the negotiation should be independent of the procurement specialist’s ego and pride.

Our intension is to present a basis for future research directions including studies on the integration of behavioural and formal approaches to design expressive and effective e-negotiation processes, relationships between the negotiation problem and context and the effective e-negotiation approach, specific opportunities and limitations of e-negotiations, and the appropriate levels of e-negotiation automation for different types of problems and categories of users.

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