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The Science and Engineering of E-negotiation: Review of the Emerging Field

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Abstract. An increasing number of negotiations are conducted via electronic media allowing for an extensive use of software in negotiators' activities. Traditionally, negotiation support was based on normative and prescriptive research; its users were analysts and experts. The purpose of the recently developed e-negotiation systems is to provide negotiators with services and to satisfy their requirements rather than direct their activities so that they conform to rationality and optimality principles. This orientation is typical to software engineering. Due to the difficulties in reconciling results of prescriptive and descriptive studies the e-negotiation design specifications are often based on selected descriptive approaches at the expense of the prescriptive support. This paper presents selected results from negotiation and e-negotiation research and provides specifications for e-negotiation system design and development. Following the review of decision and negotiation analysis, and negotiation support and negotiation systems, methodological foundations are discussed. Based on review of methodological foundations and the scientific and engineering perspectives on negotiations, an e-negotiation view integration model is proposed. This model integrates behavioural, scientific and engineering views on e-negotiation support and the media reference model.

Keywords: negotiations, electronic negotiations, negotiation analysis, decision support systems, software agents, software engineering, decision making, modelling, electronic media, protocols

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1. Introduction

Negotiation is a process of social interaction and communication that involves distribution and redistribution of power, resources, and commitments. It involves two or more people who make decisions and engage in exchange of information in order to determine a compromise. Many important decisions have to be negotiated because people need to share and distribute scarce resources. The interpersonal character, the participants' independence as the decision-making entities and their interdependence in their inability to achieve goals unilaterally contribute to the negotiation complexity.

The decision-making aspect of the negotiation process requires that participants collect and process information to determine feasible alternatives, and to formulate offers and arguments. The communication aspect of negotiations involves information exchange, including offers and arguments, in order to influence and motivate the participants' counterparts. Collecting and processing new information involves learning, leading to modifications and adjustment of the decision problem, and the interaction and communication.

Internet technologies allowed deployment of negotiation support systems (NSS) on the Web. They also made possible the design of new types of systems that can actively participate in negotiations or undertake the negotiation on their own.

Several systems based on applied mathematics have been implemented and used in research and training (Yuan et al. 1998; Kersten and Noronha 1999b; Bui et al. 2001). They show the potential of decision-theoretic models in e-negotiations. Software agents and choice models based on collaborative filtering and recommender models reinforce the engineering, user-oriented approach to negotiations. A number of prototype systems have been developed and tested with the purpose of providing a complete or partial automation of negotiations; these provide support, suggest offers and predict outcomes based on past experience (Guttman and Maes 1998; Maes et al. 1999; Sandholm 1999a). The orientation on practical relevance and user satisfaction is even more evident in systems deployed on the Web that provide electronic negotiation platforms for business and other organizations (FreeMarkets 2002; Moai 2002; Ozro 2002).

These few examples illustrate efforts for the design of human-machine systems that incorporate certain results of applied mathematics. Many of these systems were designed from the software engineering point of view and their objective was to meet users' requirements and solve their practical

problems.

Economic and social sciences recognized that people are often biased and make routine mistakes and misrepresentations. Tools that allow making decisions faster may amplify the impact of the mistakes because their users have less time to ponder and search for alternatives. Rather than focusing on decision-making speed and efficiency the initial effort should—I argue here—be focused on learning and understanding both the decision-makers themselves, their decision problems and the solutions possible implications. This imposes an important requirement on the decision and negotiation support systems, and, in particular, the systems for electronic negotiations that people use to jointly deliberate and solve problems. System designers need to consider both qualitative and soft, and quantitative and hard aspects of the negotiation process.

During the past few decades a variety of approaches and models of negotiation process have been proposed. Researchers used different assumptions, terminologies and notions to formulate concepts and models. This led to inconsistencies and contradictions (Gulliver 1979, p. 69) making integration of complementary models difficult. Such integration is necessary to construct systems that meet all requirements of their users rather then a selected few.

The proliferation of electronic marketplaces and virtual organizations, and the increasing collaboration among people and organizations using Internet technologies will lead to the design and development of new systems. These efforts will be undertaken by computer scientists and software engineers because they have the required expertise. They need systems that meet various user requirements and facilitate efficient negotiations sometimes leads—as we witnessed in several studies and on-line systems—to the use of methods that are effective but not necessarily correct from the decision- and game-theoretical viewpoints. One reason is that there is a lack of methods and procedures that can be readily adapted to design systems capable of providing comprehensive support to negotiators or engaging in negotiations. Researchers in negotiations need to take a fresh look at their work and provide guidance regarding the implementation of methods and models they devised.

To make the efforts in the development of negotiation systems better informed we need to take a fresh look at the negotiation models and methods from the perspective of their design, implementation and use. On the one hand, recent work on negotiation support systems and negotiation software agents has created some new opportunities and posed new questions for negotiation research. On the other, the richness and complexity of negotiations is matched with multiplicity of research perspectives from many different fields. The results are often difficult to compare and integrate.

This paper makes an attempt to integrate a number of results in negotiation research from the perspective of their use in the design and development of information systems which aid negotiators and which undertake some or all negotiation activities. These systems participate in *electronic negotiations*, or *e-negotiations*: processes in which information is formulated, exchanged via and processed with, the use of software. The focus is on *multi-issue bilateral negotiation* supported or conducted by software.

In Section 2 we review the use of email for negotiations, Web-based negotiation support systems (WNSS) and negotiation software agents (NSA). The three perspectives to study and model negotiations, and the proposed four views representing the science of negotiations are discussed in Section 3. These four views are used to distinguish five types of negotiation models describing the problem, negotiators, protocols, argumentation and knowledge. These models are discussed in Section 5. The software engineering views on e-negotiations presented in Section 6 correspond to the scientific views. The scientific and engineering views, and the five types of models, are used to compare the existing systems presented in Section 6. In this section an *e-negotiation view integration* (ENVI) model is proposed. The purpose of ENVI is to provide a basis for the integration of perspectives, approaches and models from economic and social sciences, computer sciences and information systems, and management to design e-negotiation processes and systems. Section 7 presents conclusions and future work in e-negotiation engineering.

2. E-negotiation processes and systems

2.1 System activities and types

E-negotiations are negotiation processes that are fully or partially conducted with the use of electronic media (EM), which use digital channels to transport data. EM may support simple communication acts between the participants (e.g., email, chat) or provide tools that allow for complex, multimedia interactions (e.g., e-markets, electronic tables). The concern of EM is to transmit and present content in a way that can be used by various participants, both human and artificial. EM are not concerned with the way this content is produced and with the use of resources required for production. They deal mostly with the three two types of activities listed below, which may be computationally complex and lead to insights and better understanding through, for example, the use of different visualization techniques, and search and retrieval of information. Other types of activities are

The use of computer and communication technologies in e-negotiations allows for the following

types of activities to be undertaken by e-negotiation software:

Table 1.

	Activity	
1.	Transport, storage	
2.	Search and retrieval	
3.	Format and presentation	Data formatting for other systems use; data visualization, alternative data presentation.
4.	Decision problem formulation	Formulation and analysis of the decision problems; feasible alternatives; decision space, measurement.
5.	Decision-maker specification	Specification of constructs describing decision makers; preferences, measures for alternative comparison; decision-makers' models, negotiators' styles.
6.	Offer and message construction and evaluation	Formulation of offers and concessions; analysis of messages and arguments; argumentation models
7.	Counterpart analysis	
8.	What-if and sensitivity analyses	
9.	Process, history and their analysis	Construction of the negotiation history; process analysis; progress/regress assessment; predictions.
10.	Knowledge seeking and use	Access and use of external information and knowledge about similar negotiation situations and specific issues arising during the process, comparative analysis.
11.	Negotiation protocols	Specification of, and adherence to, the negotiation agenda and rules
12.	Strategies and tactics	Formulation, implementation and assessment of strategies and tactics

Within each type there are various tasks; some require negotiator intervention, others can be conducted by software autonomously. The division of the scope of involvement between the negotiator and software in the activities depends on the *level of negotiation automation*. On one extreme, the negotiator controls the conduct of every activity. On the other end of the spectrum the negotiator pro-

vides the system with information about the problem, a measure for alternative comparison and the negotiation rules, the system then engages in the negotiation on behalf of the user. Based on the level of support and automation four broad types of e-negotiations are discussed.

In addition to EM, there are several other systems that for some time have been used in decision making and negotiations. Some DSS, NSS, KBS, as shown in Figure 1, were developed to provide support to individual negotiators; others to facilitate activities involving two or more negotiators. These systems contribute to content production; through interactions with their users they formulate sets of feasible alternatives, choice functions, reservation levels, profiles of the negotiators and other constructs used in decision-making and negotiations. With the introduction of the reasoning capability such systems as negotiation software agent (NSAs) can engage in negotiations autonomously thus producing content with little or no input from people.

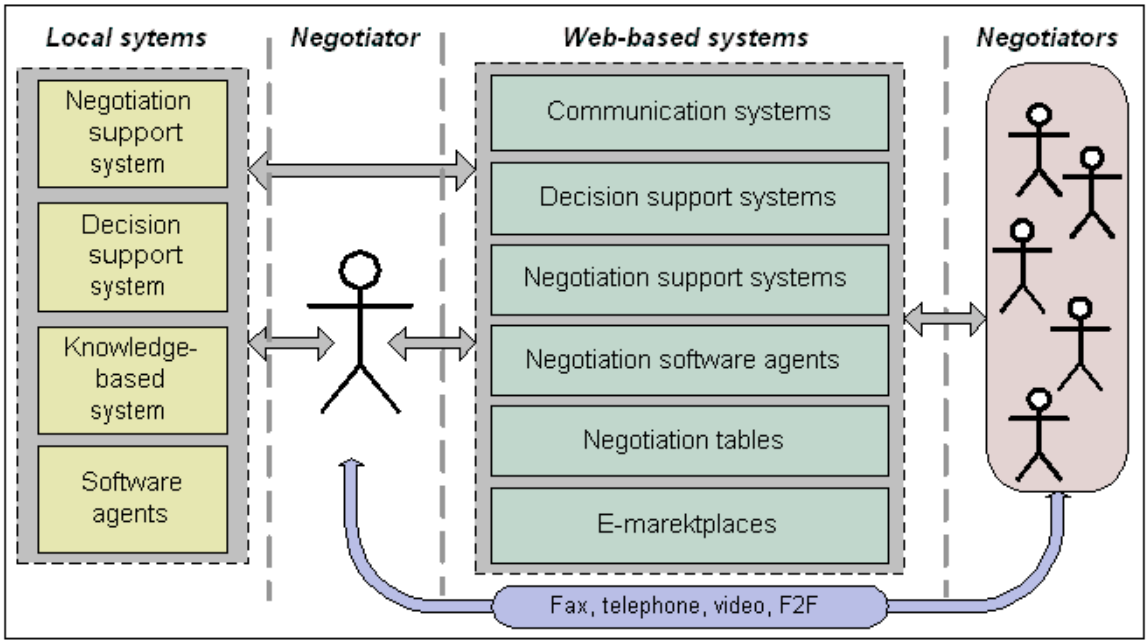

Figure 1. E-negotiation tools, systems and media

E-negotiation is a process in which both people and information systems (ISs) participate. In Figure 1, the possible interactions are indicated. A negotiator may use resources available on the Web (e.g., an NSS) to negotiate with other negotiators. She may also use local systems for decision-making support (e.g., a DSS) or she may act as a principal with a local system communicating with a Web-based system, possibly negotiating on her behalf. A negotiator may also hire an NSA and use local resources to communicate and supervise the NSA.

The e-negotiation may be undertaken solely with the use of Web-based systems or it may be augmented with traditional communication media, such as fax or face-to-face (F2F).

Traditional negotiations may also use local ISs; what distinguishes e-negotiation from them is the use of Web-based systems. All these systems use digital media to establish communication and interaction between people and/or other systems.

2.2 Communication systems

The simplest form of the e-negotiation involves the use of email to exchange offers and messages. Email negotiations require a mail server and a client program, both of which are widely available; and no training is required to use the software. There is neither support nor automation available with, the exception of the exchange and storage of messages.

Email negotiation, because of its minimal utilization of the capabilities of computer systems, is probably a temporary form of negotiation and will be replaced with a more advanced systems that utilize Internet technologies and integrate communication systems with information systems. They are included here because email is currently used in negotiations and because its use was the subject of several descriptive studies (Croson 1999; Maruca 2000; Purdy and Neye 2000; Thompson and Nadler 2002). These studies illustrate the difficulties of categorization of negotiations in which IT is used and comparisons of e-negotiations and face-to-face negotiations.

The use of email, listservers and similar technologies in computer-mediated communication has been widely studied since the late seventies (Hiltz and Turoff 1978). Introduction of the electronic communication channel in DSSs led to early computer-mediated negotiation with NSSs (Lim and Benbasat 1992). A number of NSSs were developed and used in research and training, leading to the construction of systems with active mediating and facilitating facilities. The consideration of email negotiations as ‘computer-mediated’ and using a ‘particularly important type of information technology’ (Croson 1999; Thompson and Nadler 2002) focuses on communication at the expense of information processing. Email is important because of its ease of use, popularity and very low cost but it shares many characteristics with old fashioned mail and fax. Valley et al. (1998) show that communication media influence negotiations and also that there are similarities between ‘pen and paper’ and email negotiations.

Negotiations conducted via email and via mail both use a post-office system. Although there are differences between these two forms of the negotiation, e.g., time between exchanges, the concept of

exchanging written messages in an asynchronous mode is the same. In both the communication bandwidth is narrow, the written (typed) medium reduces engagement in non-task related activities, a number of confrontational tactics, e.g., demanding immediate answers, are not effective, and there is more opportunity for a careful consideration of the process. These observations were made in comparisons of email and face-to-face negotiation (Croson 1999; Thompson and Nadler 2002); they may however, be the same if email was replaced with mail of fax. Observations of four biases affecting email negotiation: temporal synchrony, burned bridge, squeaky wheel and sinister attribution (Thompson and Nadler 2002) can also be attributed to mail- and fax-based negotiations.

Descriptive studies of email negotiation resulted in three types of observations: (1) the need to increase the communication bandwidth; (2) the role of non-task related activities on the process and outcomes, and (3) the potential of support tools. Narrow communication bandwidth and the non-task related activities are of particular importance for negotiators who need to establish rapport, trust and reduce the social-distance with the other party, and who employ positive or negative emotional style as opposed to the rational style (Kopelman et al. 2001). However, because in all these studies the subjects were students, the role of rapport, trust and social-distance between the negotiators may be different when the negotiators represent organizations and when they conduct many similar negotiations.

The potential of support tools is of particular importance for the design of e-negotiation systems. Email negotiations contribute to more equitable outcomes (Croson 1999) and increase exchange of multi-issue offers (Thompson and Nadler 2002) but require more time (Sheffield 1995) and more often result in an impasse (Thompson and Nadler 2002). This indicates that asynchronous exchanges allow for reflection and consideration of several issues simultaneously rather than sequentially. It also shows the need for support to increase process efficiency and search for agreements, as well as to provide facilitation and mediation.

2.3 Negotiation support systems

Introduction of the electronic communication channel in DSSs led to early computer-mediated negotiation with NSSs. A number of NSSs were developed and used in research and training, leading to the construction of systems with active mediating and facilitating tools. The purpose of early NSSs was to study and teach negotiations, mostly in the university setting (Kersten 1985; Jarke et al. 1987; Thiessen and Loucks 1994; Rangaswamy and Shell 1997). These systems were used in local area networks making their applicability to support real-life negotiations difficult. Internet technologies and the Web allowed for a new generation of NSSs which can be accessed by business, educational

and other organizations.

2.3.1 Research and training

The Inspire system, arguably the first WNSS, was developed in 1995 to provide training resources and to study the use of support tools (Kersten and Noronha 1999a; Kersten and Noronha 1999b). Inspire negotiations follow the phase process proposed in the descriptive literature; the negotiation progresses through pre-negotiation analysis, conduct of the negotiation and post-settlement (Gulliver 1979; Graham et al. 1994).

Inspire attempts to use decision analytic methods in an instrumental rather than prescriptive manner. It uses hybrid conjoint analysis to construct ratings of all alternatives. The process of preference elicitation is not verified which allows users to be inconsistent, for example the seller may assign a lower value to the highest price than to a middle price. From discussions with some users this reflects their assumption that extreme values are not realistic and they wish to obtain a high rating. While this has happened in less than 8% of the negotiations it indicates the need for consistency verification.

The ratings are displayed with each alternative the user considers, and with offers sent and received. Users may ignore the values, however most of them found utilities very useful (Kersten and Noronha 1999a). They may modify their preferences and thus the utility during the e-negotiation. In real negotiation, utility revision should take place in light of new information. Interestingly, in Inspire negotiations some users modified their preferences in response to positive actions of their counterparts.

There are many limitations in the Inspire system including a fixed set of alternatives, limited use of visualization and a narrow communication channel (Shim and Hsiao 1999). Its process support is limited to the requirement to follow a priori defined negotiation phases; it does not help users to seek joint improvements during the negotiation phase although it suggests efficient alternatives in the post-settlement phase. The system elicits such negotiation constructs as reservation and aspiration levels but it does not use them in offer assessment.

WebNS is another example of a WNSS (Yuan et al. 1998; Yuan et al. 1999). It focuses on process support, in particular on structuring of text-based exchanges and automatic process documentation. The system implements three negotiation phases based on Gulliver's descriptive model (1979).

The WebNS system supports the specification of, and discussion about, issues. The focus on the process can also be seen in the sequential negotiation approach which is often used in real-life nego-

tiation due to the difficulty in discussing all or many issues at the same time. In WebNS each issue is separately discussed and the information is displayed in the window containing the user messages or in the window with the counterpart's messages. When the parties reach an agreement about an issue the agreement is displayed in the 'common' window. An interesting feature of WebNS is the possibility of introducing a facilitator or advisor into the process. The advisor monitors the exchanges and establishes communication with one party; a facilitator interacts with, and provides advice to, both parties.

The descriptive and process-driven approach is both strength and a weakness of this system. It facilitates text-based exchanges allowing for bookkeeping but no analytical and solution-driven support is available (Shim and Hsiao 1999).

The experiments with these two systems, and also with ICANS, the system that led to a commercial system One Accord (discussed in Section 2.3.2) show the potential of WNSS in teaching, self-learning and research. They also show the potential of analytic methods for the preparation and conduct of e-negotiations; 75% of almost 5,000 Inspire users stated that they would use a system like Inspire in real-life negotiations and 85% would use such a system to prepare themselves to conduct actual negotiations (Lo and Kersten 1999).

2.3.2 Commercial systems

During the last few years several systems have been deployed on the Web with the specific purpose of providing negotiation support to consumers and businesses. CyberSettle (2000) is an online system that supports its users to negotiate insurance claims over the Web. It implements conflict resolution process based on the parties' agreement zone. The parties follow a well-defined protocol: one party (the insurer) specifies three minimum levels, one for three rounds of bargaining. The claimant enters an offer and the procedure determines if the agreement zone exists, if it does not, the claimant enters another offer. This continues until the third round; if there is no agreement, the parties need to restart the negotiation or use other means.

LiveExchange (Moai 2002) and EcommBuilder (Ozro 2001) also provide process-oriented support in e-negotiations but they are capable of handling multi-issue and multi-stage negotiations. The focus of EcommBuilder is to facilitate various business processes involved in commercial negotiations. It provides users with databases of potential clients (buyers and sellers) and with information about products. The process-oriented support allows for secure exchange of information between the parties, logs of the exchanges, exchange of attachments, generation of orders and forms, and legal support.

The system provides forms for many processes, including purchase orders, order and contract volumes, sales terms, request for proposal, master purchase agreement, bill of materials, delivery scheduling, payment methods, and shipping and delivery terms. EcommBuilder enhances commercial relationships by managing rules and processes at three levels: (1) the business rules of both the buying and selling enterprises; (2) the rules of the marketplace entity, whether public or private; and (3) the commercial rules of domestic and international trade with which all enterprises and marketplaces must comply.

SmartSettle, formerly One Accord, (SmartSettle 2002) is a commercial system which is an extended and ported on the Web version of a research system ICANS (Thiessen and Loucks 1994; Thiessen et al. 1998). The system uses decision analytic techniques to facilitate and support negotiations. Therefore it requires that users define the negotiation problem, agree on all negotiated issues, and determine individual sets of feasible alternatives, rating functions and satisfaction levels. These tasks are supported by a human facilitator.

The SmartSettle system provides stronger support than, for example, Inspire; because it facilitates the process using users' private information. When the parties enter their offers, it searches for a feasible alternative that is not worse than their offers. If such an alternative exists and the parties accept it as a tentative agreement then the system determines its efficiency; if it is not efficient it suggests directions for joint improvements leading to a Pareto-optimal agreement. If there is no feasible alternative which is not worse than the offers proposed by the parties, the system selects one for which the sum of the ratings is as close as it is possible to the sum of the ratings of the offers.

The analytical support of SmartSettle has its roots in decision and negotiation analysis and its objective is to direct the parties towards the Pareto-optimal frontier. It provides prescriptive advice but the parties need not follow it and they can select an inefficient agreement. It also makes use of descriptive concepts such as BATNA and satisfaction levels. In that the system utilizes both descriptive and prescriptive approaches to negotiations; it gives the parties freedom to make decisions but makes suggestions regarding possible compromises and directions for joint improvements. The strength of the system is also in its integration of human facilitation in the pre-negotiation phase with extensive analytical support during the negotiation and post-settlement phases.

2.4 E-negotiation tables

During the last few years several systems have been deployed on the Web with the specific purpose of providing negotiation support to consumers and businesses. An e-negotiation table in its simplest

form is a virtual meeting space where the parties can post offers, messages that only they can access. This service is provided by organizations which often provide additional services, including matching, mediation, legal and competitive analysis.

CyberSettle (www.cybersettle.com) is an online system that supports its users to negotiate insurance claims over the Web. It implements conflict resolution process based on the parties' agreement zone. The parties follow a well-defined protocol: one party (the insurer) specifies three minimum levels, one for three rounds of bargaining. The claimant enters an offer and the procedure determines if the agreement zone exists, if it does not, the claimant enters another offer. This continues until the third round; if there is no agreement, the parties need to restart the negotiation or use other means.

TradeAccess is an example of an e-negotiation table which, in addition to providing a meeting space gives access to a number of tools. TradeAccess was oriented to purchasing negotiation and provided an easy to navigate and well structured space for bilateral interactions. It maintained a database of potential buyers and sellers, and provided access to contract forms and access to lawyers in different jurisdictions. The company was bought by Ozro Inc. which closed TradeAccess and replaced it with an e-markets discussed in Section 2.6.

2.5 Software agents

Negotiation software agents (NSAs) conduct autonomously selected tasks on behalf of their principals, that is, human negotiators. One of such tasks involves selection of a product and its supplier; several agents were developed for this purpose. BargainFinder, the first shopping agent, has been used in merchant brokering (Maes et al. 1999). The objective of the BargainFinder agent, designed by Andersen Consulting in 1995 was searching the Web to provide the principal with the product she sought at the lowest price. This agent required full specification of the product and was capable of searching for CDs only. Jango is the first comparison shopping agent developed by Etzioni and Weld at the University of Washington and later sold to Excite.com (Karpinski 1997). It is capable of searching for different products with the use of a collection of "information adapters" which are written for each merchant site and product reviews site to identify and retrieve product information.

We mention here also PersonaLogic and Firefly because they are considered software agents capable of product brokering (Maes et al. 1999). Because they are not autonomous and cannot undertake tasks independently they are more of Web-enabled DSSs which help users to make decisions. PersonaLogic is an early Web-based implementation of a decision-theoretic model, that is, the analytic hierarchy process (Saaty 1980). Its user was asked to select a product-type from the available list, specify

the feasible set of products, and select and weight product attributes. The system determined rating function and displayed top-rated products selected from the database. Firefly uses information about some products that the principal knows or owns, to suggest products that the principal may be interested to purchase. The Firefly choice model applied in product selection is collaborative filtering discussed in Section 4.2.2.

Software agents can also be used in conjunction with NSSs with the purpose of providing: (1) help in the system use and aunderstanding of its requirements; (2) advice regarding the startegy, tactic and the formulation of offers, concessions and arguments; and (3) interpreting the counterpart's moves. An example is Aspire which is an integration of Inspire (see Section 2.3.1) and Atin, a negotiation support agent (Kersten and Lo 2002). Atin continuously monitors the negotiation process independently of the user activities. The main reason for linking Atin with the Inspire is to provide users with context-dependent support about the use of the system. Based on the descriptive models of negotiation strategies the agent also provides advice regarding the negotiation process, and parties' tactics and strategies.

2.6 E-markets

LiveExchange (www.moai.com) and EcommBuilder (www.ozro.com) are two examples of e-markets that—similarly to some NSS and e-negotiation tables—provide process-oriented support in e-negotiations. They are also capable of handling multi-party and multi-issue negotiations. The focus of EcommBuilder is to facilitate various business processes involved in commercial negotiations. It provides users with databases of potential clients (buyers and sellers) and with information about products. The process-oriented support allows for secure exchange of information between the parties, logs of the exchanges, exchange of attachments, generation of orders and forms, and legal support.

The system provides forms for many processes, including purchase orders, order and contract volumes, sales terms, request for proposal, master purchase agreement, bill of materials, delivery scheduling, payment methods, and shipping and delivery terms. EcommBuilder enhances commercial relationships by managing rules and processes at three levels: (1) the business rules of both the buying and selling enterprises; (2) the rules of the marketplace entity, whether public or private; and (3) the commercial rules of domestic and international trade with which all enterprises and marketplaces must comply.

Electronic markets can be used by both people and NSAs. Automated negotiations are conducted by NSAs who undertake all tasks required to determine a compromise. At present these agents operate in

an electronic marketplace, however in future they may use the whole Web as their environment. They use the marketplace to seek other agents as their counterparts. Each agent conducts a search through a space of possible alternatives, makes offers and counter-offers, and reaches (or does not) an agreement (Jennings et al. 2001). The space of alternatives is well-defined so that the agents can interpret and evaluate offers using a rating function. The offers may contain a set of values or be specified in terms of an acceptable region. A counter-offer is accepted if it is an element of the acceptable set.

Kasbah is an electronic marketplace populated by selling and buying software agents who engage in a single issue negotiation (Maes et al. 1999). The sellers and buyers provide their agents with price aspiration and reservation levels, and the strategy—represented as a concession function—for lowering (increasing) the price over the course of a negotiation. The agents are then loaded into the Kasbah system, search for agents who buy (sell) items of interest, and enter into negotiations. An interesting feature of Kasbah is a simple reputation mechanism based on the rating of participants; participants are asked to rate their counterparts and the aggregate rating is used to assess the participant's reputation.

Experiments with Kasbah led to a design of Tête-à-Tête, a system capable of handling multi-issue negotiations (Maes et al. 1999). Based on the users' issue weights it constructs a rating function to evaluate offers made by other agents. User may also specify bounds on the issue values which describe their reservation levels (the use of bounds on a single issue and constraints on multiple issues is also known as the constraint satisfaction method). Bounds are used to reject offers and also to formulate counter-offers, for example, if the offer violates a bound defined on the issue levels a counter-offer is presented with issue values at the bound level.

3. The science of negotiations

3.1 Three orientations

The engineering approach to e-negotiation systems design requires making use of models describing different negotiation characteristics and processes. The richness and complexity of negotiations on one hand and the significance of the negotiated decisions on the other led to numerous studies in a number of research disciplines. One perspective for the studies' comparison is their *normative, prescriptive and descriptive orientation* (Bell et al. 1991).

The focus of normative studies is on the design of models of rational negotiators and procedures of

interactions among them. Prescriptive studies are concerned with design of procedures that define the goodness of the negotiation process and its outcomes, identify 'good' processes and compromises, and help negotiators to achieve good outcomes. Descriptive studies are involved with understanding of how people negotiate, why they engage in a particular type of a process, and why particular outcomes are achieved.

Studies in economic sciences concentrated on the design of formal models of negotiations which, under rationality assumptions, allowed for the selection of an efficient and stable compromise (Nash 1954; Young 1975; Munier 1993; Roth 1995b; Harsanyi 1997). Normative approaches, based on the economic rationality, have been expanded with studies in experimental economics seeking reasons underlying deviations from rationality and extending the problematique, from well-defined representations of negotiators and negotiations to situations in which previous and later events may influence behaviours and decisions (Roth 1995a; Sethi and Somanathan 2001).

Many of the developments in management science, decision analysis and negotiation analysis have prescriptive orientation. Models based on the multi-attribute utility theory, optimization models and multiple criteria decision making are examples of solutions proposed to represent and support negotiators (Kersten 1988; Bui 1994; Kilgour 1996; Teich 1996). Being concerned with providing a meaningful and helpful support, they typically take external perspective, that is, models are developed to allow analysts to help negotiators to make good decisions.

Studies in behavioural sciences, political science and law concentrate on the description and analysis of negotiators' perceptions, assessments and interactions, and their implications for the process and outcomes. Individual differences, social influences and situational characteristics were discussed in many papers in psychology, sociology and anthropology (Rubin and Brown 1975; Druckman 1977b; Gulliver 1979; Pruitt 1981; Bazerman et al. 2000). People's use of irrelevant information, their inconsistencies and deviations from rationality principles were discussed by (Kahneman and Tversky 1979) and applied to negotiations by Bazerman (1998), Neale (1987) and others.

Many descriptive studies of negotiations resulted in suggestions about "good" approaches and behaviours. The difference between prescriptive research and descriptive research is that the former proposes a model of a negotiator and the latter outlines activities that a negotiator should undertake. This difference is highlighted in negotiation analysis which is based on prescriptive/descriptive orientation concerned with providing advice to utility maximizing negotiators given information about their (not necessarily rational) counterparts (Sebenius 1992; Young and Parks 1994).

The results of normative, prescriptive and descriptive studies have been applied in numerous information systems developed to support one or more negotiators, and to conduct some or all negotiation activities autonomously. Normative models, mostly based on game theory, were used in research and simulation (Rapoport and Chammah 1965; Lendenmann and Rapoport 1980; Axelrod 1984). Early decision and negotiation support systems (DSSs and NSSs) were based on prescriptive models (Fang et al. 1985; Kersten 1985; Korhonen 1986; Jarke et al. 1987; Thiessen and Loucks 1994); their role was to give users efficient solutions and indicate what is good for them. These systems were used to study and teach negotiations; hence their prescriptive orientation was justified.

Dramatic increase in computer literacy among managers, coupled with improvements in computer technologies (e.g., the user interface and context-dependent help) and the incorporation of artificial intelligence, allowed construction of systems that could take negotiators requirements into account and provide advice that the users sought rather than ought to obtain. Some of the systems used decision and negotiation analysis in an instrumental manner without strict enforcement of logical consistency (Rangaswamy and Shell 1997; Kersten and Noronha 1999b; Bui et al. 2001). The objective of these systems was to provide users with a structured process support and easy to use tools for preference elicitation and offer assessment. Other systems provided expert advice for a particular type of the negotiation (Rangaswamy et al. 1989), manipulation and synthesis of negotiation cases to provide support (Matwin et al. 1989; Sycara 1989), and manipulation and assessment of negotiators' perceptions (Bonham 1993). Although these systems used logically consistent procedures they were not based on rationality assumptions. Those which required preference formulation and utility construction used it as a rough and tentative measure rather than as an expression of the negotiator's true utility.

3.2 Methodological foundations

The three orientations on the science of decision making and negotiation can be used to formulate the scientific views on the participants involved in the processes, their characteristics, roles and theories, the approaches and the models used for the construction of their representations. Four views and two types of processes are presented in Figure 2.

The two types of processes are:

1. Pre-negotiation processes which include formulation and analysis of the negotiation *problem*, the incorporation of *context* of the problem, and in the access and use *knowledge* about the participants, problem and context; and

2. Negotiation and post-negotiation *processes* which include strategies and tactics, *context* in which the negotiation takes place, and the *exchange* of information, including offers and arguments.

The four views take into account the following:

1. The *participants* involved in decision-making and negotiation include the negotiator, advisor, principal and an agent (e.g., NSA) who represent the principal. Third parties and stakeholders (e.g., public and interest groups) may also be involved.

2. Participants may have different set of *characteristics* such as their preferences, attitude to risk, attitude and concern towards others, power, negotiation style, and culture. We also distinguish between people and NSAs as the approach to the modelling of their behaviour and actions differ.

3. The third view represents the participants' *roles* that define sets of activities, for example, analysis, decision-making or advice. The differentiation of roles is related with participants' grouping, however it is separated here because one participant may perform several roles (e.g., a negotiator may be perform all roles), and a group of participants may jointly perform one role (e.g., an expert group providing advice to the negotiator).

4. Both characteristics and roles are studied and generalized in order to formulate *theories*, *frameworks* and *models*. They represent the fourth view; they are tangible results of the scientific approach to negotiations.

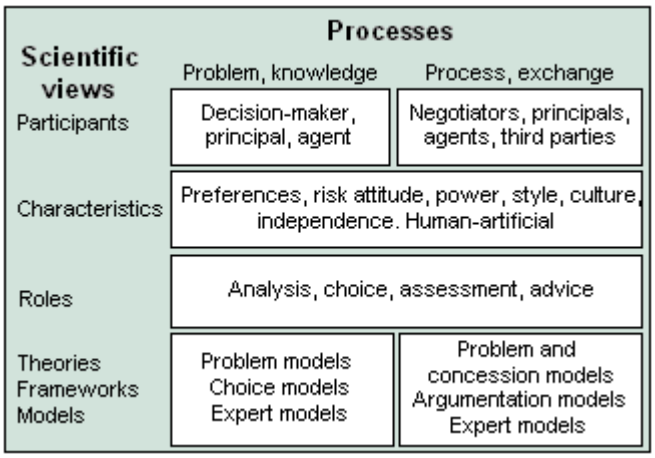

Figure 1. Scientific views on negotiations

The differentiation between two types of processes and participants, indicated in Figure 1, allows distinguishing two categories of models. Models of the problem, individual choice and expert knowl-

edge are used in pre-negotiation processes. The negotiation and post-negotiation processes are described with models that incorporate the dynamic aspect of the negotiation, choice and concession models, argumentation models, and models which describe the negotiation protocol. We also include expert models that can be used during the negotiation.

The two types of processes and four views provide the basis for the categorization of approaches to negotiation modelling. Focussing on a particular group of participants, their characteristics and roles, together with the selection of a research orientation leads to the formulation of assumptions and construction of models that represent the participants' negotiation activities. We use this categorization to review models that have been used in negotiations and e-negotiations.

4. Models and representations

4.1 Problem models

Negotiation is a decision-making process in which the parties seek an agreement. This agreement has to be a feasible alternative—therefore one needs to differentiate between feasible and infeasible alternatives. Because the process involves two parties, each party may have different understanding of what is feasible. Also each party's space of alternatives may have different dimensions as it is the case when the parties consider different issues.

Problem models are used to define the set of alternatives through their implicit and explicit specification. *Implicit specification* is one in which the decision maker formulates constraints and bounds which a feasible alternative must satisfy. The alternatives are unknown so they need to be generated and their feasibility determined as, for example, in mathematical programming models. In the *explicit specification* the alternatives are defined and can be enumerated in a list or database. In decision trees and tables, for example, alternatives are explicit. In this case an alternative is feasible, if it appears on the list.

The constraints that define the feasible set are *hard constraints* because they cannot be modified; they describe conditions that are beyond the decision maker's control. *Soft constraints* describe the decision maker's aspiration and satisfaction levels. They are often used to partition the feasible set into the *acceptable* and *unacceptable* subsets. Similarly, the list of feasible alternatives may be divided into two sub-lists with the use of *soft bounds* on the issue levels. Although soft constraints and bounds are part of user models discussed in the next section, we introduce them here to outline the use of

problem models in e-negotiations.

Negotiations in the alternative space follow one of the three situations:

1. Each party has its own set of feasible alternatives and their dimensionality differs;
2. Each party has its own set of feasible alternatives and they are in the same decision space;
3. Each party has its own set of feasible alternatives and all the sets have a non-empty intersection.

When the parties have their own set of feasible alternatives of different dimensionality, they need to agree on the negotiated issues (that is attributes). Once this is accomplished the parties face Situation 2. If the intersection of feasible sets is empty and these sets cannot be modified, then the negotiations fail. This means that there is no zone of agreement. When the intersection is non-empty, then this intersection may be seen as one jointly feasible set and the parties face Situation 3.

In Situation 3, if there is one feasible set for all parties the issue is of selecting one of the feasible alternatives based on the application of user models. This is a standard approach in game theory; the search is for an alternative which each party would accept. This alternative is an equilibrium and the parties accept it because otherwise their situation would be worse. Interactive approaches have been used in several NSSs (Kersten 1985; Thiessen and Loucks 1994); they require the parties providing the system with information about alternative acceptability and their individual preferences.

Initially and empty set of acceptable alternatives (Situation 2) does not imply failure. The parties may try to modify their individual sets through the changing soft constraints and bounds. In order to achieve a progressive modification, one that gets the parties closer to a compromise, this process may be supported with suggestion of directions for expansion. This, however, requires the use of a measure defined on the feasible set, calculation of the distance between the acceptable sets, and the determination of those constraints which change allows for the distance decrease.

The measure between subsets of alternatives need not take into account the participants' preferences if all issues are quantitative. Irrespectively of the parties' possibly very different preferences the premise behind the process of decreasing the distance is that when a compromise is reached, the distance is zero. Therefore *objective distance measurement*, for example the block or Euclidean measure, can be used.

If some or all issues are qualitative then the decision science proposes to apply a representation theorem to provide a numerical representation of the qualitative relations (French 1998). The difficulty is that this requires the use of a scaling function which has to take into account subjective preferences.

Thus *subjective distance measurement* needs to be applied. While a scaling function can be used in the distance reduction process it has to be done through either an aggregation of all participants' scales or for each participant separately. Aggregation of scales has been proposed in game-theoretical approaches and the use of a scale (i.e., utility) for each participant is the cornerstone of negotiation analysis (Raiffa 1996). These are further discussed in the following section.

4.2 User models

Choice is one of the most important negotiation activities. The parties engage in decision-making and choose from the possible alternatives one which is presented as an offer. They also need to decide on their response to counter-offers and choose a concession. Choice models are used to determine, or help to search for, an alternative having certain desirable characteristics. There are, however, other models that do not describe choice per se but describe the negotiators and the impact of their education, gender, culture, and organizational and social context in which they operate. Much descriptive research has been concerned with these issues and showed how strongly they influence negotiators' bahaviour. Noting that both choice and behavioural models are models of the negotiators, they are presented here separately.

4.2.1 Normative and prescriptive choice models

In the previous section scale functions were introduced in order to discuss partitioning of the alternative space. Scaling functions used for subjective distance measurement are normative user models, the best known of which are value and utility functions based on, respectively, the ordinal value theory and multi-attribute utility theory (Raiffa and Keeney 1976; French 1998). Value theory deals with choice under the condition of certainty and utility theory – with choice under the condition of uncertainty incorporating the decision-maker's risk attitude.

Normative user models are idealized in that they represent a decision-maker who is always consistent with the underlying axioms representing cannons of rational behaviour. They tell what the choice should be, if one wishes to be consistent with the axioms. Their logical structure implies that the choice is determined by the maximization of a value or utility function defined over a set of decision alternatives.

Negotiations have been studied from the game-theoretical perspective. Normative game models make use of the participants' utilities to determine an equilibrium point, that is, the solution from which no party is willing to deviate. Different solution concepts have been proposed some of which require the

aggregation of utilities. Although aggregation requires, as Arrow proved in his impossibility theorem, interpersonal comparison of preferences which has no theoretical basis, it can be used to determine solutions with certain desirable qualities. The best known solution concept is Nash equilibrium which uses the product of utilities. Other types of stable solutions which differ in the decision maker's ability to foresee counterparts' offers and her own responses, and their possibility to make concessions in order to block unilateral improvements of her counterparts have been proposed (Fang et al. 1993).

There has been much discussion about people's deviation from the rationality principles. Some deviations are the result of heuristics, biases and framing (Tversky and Kahneman 1974). These deviations are the focus of prescriptive models; they are based on the recognition of people's cognitive limitations and their bounded rationality. The models are used to train, guide and help people make good decisions. They interact with decision makers during the process, informing them about their inconsistencies and possible improvements. This is in contrast with the normative models which are "closed" and decide on the best course of action (alternative), given information about the decision maker's preferences.

Negotiation analysis integrates decision analysis and game theory; it bridges the gap between descriptive qualitative models and normative formal models of bargaining. Using the descriptive orientation it adopted a number of behavioural concepts (for example, reservation values and BATNA) and incorporated them in quantitative problem and user models. 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 "asymmetrically prescriptive/descriptive" orientation possible (Sebenius 1992; Raiffa 1996).

Multiple criteria decision making (MCDM), which includes goal programming, is an area within which a number of prescriptive models were formulated (Zeleny 1992). MCDM models do not require the specification of a value or utility functions explicitly thus allowing for deviations from rationality. They are designed to guide decision makers and help them to achieve a Pareto-optimal compromise. Several MCDM models have been proposed in the design to support negotiators all heavily relying on the participants' input during the process (Kersten 1985; Korhonen et al. 1986; Bui 1994).

Prescriptive models often use the normative components, for example, in prospect theory value functions are used to explain different attitudes to a loss and to a gain (Bazerman 1998). Value-focussed

thinking proposed by Keeney (1992) is a comprehensive framework based on the methodological underpinnings of decision science which helps people to think constructively and analytically about their value system and decision problem. Because of the analytical methodology, the objective of providing solution-oriented support during the process and the ability for their users to control these models makes the value-focussed framework a good candidate for decision and negotiation support software (including software agents).

4.2.2 Descriptive choice models

People's cognitive limitations and their unwillingness to engage in time consuming interactions necessary to determine the optimal solution, or the Pareto-efficient solutions, led to alternative approaches to choice. Descriptive models use past incidents, cases and histories to determine a solution that may satisfy the decision maker. Case-based reasoning, neural networks and genetic algorithms are examples of descriptive approaches to decision-making and negotiations. Persuader is a prototype negotiation system that used past cases to determine a negotiation plan (Sycara 1991). Matwin at al. (1991) proposed a model based on the application of genetic-algorithm to suggest possible compromises and Oliver (1997) designed software agents capable of learning strategies for specific negotiation games.

The Web provides a unique opportunity to collect information about choices people make. This opportunity has been utilized in *collaborative filtering* which goal is to predict the preferences of the decision maker based on the preferences of those who made decisions in the past. Collaborative filtering is based on the premise that people's preferences are correlated; groups have similar preferences so that the person who needs to make a choice can instead utilize the choices made by others in the group (Pennock et al. 2000). Therefore, it can be used if there is a database containing alternatives that a sufficiently large number of people selected and if these alternatives are relevant to the choice the user faces.

The user is asked to provide either a holistic evaluation of several similar objects (for example, books, cars and suppliers) or select short list of objects that satisfy him. Based on this information one of two types of approaches are used. Memory-based methods use a measure to determine similarity between the users' choice and choices stored in the database. A similarity score is calculated for every record in the database and alternatives associated with the highest scores are selected. Different measures of similarity have been proposed, including the Pearson correlation coefficient (Resnick et al. 1994), and correlation and mean squared differences (Shardanand and Maes 1995). These methods are used to

propose a good alternative that the user may not know; they have been implemented in e-commerce applications including Amazon.com and Alexa Web browser plug-in.

Memory-based methods do not specify the user's preferences, which is the goal of model-based methods. These methods use models, for example, clustering and Bayesian networks, to determine preference structures for groups of previous users whose choices are stored in the database (Breese et al. 1998). Combination of the two methods and the use of additional information (user age and gender) have also been proposed (Pennock et al. 2000).

4.2.3 Descriptive concession models

Descriptive choice models provide decision makers with alternatives that should satisfy them if they are indeed members of the group they were classified to. They, similarly to prescriptive models, indicate what decision should be made. However, they do not take into account the possible reactions of the opposing party and the party's further responses. Normative game-theoretic models take into account possible actions and reactions of the participants seeking for stable solutions. The parties are rational and therefore they need not to make offers and concessions, if a solution can be found. Negotiation analysis and MCDM propose directions of joint improvement so that the parties reach a Pareto-efficient compromise.

Behavioural studies of negotiations consider initial offers and subsequent counter-offers from the perspective of how they can influence the participants' actions and what impact they have on the outcome (Druckman 1977a; Lewicki et al. 1999). The perspective is broad and it includes social relationships between the parties, perception of fairness, emotions, the impact of possible future interactions with the counterpart and with others (Morgan and Sawyer 1967; Bazerman et al. 2000).

Experimental studies show that in *distributive negotiation* hard, positional strategy which is characterized with high initial offer and small concessions lead to a favourable compromise but decrease the possibility of an agreement (Morgan and Sawyer 1967; Bartos et al. 1983). When the counterpart uses soft or accommodating strategy, the achievement of a favourable compromise by the hard negotiator may seem obvious. But the experiments also show that hard negotiators achieve a more favourable compromise than the soft ones. This—I think—is caused by the greater chance to achieve a Pareto-efficient compromise when both sides begin with an extreme offer and make small concessions each trying to achieve as much as possible. While there is no guarantee for a Pareto-efficient compromise the parties yielding on least important issues and keeping the important ones at the highest possibly levels increase the chance of traversing the neighbourhood of the efficient frontier. In contrast, the

negotiators whose initial offers are lower and/or who make large concessions have difficulties to move towards the efficient frontier (Alemi et al. 1990).

Walton and McKersie formulated a behavioural theory of negotiations based on two types: distributive and integrative (1965). Since then, a significant effort was made in the formulation principles and strategies underlying *integrative negotiation* also known as principled and win-win (Druckman 1977a; Fisher and Ury 1983). Integrative negotiation has been considered superior to distributive because it reduces the possibility of a failure and agreement repudiation while contributing to the positive relationship (Pruitt 1981; Lewicki et al. 1999).

Definitions of integrative negotiations are not precise although they all underlie the fact that both parties should win. They cover one or more of the following three forms (Pruitt 1981; Lewicki et al. 1999): (1) the expansion of the set of feasible agreements in directions preferred by all parties; (2) the alternation of agreements which is possible in recurring negotiations and requires that one party gains at one time and the other gains later and so on; and (3) logrolling, which is the synonym for trade-offs, meaning that each party yields on less important issues in exchange for more important ones that—in turn—are less important to the other party.

Descriptive studies recognized the fact that negotiations often end in inefficient agreements and that a move from such an agreement benefits both parties. The logrolling was introduced as it allowed for joint agreement improvement. However, logrolling is automatically introduced into every negotiation, irrespectively of their type, in which the participants use value or utility functions. Therefore, if the set of feasible alternatives is known, joint improvements may take place also in distributive negotiations (Kersten 2001).

Alternation of agreements requires a series of consecutive negotiations between the same parties. This situation occurs between business partners, within organizations and social groups. In this paper recurring negotiations are not considered.

It is the first form, that is, the expansion of the feasible set for the parties' mutual benefit that is considered the cornerstone of integrative negotiations (Fisher and Ury 1983; Kersten 2001). This is also perhaps the most difficult undertaking in negotiation as it requires the parties to create value rather than claim, which, in turn requires openness, learning, ingenuity and joint problem solving attitude (Lax and Sebenius 1986). The parties need to engage in the discussion about their goals and objectives rather than issues and positions. Disclosure of true interests, however, carries risk of the opponent being able to use information for his own benefit. In effect, the negotiator faces the dilemma of

managing activities which leads to claiming value and creating value (Lax and Sebenius 1986, p. 154-182).

Behavioural studies suggest the use of brainstorming, "full, open, truthful exchange" (or "partial, open, truthful exchange"), avoidance of offer evaluation, and involvement of the third parties to construct new and jointly beneficial alternatives (Raiffa 1996; Lewicki et al. 1999). Keeney's (1992) value focussed-thinking and the descriptive models of choice (see Sections 4.2.1 and 4.2.2) provide new possibilities for the expansion of the feasible set. The goals of value-focussed thinking are to clarify the distinction between alternatives and objectives, structure objectives qualitatively and quantify them. Evolutionary systems design methodology provides modelling and design framework for the integration of key constructs used in decision-making and negotiations (Shakun 1996). It has been used in the design of at least two NSSs: Mediator and Negotiator (Jarke et al. 1987; Bui 1996). Descriptive choice models, such as case-based reasoning and collaborative filtering, use previous events and can, therefore, suggest new alternatives. Models based on genetic algorithms can generate new alternatives through splitting and joining feasible alternatives.

4.2.4 Behavioural user models

Engineering is concerned with the construction of tools to solve practical problems. For these tools to be effectively used, they need to meet users' requirements. In negotiation, this includes the users' approach to the decision problem and its solution, interaction, concession making, and so on. Studies in psychology, anthropology and management are concerned with the impact of negotiator characteristics on problem solving and decision-making, and the process and outcomes of negotiations. These studies have shown that the characteristics of the negotiators' influence their risk attitude, consideration of the problem, attitude towards, and expectation regarding, the counter-parts, and exchange of information.

The importance of the negotiators' culture is well known and it has been widely studied (Gulliver 1979; Graham et al. 1994; Kersten and Noronha 1999a; Lewicki et al. 1999; Bazerman et al. 2000). Models of culture have been proposed by Hall (1976), Hofstede (1997), (Bohanan 1995) and others, and applied to negotiation research (Adler and Graham 1989; Chan et al. 1994; Graham et al. 1994; Köszegi et al. 2002).

Culture, education, gender, economic situation and social position impact the negotiators' cognition and behaviour. They also impact the acceptance and use of such concepts as utility, risk, time and context. Therefore one may expect that these characteristics influence the types of biases and the

preference for different types of prescriptive models. However, behavioural studies on decision-making and negotiations have little impact on the construction of negotiation models and the design of e-negotiation systems.

The question is if and how culture and other negotiator characteristics should be introduced in e-negotiation systems and in software agents that use argumentation in negotiations needs to be addressed. The rationale for WNSSs is that they can be used by negotiation experts and non-experts alike who are coming from any place. While the experts may share many similarities irrespectively of, for example, their culture, the non-experts may require systems that conform to their cognitive and behavioural patterns. While there have been a few suggestions (Kido 1988; Kersten et al. 2002), there have been no experimental studies and design efforts leading to the integration of behavioural user models with prescriptive and descriptive models of choice and concession-making.

4.3 Protocols

4.3.1 Models and rules

Negotiation is a purposeful process governed by some explicit and implicit rules. A number of behavioural researchers propose rules for different negotiation situations and types, strategies and tactics, and negotiators' attitude, relationship and bargaining power (Walton and McKersie 1965; Lewicki et al. 1999). Wall (1985) formulates a set of rules to define tactics a negotiator should use and rules for the elimination of tactics that depend on the counterpart's behaviour, cooperation, future relations with the counterpart, and the degree of the counterparts' flexibility. Many negotiation handbooks propose "winning" rules in the form of context-dependent "dos-don'ts".

All models discussed in the previous sections are based on rules that specify a particular type of the negotiators' actions and behaviours. These rules were often not explicitly specified in NSSs and WNSSs that incorporated one model, or several complementary but not competitive models. In some cases the system's purpose was to study negotiations and verify a particular modelling approach. In other systems the model was assumed to allow for support that the user could not obtain otherwise; the decision about utilizing the systems' outputs was left to their users.

In automated negotiations the NSAs make all decisions that are only based on the initial input from their principals (users). Therefore, the principals may wish to know what rules their agents follow because these rules determine the negotiation success and the compromise, or a failure. This necessitates explicit specification of all rules that the NSAs may use. Also, rules are required because the

agents have to be able to receive, interpret, formulate and send offers. This led the designers of NSAs to propose a *negotiation protocol*; a model that guides software processing and communication tasks, and imposes restrictions on activities through the specification of permissible inputs (Sandholm 1999b; Jennings et al. 2001).

The concept of the negotiation protocol is one of the most important computer science contributions to negotiation modelling and representation. In autonomous negotiations a negotiation protocol is a complete set of rules that govern the NSAs' reasoning, actions and interactions; it determines the logic of the process, construction of alternatives, and the formulation and interpretation of offers and messages. The protocol is formulated as a model, e.g., a rule-based model that is separate from, and used to control the application of, other models.

Negotiation protocols are also required in other e-negotiations, in particular in those which make use of several models. They are used to define the division of responsibilities and interactions between the systems and their users, and control the application of models embedded in the systems.

A protocol may be *closed* when all rules are defined a priori; new rules cannot be added during the process and the existing rules cannot be modified. This type of a protocol is typical for automated negotiations. An *open* negotiation protocol is one that is not complete; new rules may be constructed and added due, for example to the participants' learning or encountering a problem that cannot be addressed with any existing rule. In e-negotiations in which people are involved in some decision-making activities protocols are open because users need not to follow the protocol's rules.

A closed protocol should be *complete* so that it covers all negotiation situations which the system may encounter according to the design specifications. An open protocol may be either complete or *incomplete*. A complete open protocol allows the system to negotiate autonomously in a given set of negotiation situations. However, it also allows users to take over certain activities and apply rules that have not been included in the protocol. It also allows adding new, and modifying existing, rules when new situation is encountered.

Incomplete negotiation protocol is typical for e-negotiations that involve people. The less complete a system's protocol is the more intervention is required from its users. The less incomplete an open protocol is the more support can the system provide within, however, the defined set of negotiation situations.

4.3.2 Private and public protocols

An e-negotiation system may have several protocols. In automated negotiations NSAs use their individual protocols in decision-making and offer assessment, and communication with principals. They also need to use a joint protocol to exchange offers and messages. Similarly WNSSs may have different protocols for system-user interaction and a different one used in communication between users via the system. The role of public and private rules differs depending on the degree of negotiation automation. In automated negotiations both types of protocols should be complete. In the negotiation in which people participate some public rules are required but private rules may be absent.

Private negotiation protocol defines the valid actions of participants' imposing constraints on their activities. The most important are private rules defining negotiation *strategies* and *tactics* which determine the choice model and the way it is used in the selection of alternatives, and the construction of offers, concessions and the formulation arguments.

The design of negotiation protocols is of particular importance for multi-agent systems. Private protocols determine the agents' bahaviour. Thus they may be used to equip agents with mechanisms guaranteeing their rational decision-making. This may, however, may contradict the agents' subservient nature.

Studies in experimental economic show that people deviations from economic rationality are not caused solely by biases and misconceptions. Biologically and socially ingrained norms and principles like altruism, fairness, reciprocity and image play significant roles in that they impact how the counterparts in future negotiations perceive and interact with the negotiator (Bowles et al. 2002). Furthermore, rationality is based on the closed-world assumption which implies that that there are no other processes that compete with the negotiation (e.g., other negotiated decisions). If the agents act on behalf of people then their rationality may need to be constrained and allow for the interference of external, to the negotiation, aspects.

Public negotiation protocol comprises public rules of interactions. It may include the agenda, the kinds of deals that the participants can make, the message structure, and the sequence of offers and counter-offers. They may also include the requirement that the negotiation is conducted in good faith and that an issue that both parties agreed upon cannot be renegotiated.

Sandholm (1999b) proposes that public negotiation protocols assure social welfare, and compromise efficiency and stability. These properties are an extension of individual rationality and similarly to it their applicability may need limited. Maximization of social welfare may be questionable for an agent representing a selfish individual. Formulation of an acceptable social welfare function may not be

possible; even if the agents use individual utility functions it is not possible to compare them. Furthermore, it assumes a third party or an authority capable of obtaining information from the agents.

The ability to verify offer and agreement efficiency is a desirable property. However, the agent may decide to accept an inefficient agreement if, for example, the costs or efforts required to continue the negotiation exceed the possible improvements. This includes situations when the agents discover new issues or options and decide to accept them without further search.

Some normative models of negotiation utilize the concept of solution stability, Nash equilibrium being the best known. The limitations of stability in a sequential processes (including games) have been recognized (Sandholm 1999b) and they are even more restrictive in situations which are dependent on the context and events that are external to the negotiation.

4.3.3 Properties

The economic rationality properties of protocols impose strong limitations on NSAs and WNSSs. It is widely recognized that people do not follow the rationality principles but because every decision-making process takes place in a context, people are concerned about others, future, and so on. Furthermore, rationality imposes informational requirements that are often difficult to be met. The latter causes that designers replace a utility construction with a simple rating function which does not take into account rationality axioms.

Instead of rationality-type properties we propose consistency, transparency and explicability properties.

Input consistency means that all available input has to be used even if this means the need to resolve possible input inconsistencies. Consistency means that, for example, if BATNA and reservation levels are available then it has to be considered in offer assessment; if the BATNA rating is higher than the offer that defines her aspiration level then this inconsistency has to be resolved. This example shows the requirement of maintaining consistency during the process and not at a point in time only.

Transparency is required for users to know what a system is doing and what it will do. It means that the behaviour and actions of a system may be observed and understood. In complex systems this requires grouping of rules in mechanisms that can be applied to a particular activity in a given context. For a meaningful behaviour from the user perspective these mechanisms need to be linked with others. For example, a set of rules used to asses the counter-part as a hard negotiator is linked (through

the opponent's assessment) with a set of rules used to make a concession.

The *explicability* properties include *simplicity* ensuring that the selected strategy and tactic are "obvious" and the reasons for their selection are easily traceable and justifiable (Jennings et al. 2001). *Computational efficiency* assures that the software agent uses as little computation as it is required (Sandholm 1999b). This property supports explicability because it allows for the justification of computational activities and relates them to the negotiation activities. *Tractability* means that the there is a reason for the selection and use of every rule and that this reason can be explained.

4.4 Argumentation models

Many negotiations involve exchange of messages containing offers, supporting arguments, counter-arguments, threats, explanations and "small talk". In email e-negotiation all exchanges take the form of a message and the user has to distinguish between an offer and a text message. In structured e-negotiations, conducted via NSSs and software agents, only offers are assessed, processed and used to construct counter-offers. These are the objectives of the problem and user models discussed in Sections 4.1 and 4.2.

Some NSSs and software agents allow for the exchange of text messages, for example, by using an email server, but they do not relate them to offers. The messages need to be interpreted and analyzed by the user because these systems do not have the capabilities to do so. This imposes a two-channel communication: offers are processed and analyzed by a system which can also formulate counteroffers, while messages which provide offer supporting arguments are processed by the user.

Argumentation models can be implemented in support systems and software agents in order to:

1. Extend the capabilities of NSSs with components (possibly software agents) that can interpret text messages and relate them to the offers;
2. Design support systems that can interpret, relate and manage text messages (Schoop and Quix 2001);
3. Provide negotiation agents with the ability to formulate and interpret offer supporting arguments; and
4. Provide negotiation agents with the ability to negotiate using argumentation-based exchanges (Sierra et al. 1998).

The extension of NSSs and software agents' ability to interpret text messages allows for the use of formal models describing users and their negotiation problems. Systems that support people in the

interpretation and management of text, including documents, may be used in complex negotiations in which the participants cannot or do not want to specify issues, alternatives and preferences. These systems can also be used in conjunction with other systems increasing the scope of support. Development of software agents that engage in automated negotiation and use only text (arguments) allows for content-rich studies and training.

Communication theories, in particular, theory of speech acts (Searle 1969) and theory of communicative action (Habermas 1981) provide foundations for the design of argumentation models and systems messages. Schoop and Quix (2001) formulate a model for document and communication management using the language-action perspective which is based on these two theories. Both messages and documents need to be structured so that they can be decomposed, ordered and linked with other messages and documents.

A number of models have been developed following formal logic methodology in which arguments are de-contextualized sets of sentences considered in terms of their syntactic or semantic relationship (Karacapilidis and Papadias 1998). Research on formal models of argumentation based on different logics is a large area of artificial intelligence and many proposed representations have been implemented. Several approaches to provide NSAs with argumentation capabilities have been proposed (Sierra et al. 1998; Schroeder 1999; Karacapilidis and Moraitis 2002).

4.5 Expert models

NSAs engage in activities, including decision-making, which may require knowledge. Access to knowledge may also be beneficial for NSSs to provide their users with context-sensitive help and advice. Knowledge may also be incorporated in stand-alone systems and provide generic expertise about negotiations or problem specific advice. Druckman et al. (2002) developed a system for diagnosing negotiation progress and predicting its outcomes. Knowledge is represented with a rule-based model comprising of over 50 rules describing the parties, issues, delegation characteristics, situation and process. The application of rules is managed with weights which have been derived from statistical meta-analysis of bargaining studies.

Rangaswamy et al. (1989) designed Negotex, which is also based on a rule-based model, with an objective to provide guidelines for an American preparing to negotiate with a Chinese negotiator. Other potential application areas of knowledge-based systems include negotiations involving complex problems, for example, environmental, technological, financial, in which the parties may have limited technical knowledge and access to experts. For example, successful involvement of the public in en-

vironmental negotiations may largely depend on public access to expertise.

A number of different approaches to knowledge representation have been proposed in the AI field. While rule-based models are most popular, representation with neural-networks, frames, and scripts.

4.6 Orientations, models and systems

Different types of software used in e-negotiation were discussed in Section 2. In Section 3 three types of orientations regarding the modelling and representation of negotiation were presented, and in Section 4 the user, problem, process and knowledge models were discussed. Using the three orientations, models, and key activities undertaken by the software, the systems discussed in Section 2 are compared in Table 1.

Table 1. Software for support and conduct e-negotiation

System	Focus	Orientation	Models	Support/Automation	Key activities
Email, Chat	Process	--	--	--	Communication
Inspire	Process, solution	Prescriptive	Phase model, value function	Ratings, automated messaging, visualization, history, compromise efficiency	Communication, analysis, choice, concession
WebNS	Process	Descriptive, prescriptive	Phase model	Message classification, history	Communication
SilkRoad	Process, solution	Descriptive, prescriptive	Value function, matchmaking	Business rules, task automation	NSS generator
CyberSettle	Solution	Descriptive	Agreement zone	Offer acceptability	Price comparison
LiveExchange	Process	Descriptive	Unknown	Product brokering, clients, business rules, documents, legal	Communication, documentation
EcommBuilder	Process	Descriptive	Unknown	Product brokering, clients, business rules	Communication, documentation
PurchaseSource	Process, solution	Descriptive, prescriptive	Unknown		
SmartSettle	Process, solution, advice	Prescriptive, descriptive	Phase model, problem model, acceptable set, value function	Model construction, ratings, efficient direction, compromise efficiency	Communication, analysis, choice, concession
BargainFinder	Pre-negotiation	Prescriptive	Price comparison	Product brokering, task automation	Search, price comparison
Jango, Firefly	Pre-negotiation	Prescriptive	Collaborative filtering	Product brokering, task automation	Search, product comparison
PersonaLogic	Pre-negotiation	Prescriptive	Value function	Product brokering, task automation	Search, product comparison
Aspire/Atin	Process	Descriptive	Rule-based	Assessment, strategy, concession	Context-sensitive advice
Kasbah	Solution	Descriptive	Concession function, acceptable set	Negotiation automation	Offer exchange
Tete-a-Tete	Solution	Descriptive	Value function, concession function, acceptable set	Negotiation automation	Offer exchange
Druckman	Process	Descriptive	Rule-based	Parties' flexibility, outcome prediction	Context and user analysis
Negotex	Pre-negotiation	Descriptive	Rule-based	Cultural difference identification	Context

5. Engineering approach

5.1 Software engineering

The goal of the scientific approach to negotiation is to understand the participants' behaviour, and the impact of the situational, contextual, individual and group characteristics on the process and outcomes. Design of systems that are useful and can satisfy negotiators' requirements reflect the *engineering approach* to negotiation. The engineering approach is concerned with the use of every possible result in order to find solutions to practical problems. "Engineering is the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind." (ABET 1992). The "benefit of the mankind" defines the purpose of engineering which often is formulated in terms of finding solutions to practical problems and satisfying customer requirements (AIAA 2002).

Software engineering is based on two principles: (1) the utilization of the mathematical results in the design and construction of systems, and (2) the use of behavioural and cognitive results to determine the needs, capabilities and requirements of the systems' users. This is of particular importance in the design of systems which are immersed in a social setting, address social problems and involve many different users. Thus negotiation engineering needs to incorporate the normative, prescriptive and descriptive orientations. The difficulty is that the results of these three orientations are difficult to reconcile, some are based on undefined assumptions, and others use ill-defined and contradictory concepts (Gulliver 1979 30; Kersten 2001). The need to design useful systems meeting users' requirements resulted in arbitrary bundling of methods accompanied by claims of their usefulness in a wide range of negotiation processes.

Software engineering is composed of steps encompassing methods, tools and procedures that are used in the development process. The steps are referred as software engineering paradigms, such as the classic life cycle, prototyping, rapid application development, and object-orientation. Every software project follows three phases: definition, development and maintenance, regardless of the paradigm selected (Pressman 2001). The focus of the *definition phase* is the specification of the key requirements of the system, including definition of the problem, identification of users and their requirements, identification of the information the system will process, and models and procedures used for processing on production of outputs. Three key elements considered in the definition phase are identified are presented in Figure 3.

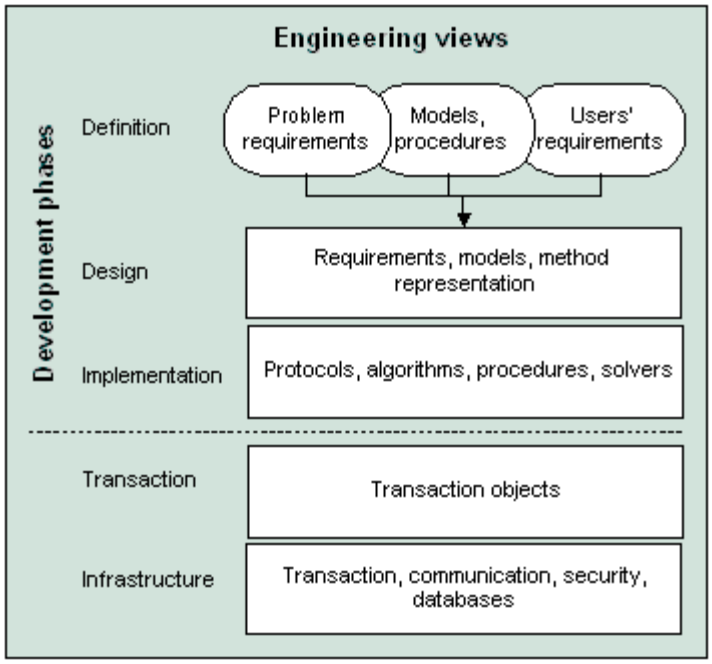

Figure 3. Software engineering perspective

The *development phase* comprises software design and implementation, see Figure 3. Design translates the requirements, models and methods into the set of representations that are subsequently implemented, i.e., coded and tested (Pressman 2001).

The outcome of the implementation phase is a software program. Its activities result in transaction objects and it uses different forms of services provided by other programs, including transaction processing systems, communication and security systems, database management systems and so on.

5.2 Electronic media

Communication, one of the key elements of every negotiation, is conducted with the use of one or more media. Traditional negotiations are conducted face-to-face, via telephone, or paper and pen. E-negotiations are processes that use electronic media (EM), i.e., media with digital channels to transport data and to allow the negotiators to communicate and coordinate their activities.

Media used in traditional negotiations are not designed specifically to help negotiators and support the process. Therefore, while they may require engineering, the purpose is general communication rather than negotiation. In contrast, in e-negotiations the issue of media design and their relationship to other participating components gains importance. This is because the medium may: (1) be constructed for the specific purpose of supporting or facilitating one or more of e-negotiation activities;

(2) it is either a software program or it is generated by software so it is—directly or indirectly—constructed by software engineers; and (3) it is a component of a complex engineered system in that it uses, controls and is controlled by other programs.

The role of electronic media on all activities conducted with the use of Internet technologies (e.g., e-business, on-line learning, virtual communities and e-government) led researchers' attention to the issues of their design. Schmid and others (Schmid and Lechner 1999; Lechner and Schmid 2000) propose a *media reference model* (MRM) in which media are described in terms of (1) language employed in communication, (2) channels transporting information, and (3) an organization describing the roles of the participants and protocols defining the permissible interactions.

The MRM model, depicted in Figure 4, is used to describe the role of media in a community that, according to the model, comprises agents and media. The community members (i.e., agents) undertake activities that belong to one of the four phases: (1) knowledge seeking, (2) communication of intentions and requests, (3) specification of contracts and agreements, and (4) meeting obligations and performing contract tasks. The agent's activities are implemented in media. This means that virtual communities can exist, if appropriate media are built allowing for communication, coordination and access to storage facilities. Also in the implementation view the model is represented in software leading to the software engineering two views: the transaction view and the infrastructure view.

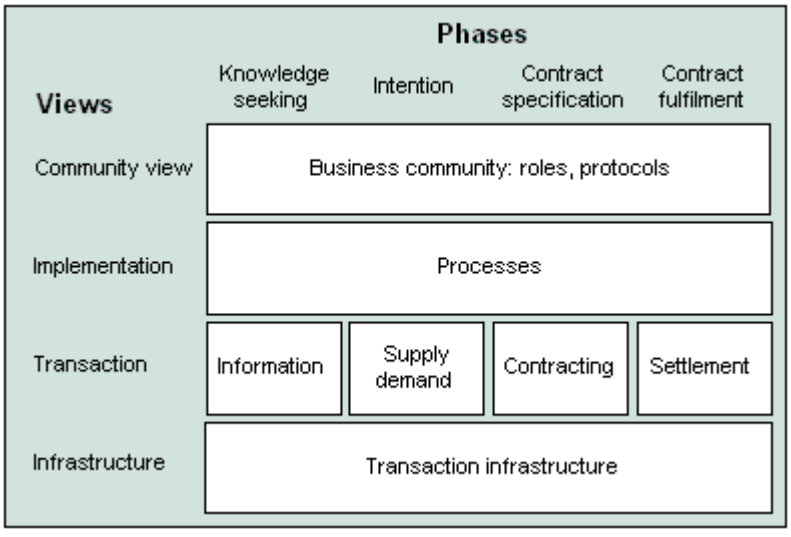

Figure 4. Media reference model (Schmid and Lechner 1999)

The importance of the MRM model is its focus on the integration of social and engineering perspectives through linking the community view, describing the members' needs, interests, roles and also

protocols that they have to conform to, with the implementation view in which descriptive model of the community, its members and their activities is defined. For these reasons Ströbel (2001) adapts the model to construct a media-implementation SilkRoad platform where the exchange of objects is coordinated through an agent (human and artificial) interaction. The novelty of SilkRoad lies in its ability to generate different e-negotiations media for a given requirement set. Another application of the MRM phases and media-types is the Montreal e-negotiation taxonomy proposed by Ströbel and Weinhard (2002).

The use of systems that utilize the variety of models described in Section 3 is not necessary for e-negotiation. Negotiations that use streamlined video use electronic channels, are conducted via e-mail, or engage NSAs that interact on the e-marketplaces and convey requests made by their principals (e.g., Kasbah) are examples of e-negotiations. In these cases the MRM model is sufficiently rich to describe interactions among community members.

Both the strength and the weakness of the MRM is its focus on media. The strengths are mentioned above. The weakness is because the concept of community comprising agents and media is too narrow to account for systems that support the negotiators and facilitate the process. The computational processes that aim at such activities as the specification of decision alternatives, their comparison and evaluation, integration of interests, and interpretation of offers, and which are undertaken by DSS, NSS and software agents need not belong to the community but their importance and impact cannot be ignored. Although the MRM allows for the community members to search for information and knowledge these activities need not be done by the members themselves but by others: people, software agents and/or support systems. Extension of the community with these entities, while possible, makes little sense because—in the on-line environment—its boundaries would disappear.

The MRM model is concerned with transport and presentation is not sufficiently rich for the purpose of e-negotiation which can be conducted by people and software agents belonging to different communities, communicating with experts and using support tools. The significance of the e-negotiation is that the processing and storage of information and production of knowledge becomes possible. The loss of a wide communication bandwidth that allows for the use of all senses and the use of media that use much narrower bandwidth can possibly be offset with the computational capabilities coupled with access to information and knowledge stored in computer networks.

6. E-negotiation view integration

E-negotiation is a process and it is also a complex system which consists of the negotiators, models, decision and negotiation support systems, knowledge based systems and media. If the negotiators are software agents then the whole system needs to be engineered. If the negotiators are people then the remaining components of the system need to be engineered to meet the users' needs and requirements. To achieve this we need a comprehensive e-negotiation reference that integrates the scientific perspective discussed in Section 3 and the engineering perspective discussed in Section 5.

As the starting point we use the MRM model discussed in Section 5. This model is modified and extended in order to:

1. Incorporate the three orientations, theories and modelling approaches;
2. Position e-negotiations in a broader organizational and social context;
3. Strengthen the role of processes which may incorporate different action types;
4. Differentiate between users and other participants, and their roles and characteristics; and
5. Establish the relationship between the scientific and engineering approaches to e-negotiations.

The proposed e-negotiation view integration (ENVI) model—shown in Figure 5—has six views (three scientific and three engineering) and four negotiation processes (pre-negotiation, negotiation, post-settlement, and knowledge integration).

The three scientific views are (1) the user group; (2) participants' and other stakeholders' roles and characteristics; and (3) theories, models and approaches. These views now correspond to the definition and design views in the engineering model illustrated in Figure 3. Therefore, the engineering views comprise now three views (4) implementation; (5) transaction; and (6) infrastructure.

The user group view identifies all participants and stakeholders, including organizations and social groups, who are involved in the negotiation process, evaluation of agreement, its implementation and the codification of acquired knowledge for further use. The participants and stakeholders have different roles and characteristics. The theoretical views depend on the users' type, their characteristics and processes. The normative, prescriptive and descriptive modeling orientations and the underlying theories are used in theories, models and approaches. These orientations allow distinguishing five categories of negotiation models discussed in Section 4.

The implementation, transaction and infrastructure views correspond to the engineering approach to e-negotiation. The implementation view identifies protocols, algorithms and procedures necessary to realize different models, define the sequences of tasks, actions and services, and bind models to ser-

vice providing modules. The transaction view provides various generic services, including communication, interaction, solution, storage and retrieval. Finally, the infrastructure view provides the means for the physical implementation of the selected services, databases and knowledge bases.

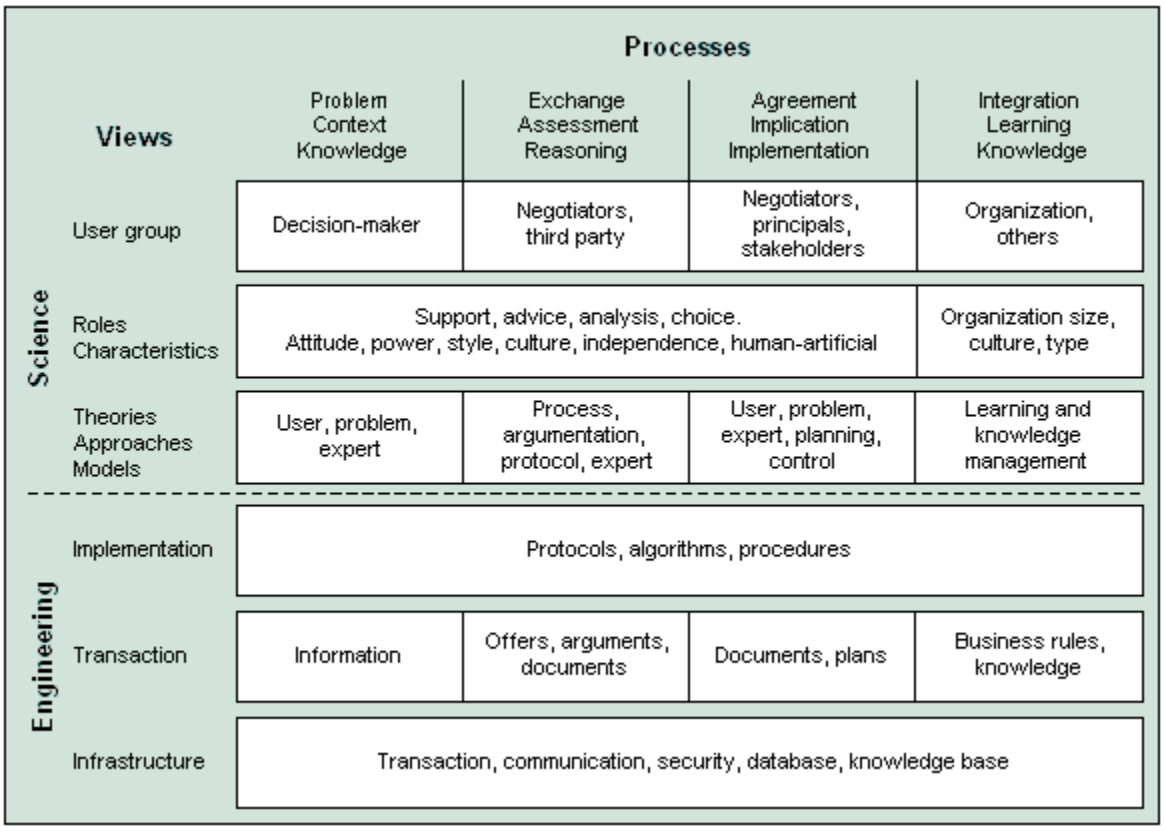

Figure 5. E-negotiation view integration (ENVI) model

The MRM model groups all services in four action types (Schmid and Lechner 1999). In an effort to relate the scientific and engineering approaches the processes required to construct, analyze and solve models of the problem, user, argumentation, negotiation process and so on are distinguished from services which implement these processes. Note that the meaning of "process" is generic and it involves a series of activities and interactions leading to the achievement of a specific goal, for example, a model, solution, expertise or argument.

The four processes identified in the ENVI model describe: (1) preparation to negotiation; (2) negotiation; (3) agreement and post-settlement activities; and (4) integration of lessons learned from the negotiation.

The goal of negotiation and other decision processes is to determine a solution in which possible im-

plications are assessed and which is implemented. Negotiations are undertaken in a particular context that needs to be recognized. Through the agreement implementation the parties change this context. This often requires preparation of documents and plans which can be undertaken with planning and control models.

The direct outcome of the e-negotiation may be an agreement or a deadlock. In many situations, however, there is also another outcome often of no less importance, namely knowledge that the participants and stakeholders gain and which can be used in the future. Therefore the processes involved in learning and knowledge management are identified in the proposed ENVI model.

7. Conclusions

The objective of this paper is to build a case for e-negotiation engineering which—as we tried to show—can and should integrate various results from all the fields of negotiation research. Not all developments in negotiation and e-negotiation research are presented in this review. Similarly, not all approaches to modelling and representation to NSSs and NSAs are discussed. The effort was on providing several classifications that, in our view, support the case. These classifications accompanied with the comparison of different ENM led to the e-negotiation reference model in which the scientific and engineering views and processes are identified.

Negotiation process is often fluid, multifaceted, rich in content and context, involves negotiators and other stakeholders. It has been considered an art of interpersonal skills, persuasion, motivation, understanding, body language, etc. Raiffa (Raiffa 1982), in his seminal work on studying and representing negotiations using applied mathematics, affirmed the role of the scientific approach.

Advances in decision and negotiation analysis, behavioural research, cognitive science, AI and computational linguistics allowed that the richness of the negotiation can be matched with configurations of complementary model. More work is necessary on the integration of the existing descriptive and prescriptive models to represent both the art and science of negotiations. I think that the review of models presented in Section 4 gives grounds that this is feasible. Models that are proposed in experimental economics, anthropology, psychology and other areas that incorporate the social concepts as fairness, reciprocity, attitude and culture allow to enrich the expressive powers of ENM and to establish some form of synergy between the user and the system.

Advances in system design and development methodologies, and in information and communication

technologies made it possible to implement these models and to introduce meaningful user-system dialogue. From the engineering perspective, one direction is the use new software engineering paradigms like aspect-oriented programming and subject-oriented programming (Ossher and Tarr 1999; ACM 2001). They recognise the cross-cutting and similarity of objects and therefore may be used to construct ENM capable of adapting themselves to different user styles and cultures, and model configuration during the negotiation. A step to this direction is Ströbel's SilkRoad platform designed to generate, at the run-time, a number of different ENM for different types of negotiation processes (2001).

Several research directions may be suggested. Behavioural studies of users who engage in e-negotiations link the engineering with descriptive perspectives. More research on protocols, in particular comparison and integration of protocols proposed in behavioural studies and those designed for NSAs is required. People have different agendas, expectations, attitudes; they also differ in their cultural, social and educational backgrounds. The same goes for organizations. It is an open question if these differences ought to be incorporated in WNSSs that support, and in NSAs that represent, people and organizations. Descriptive research provide strong arguments for culturally- and socially-sensitive ENM but software engineering recognizes these differences at the interface level through software internationalization architecture. More research on the roles that systems play in negotiations (and other social processes), their impact on these processes, and shape the behaviour of the participants is required.

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