Examination of the negotiation domain

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Contents

1. Introduction

"Leo Baekeland sold the rights to his invention, Velox photographic printing paper, to Eastman Kodak in 1899. It was the first commercially successful photographic paper and he sold it to Eastman Kodak for $1 million. Baekeland had planned to ask $50,000 and to go down to $25,000 if necessary, but fortunately for him, Eastman spoke first." [Asi82]

More than one century later, this example of the importance of negotiation processes is still valid. In the new business paradigm, where businesses all around the world are connected via Internet, the importance of negotiation stays the same. Electronic commerce enforces completely new infrastructures for doing business and negotiation has certainly its part in it. In order to complete the whole business cycle, electronic commerce systems need the ability to negotiate.

This survey is motivated by the goal of creating a software agent that can negotiate. Section 4, elaborates the goal statement and the questions that arise. The main question that motivates this survey is 'What is the architecture of a system capable of automated negotiation?'.

Whatever the way of approaching the automated negotiation architecture problem is, requirements for automated negotiation architecture are needed. The goal of this survey is, first, to discover the places where the requirements could be taken from and second, to find existing solutions and to investigate them. This survey provides a detailed investigation of negotiation domain and a comparison among several existing negotiation frameworks.

This survey has the following structure. In the next section, a close look at the negotiation domain is taken. Definitions of negotiation are stated and a motivation for automating the negotiation process is given. In section 3, some existing frameworks are chosen and they are investigated and compared. In section 4, this survey discuses the research question that motivated it and also makes a plan for future work. This survey includes in the appendix some of the abstracts of the papers used.

2. Negotiation domain

This section aims to clarify the negotiation domain. It is intended to define frequently used words in the area like 'negotiation', 'automated negotiation', 'auction', 'agent', 'negotiation scenario', and 'negotiation strategy'. Its goal is to find relations between negotiation and concepts like e-Commerce, e-Business, e-Contract, e-Market, B2B, and B2C. Classical who, when, where questions will be answered to light up the negotiation domain from different prospects.

a. Definitions. The What question

The following structure will be followed. Some definitions, commonly found in the literature, will be given and compared.1 After that, a working definition of automated negotiation will be stated. It will be used as a filter for clarifying the negotiation domain.

The first definition can be found in the work of Roger Clarke [Cla93].

Definition 1: Negotiation is a process involving dealings among persons, which are intended to result in an agreement, and commitment to a course of action.

The following definition can be found in [Lom01].

Definition 2: Negotiation is the process by which group of agents communicate with one another to try and come to a mutually acceptable agreement on some matter.

The next definition is taken from [Bea97].

Definition 3: Negotiation in electronic commerce is the process by which two or more parties multilaterally bargain resources for mutual intended gain, using the tools and techniques of electronic commerce.

The last definition is extracted from [Jen00].

Definition 4: Negotiation is a distributed search through a space of potential agreements.

Definitions 1 to 3 show a shift from human-based negotiation to automated negotiation. Definition 1 defines the negotiation process as a process between persons and the result is an agreement for future actions. In definition 2, the accent falls on words as '*agent*', '*communicate*', and '*mutually acceptable*'. The parties taking part in the negotiation process are not necessarily people, but can be any type of actor. Definition 3 underlines the need for tools and techniques from the electronic commerce field. And finally, definition 4 defines the most abstract

concept for negotiation. It is valid in case of negotiation between persons, software agents, in real business, in electronic business, or for politics.

These definitions show that negotiation is an interaction process between two or more parties and their goal is to reach an agreement about mutually acceptable reallocation of resources. The parties communicate information in order to express their expectations for the agreement. Based on the received information and their initial goals, parties take decisions how to continue the negotiation process. This decision-making process could be done in three ways. The first way is when the decisions are taken by people. The second one is when the final decision is taken by people but the options are given by a computer system. These computer systems are so called Negotiation Support Systems (NSSs). More information about NSSs can be found in section 2.d, in [Lim93], and in [Yan00]. The last way is when the decisions are taken without human interference – fully automatically. The term for this kind of negotiation that is commonly used is automated negotiation. In this survey, the following definition of automated negotiation will be used.

Definition 5: Automated negotiation is a process by which actors reach agreement about joint future behavior, where at least one of the actors is an autonomous software agent.

The term autonomous software agent is taken from Wooldridge and Jennings' publication in The Knowledge Engineering Review in 1995 [Woo95]. An agent is autonomous when it chooses its actions through the negotiation process without human interference [Jen01].

The following definition of e-commerce, e-business, e-contract, e-market, etc. will be used in the rest of this survey.

Definition 6: e-*<concept>* is a *<concept>* that uses for its purposes an information system capable of communicating with other information systems. Where *<concept>* represents the following concepts: commerce, business, contract and market.

The level of involvement of automated negotiation in e-<concept>s depend on the level of automation in them.

b. Place in the real world. The Where question

In order to find the precise place for negotiation and automated negotiation in a business process, a closer look at the business domain will be taken. In the business world, everything is driven by the interest of earning more money. The rules for exchanging (reallocating) money (in a form of gold equivalence, goods, or services) are written down (agreed upon) in a contract. The contract is evidence of a mutually accepted agreement. Having in mind that parties in a contract usually have

conflicting interests, a negotiation phase takes place in shaping a contract [Ang02]. In conclusion, negotiation is one of the phases in a business process resulting in a contract. The output of this phase is an agreement for some course of actions. Automated negotiation has its corresponding part in electronic commerce (e-commerce) infrastructure.

c. Goals of automated negotiation. The Why question.

This section aims to answer the question why an automated negotiation is needed. The need of negotiation arises in cases with need for coordination. Coordination is needed every time when a group of actors wants to perform a common task. Even in a situation with actors with different and antagonist tasks in a shared environment coordination is needed for fulfilling each actor's task. By default, actors are different in almost every aspect. They could differ in goals, in their level of autonomy, in their level of rationality, and in interfaces to the environment. This variety generates the coordination problems.

Coordination of such a variety of actors is done with a full spectrum of methods with the two extremes: first is the coordination with standards and second is the coordination with negotiation. Every coordination effort is a mixture of the two: standards and negotiation. By standards, it is meant the rules, agreed beforehand, which define a protocol for communication or standardize the behavior of the actors. By negotiation, it is meant a process of exchange of messages based on some rules (standards) leading to resolving the coordination problem.

The interest of this survey is in approaches that involve negotiation, purely standards solutions to the coordination problem are off its scope. The following arguments motivate solutions with negotiation involved.

- standards for this coordination problem does not exist – solution only with standards is not possible, because not standards are established.

- standards are too many and coordination for coordination standard is needed – non of the standards satisfies all actors and they agree to solve the coordination problem with negotiation

- standards are not complete – available standards cannot resolve all possible conflicts in the coordination process

- actors require flexibility – actors feel restricted from the standards

- actors are autonomous - it is not possible actors to be forced to use prescribed rules

The motivation for automating negotiation is resource constraints and technology push. The number of situations that require negotiation for coordination are growing very fast. Internet, mobile networks and e-

business environment are examples of areas with many actors and many coordination problems. The available human resources are not capable of fulfilling the needs for negotiation because of availability, cost and quality reasons. In the same situation, there are cases where manual negotiation is impossible because of time constraint. The second motive for automating the negotiation process is technology push. With every new technology, new coordination problems and new technique for solving them arise. This opens room for new and more efficient negotiation process.

If a look from another perspective is taken, the goal of negotiation is to give optimally efficient solutions to coordination problems among heterogeneous actors. (For measuring efficiency the following criteria can be used: social welfare, Pareto efficiency, stability, and computational efficiency. These criteria are taken from [San99].)

d. Parties taking part into automated negotiation. The Who question

This section aims to give more details about the participants in a negotiation process. Conditions for naming a negotiation an automated negotiation will be given.

Participants in a negotiation process could be divided into several groups, assuming different criteria. This section divides them using *level of automation*, *role* and *cardinality* as criteria for grouping. See Table 1. This survey is interested in who or what could be the representation of a participant in a negotiation. The term '*agent*'' will be used to indicate a company, a group of people, an individual, or any other legal entity represented in a negotiation.

The first criterion in this survey is the level of automation. See Table 1. This division is based on the composition of the entities representing parties in the negotiation process. The division distinguishes three types of entities: people, NSSs, autonomous agents.

The first type is seen when only people take the decisions during the negotiation process without any support from computer systems. The second type is when people use a support from a NSS. NSS are discussed below in this section. The last type is when the negotiation is held by a software system with minimal or without human interference. These human-independent software systems are called autonomous agents.

Criterion	Groups…				
Level of automation	People		NSSs		Autonomous agents
Role	Central role		Neutral role		
	Self present	Representative	Regulator	Facilitator	Mediator
Cardinality	Two parties			Many parties	

Table 1. Negotiation participants

Historically, the first type of representation of a party is composed of *people*. This type of representation is outside the scope of this survey.

After that, as a transition to fully automated negotiation, *Negotiation support systems (NSSs)* appeared as a component in the entity representing one party. Negotiation support systems are decision support systems in the domain of negotiation [Su01]. According to Alter's classification [Alt77], Decision Support Systems are generally divided into two groups: data-oriented and model-oriented. The former class presents group of systems which are based on large databases with domain specific queries and statistical functionality on top of them. The model-oriented DSSs use a domain specific model for their data base, which gives them advantage in storing and retrieving data. NSSs are mainly based on DSSs from the model-oriented group [Ker98]. NSSs are mostly used in education with two notable exceptions: The Law of the Sea [Seb84] and the RAINS system used in EU trans-boundary air pollution negotiation [IIA98]. Carrie Beam and Arie Segev [Bea97] provide an investigation in the NSSs domain and their conclusion is that NSSs are powerful systems but they require constant human interference.

In this survey, *autonomous agents* are proposed as the most suitable technique for fulfilling automated negotiation requirements. Viewed as autonomous, flexible, problem solving entities, they should be capable of reaching agreement on some issue.

A necessary condition to define a negotiation as an automated negotiation is at least one of the parties to be from the third type – an autonomous software agent. Thus in a general case, a combination of people, NSSs and autonomous agents is possible.

The second dimension of the classification scheme used in this survey is the role played by the participants in a negotiation process. This division consists of two groups: the central roles group and the neutral roles group. See Table 1. These two groups are further divided into concrete roles. An entity in the negotiation process plays a central role when it is a party and/or a representation of a party in a potential agreement. This entity is interested in realizing the agreement. In cases when it is a party (not a representative), it has a continuing role after reaching an agreement. An entity in the negotiation process plays a

neutral role if it only helps in reaching a commonly accepted agreement. Their further division is based on the level of their influence into the negotiation process.

The *Central role* group is divided into two subgroups:

Self-present. An entity is self-present when it takes responsibility for the commitments in the agreement. Resources, reallocated in the negotiation process, are owned by the entity. A self-presented entity is not restricted in the offers it proposes and accepts.

Representative. An entity is representative when it represents the interest of another entity and the commitments it takes are on behalf of the other entity. Resources, reallocated in the negotiation process, are not property of the representative. Representatives are restricted in their freedom by the represented entity.

The *Neutral role* group is divided into three subgroups. A detailed division can be found in the classical book of Howard Raiffa [Rai82].

Regulator - This role is the one with the least influence in the parties' behaviour. It is held by the organization that organizes the negotiation environment. It should not be seen as a real agent that takes decision during the negotiation process but as a preliminary defined regulation that all participants must obey. An example of this is an '*auctioneer*' – the one that runs an auction.

Facilitator – This role is more influential and takes place during the negotiation. A facilitator provides competent and neutral facilitation services to parties in a negotiation. A facilitator keeps the agenda, and clarifies who, why and how should attend the negotiation. A facilitator helps running negotiations that are expected to be complex.

Mediator - Mediation is a voluntary and confidential process in which a neutral agent assists disputing parties to clarify issues, develop options and work toward a mutually agreeable resolution.

Roles that are mixture of the three listed above are possible.

Another division in the negotiation domain could be made according to the cardinality of the parties in a negotiation process. A detailed classification can be found in [Rai82]. Negotiation between two parties is the first type of cardinality and negotiation among more that two parties is the second. The major difference is in the possibility of forming a coalition when there are more than two parties. As long as the common interests are temporary, there is a loose connection among agents and the coalition is not stable. It is not trivial to reduce the number of agents with the agents that form a coalition. This classification is shown in Table 1.

e. Scenarios in negotiation. The How question

This section aims to clarify the use of terms like strategy, tactics, plan, and scenario. The definitions of strategy and tactics are adapted form [Ant65]. The terms strategy and tactics are used in the sense of prescription of certain action that have to be taken to achieve a certain goal. The difference between them is seen in terms of time or generality. Strategy is used when the final goal is relatively far ahead in the time. Strategy is the more general term. A strategy can be divided into several tactics. Strategy should not be expected in all negotiations. The term tactics is used for certain actions for achieving relatively near-future goals or if the goal is relatively simple and no further division is needed. The term plan will be rarely used in this survey and the meaning will be a detailed list of actions that implements a strategy or a tactics. More definitions can be found in [Lom01] and [Bar01a].

Strategy, tactics, and plan are terms used to represent the negotiation process from a participant's point of view. If a global perspective on a negotiation process is taken than some patterns in applying different strategies and tactics can be seen. A common pattern observed in the behaviour in certain circumstances in a negotiation process is a scenario. A scenario is a global characteristic of a negotiation.

Scenarios are divided into three types, depending on how parties estimate the negotiated issue. A similar classification is given in [Cla93]. The three types are cooperative, competitive and mixed. The *Collaborative* scenario occurs when all parties in a negotiation process could generate offers which satisfy their wishes. This is a 'win-win' situation according to [Cla93]. According to game theory, this is a positive sum game. In other cases, fulfillment of the wishes of one party may be directly detrimental to the fulfillment of the wishes of another party. This is a 'win-lose' situation [Cla93] or a zero-sum game in the context of game theory. This is a *competitive* scenario. If some of the parties have to make some compromises or they have to accept something for their own good and for the good of their competitor then a *mixed* scenario is seen.

Applying different strategies and tactics and varying different scenarios, the negotiation process could finish in one of the following ways. 1. Agreement is reached, all parties accept the agreement. 2. No agreement is reached, all parties agree that no agreement is possible. 3. 'stand-off' situation [Cla93] , on a single issue no commonly acceptable agreement could be found. 4. 'dead-lock' situation [Cla93], on several different issues no mutually acceptable agreement could be found.

The rest of this section is about the causes that force the agents to choose one or another tactics and, as a result of that, to shape one or another scenario.

Cardinality of the issues in a negotiation could be a cause for different scenarios. Cooperative and competitive scenarios are typical in one-issue negotiation. In many-issue negotiation the common scenario is mixed. If one party rates one of the issues very high it could chose a tactics to loose the other issues and form a mixed scenario.

Cardinality of the parties taking part in a negotiation could be another cause for differentiation in scenarios. In cases where only one party offers or looks for resources, the rest of the parties could be involved in a competitive scenario. In the same cases, parties can choose a certain search tactics or certain tactics for attracting parties.

Time could be another cause for different scenarios. Time in negotiation is discussed in the next section. If one of the parties has time limitations, this could be a reason for changing the tactics and therefore to change the scenario from competitive to mixed. If the negotiation is not repetitive, parties could choose threat, as a primary element in their tactics, or opposite in repetitive negotiation, parties could choose to be yielding to keep good relationships.

f. Time and negotiation. The When question

This section discuses the role of time in the negotiation process. Time is important for negotiation as a sequence of events time and as duration.

In the contract process model [Ang02], negotiation has its specific place. It appears as a phase before signing a contract. Negotiation could reappear later as need of renegotiating unspecified issues or changes in the business environment.

Time could influence the tactics of a party. In a particular negotiation, time could be an important issue if there is a deadline for reaching an agreement. The result could be a change in the tactics or non-optimal agreements could be seen as better than no agreement.

When a negotiation is one of series of negotiations then parties could afford to lose one or two negotiations. This again influences their tactics or strategy. This could also influence the parties to act more 'nicely' in order to build a fruitful environment for the continuing negotiation.

Another indirect influence of the time could be seen in long-term contracts. As far as all agreements are based not only on mutual benefits but on trust, in a long term contract, negotiation could be a milestone in building trust. This again is an influence in the way parties act.

g. Status. What are the available technologies, infrastructures and standards?

This section will give a brief overview of available technologies, infrastructures and standards on the implementation level. It aims to discover the places where the negotiation process is automated or could be automated.

Table 2 lists the available infrastructures and gives the applicability of each of them in a particular business relationship. The level of involvement of the negotiation in each of these technologies is further discussed in this section.

	C2C	B2C	B2B
e-catalogue		X	X
e-auction	X	X	X
e-market	X		
business process schema			X

Table 2. Available Infrastructures

E-catalogue is a solution widely applied in B2C relationships. An example of this kind is Amazon.com (http://www.amazon.com). This infrastructure is based on concrete products with concrete prices. This infrastructure provides an interface for searching, choosing and buying a product or service but hardly uses any negotiation. It is out of the scope of this survey.

E-auction is a solution applied in all relationships. An auction is a place where buying and selling parties meet each other. Parties follow certain rules to reach an agreement on exchanging conditions. Several types of auctions exist. The ones commonly seen are open-cry auctions, single and multiple round sealed bid auctions and Dutch auctions. Subtypes exist such as the Yankee Auction and the Vickrey Auction. A full classification of auctions can be found in [Kum98]. In all kinds of auctions, negotiation is seen as fixed set of rules that agents follow to agree on exchange value and/or exchange conditions for a product or service. A design model for an Internet auction system can be found in [Kum98]. An overview of some available Internet auctions can be found in [Su01] and [Bea97]. E-auctions are example of successful implementation of simple negotiation techniques.

E-market is a solution applied in C2C relationship. E-market is a common term for web places that offer some kind of interface for trading. These places are the electronic analog of open markets. The negotiation there is between people, the same as in the non-electronic case, but the media is different. Automated negotiation has its place in this e-Market

Interface category but no implementations are possible as long as it is only an interface for announcements.

Business process schema is a combination of technology infrastructure solutions and standards applied in B2B relationship. These schema form a framework conducting the business process between two or more legal entities (organizations or institutions). Currently available frameworks at the implementation level are RosettaNet, ebXML and BizTalk. RosettaNet is a consortium of companies working to create and implement industry-wide, open e-business process standards. The proposed scheme describes the supply chain between partners on process level. EbXML defines an architecture for business-to-business interaction. EbXML includes the following two specifications which are based on XML: UDDI (Universal Description, Discovery and Integration), SOAP (Simple Object Access Protocol). EbXml sees the negotiation process as exchange of messages which contain business offers - Collaborative Protocol Agreement (CPA). One of the party generates CPA and sends it to the other party. This process goes on until they agree on the content of CPA. BizTalk is a Microsoft proposed framework for data and business process integration. It is built on XML technology. It includes engine for document exchange, business process execution engine and tools for managing trading partner relationships and tracking transactions. Comparison among these implementations can be found in [Wen00]. Negotiation in this technology is an important issue. No implementation is available now.

Another example of a negotiation implementation is in the form of a game. The Trading Agent Competition (TAC) is an Internet game that runs on the Michigan Internet AuctionBot platform. AuctionBot is a configurable auction server that supports participation by software agents in a simulated auction in the TAC. Software agents play the role of travel agents and they compete among each other in assembling travel packages. More information can be found on http://auction2.eecs.umich.edu/.

3. Negotiation frameworks

This section selects some frameworks from the published results. It aims to make a small investigation in the literature and to relate it with the terms introduced in the previous section. The selected frameworks will be briefly described and compared.

The following definition of a framework is used in this section. Every reasonable collection of objects, rules and relations that conducts a negotiation process is referred to as a framework.

Four frameworks were selected for this investigation of the framework space. They are: framework one by N.R. Jennings, S. Parsons, C. Sierra, P. Faratin, P. Noriega, A.R. Lomuscio and M. Wooldridge; framework two by C. Bartolini and C.Priest; framework three by K. Lee; W. Y. Wong, D. M. Zhang and M. Kara-Ali framework four by. The references are given below. These four frameworks are considered relatively sufficient and they are believed to cover big percentage of possible negotiation framework variations.

The selected frameworks are classified and compared according the following criteria: presence or absence of negotiation protocols, presence or absence of negotiation objects and presence or absence of decision making models. All the three elements that form the three criteria are element from the framework of N.R. Jennings, S. Parsons, C. Sierra, P. Faratin, P. Noriega, A.R. Lomuscio and M. Wooldridge [Jen00] and [Jen01]. This framework is discussed later in this section. These three elements are chosen because they form a union of the elements of the selected frameworks. For better positioning of the selected frameworks into the negotiation domain, these elements will be related with the terms used into the previous section.

Negotiation protocol as an element of a framework represents the rules that conduct the negotiation process. These rules most closely relate to the negotiation process rules that *Neutral role participants* enforce (Neutral role participants are regulator, facilitator and mediator. See section 2.d). Negotiation protocols could shape the scenario of a negotiation process, i.e. established rules can lead to a particular scenario type in term of section 2.e. From a technology point of view, negotiation protocols are discussed in section 2.g. The technologies introduced in that section are mainly implementation of negotiation protocols.

Negotiation objects represent the matters on which the negotiation process takes place. The influence of the negotiation objects in negotiation strategy, tactics and scenario are discussed in section 2.e.

Decision making models are one of the criteria for classification of the participants in negotiation process in section 2.d. This criterion divides participants into three groups: people, NSS – with decision supporting models and autonomous agents – with a variety of models of environment, of other agents, of desired objectives. Decision making models directly reflect into the strategy and tactics that participants could chose (section 2.e)

a. Framework one

The first framework discussed is the framework by N.R. Jennings, S. Parsons, C. Sierra, P. Faratin, P. Noriega, A.R. Lomuscio and M. Wooldridge. It appeared to be the most exhaustive and complete. For more information see [Jen00] and [Jen01]. A short description of the framework is given bellow.

The discussed negotiation framework consists of three major elements. They are negotiation protocols, negotiation objects and agents' decision making models.

The first element, *negotiation protocol*, represents the rules that govern the negotiation process. These rules are agreed beforehand among parties. The negotiation protocol defines the type of the participants (in terms of section 2.d, the role of each participant), negotiation states (e.g. negotiation started, accepting offers, negotiation closed), events that change the negotiation state (e.g. time elapsed, no more bids) and valid actions in each negotiation state.

The second element, *negotiation objects*, represents the issues that the participants negotiate. Objects could consist of one or many issues. An example of one issue object is the price of a resource. Some example of many issues object is one that contains price, quality, quantity, delivery, etc. In a negotiation process, negotiation objects and issues could be static or dynamic. An example of a static negotiation process with respect to a negotiation object is a negotiation for one resource with only one issue (price). The other extreme is dynamic negotiation process where parties could generate new negotiation objects with more than one issue in them. A simple example of dynamic objects negotiation is when one receives something as a present in addition to the main negotiation object.

The third element, *agents' decision making models*, represents the models that parties use to represent the negotiation environment. Based on these models, parties build their strategy to achieve their objectives in a negotiation process. The complexity of the model can vary depending on the negotiation protocols and negotiation objects.

The authors of this framework see the negotiation process as a distributed search through the space of all possible agreements. Every issue of a negotiation object can be seen as an additional dimension of the negotiation space. Every party has a set of preferred points in this space, which form the party's acceptability space. During the negotiation process, parties are changing their acceptability space in order to find intersection with the acceptability space of the other parties. For this search procedure, parties have to be able to make and respond to offers. In the following three paragraphs, three types of interaction between parties are given.

In the first type, parties have to accept and reject offers. An example of this interaction is an auction. The only feedback that participants give to the auctioneer is their acceptance or rejection of the current offer.

In the second type, the interaction process is richer. As a response to an offer parties give critiques. This helps the parties that give the offers to look for mutually acceptable point in the negotiation space more efficient.

In the third type, all parties are actively looking for mutually acceptable point. This means that the response to an offer is not simple a critique but a counter offer.

These three types of interaction among parties result in different in complexity of the agents' decision making models. The authors propose the following three approaches for building such models: Game theory, Heuristic and Argumentation-based approaches.

The game theory approach follows game theory techniques, which suppose rational behavior and common knowledge. The heuristic approach is based on imitating human behavior in certain situation and modeling it as a set of strategies. The argumentation-base approach is a logic-based approach, in which the other parties are influenced with promises, appeals and threats. More information about these approaches can be found in [Sie98],[Jen98],[Mat98] and [Vul00].

b. Framework two

The second framework discussed is the framework by C. Bartolini and C.Priest from HP Labs Bristol [Bar01b]. This framework focuses mainly on the protocols level and gives detailed technical view on the negotiation process. A short description of the framework is given bellow.

This framework has a strong notion for negotiation protocols and a weak one for negotiation strategies and negotiation objects. This frame work is not interested in decision making models. The main focus is on the negotiation protocols. The negotiation strategies are seen as private for every participant and not an essential part of the framework.

The frameworks is based on a use-case driven approach. The intention behind this approach is to build a general negotiation framework. So designed framework will be a template for future specialization for concrete negotiation cases. The framework is an extension of a general message exchange system. The negotiation protocol that determines the rules that participants have to obey is a generalization of rules for exchanging messages. The authors list the following requirements for the negotiation protocol. (copied from [Bar01b]):

- Be sufficiently formal that automated entities can interact using it.

- Support negotiation about simple and complex objects.

- Be sufficiently general that a variety of different market mechanisms (e.g. one-to-one negotiation, combinatorial auctions, exchanges) can be expressed as specific instances of it.

- Support security mechanisms and protocols that enable participant to do business in a trusted way.

- Allow, but not require, the existence of a third party to arbitrate a given negotiation (e.g. an auctioneer in an auction)

- Support existing ways of doing business, as well as permitting more radical approaches in the future.

The proposed framework defines in addition some primitives as a language for defining the rules of negotiation, a language for expressing negotiation proposals and taxonomy of rules of negotiation. The relationship between rules of negotiation and protocol is given below.

The *rules of negotiation* are parametric versions of the general protocol. This casting mechanism is used to customize the general protocol for a specific market. The authors propose a *language for defining rules of negotiation* - a declarative language for describing the rules in way readable and understandable for the participants.

Away from the negotiation protocol side, the authors propose a *language for expressing negotiation proposals* as a part of the framework. This language is meant for describing the content of the exchanged messages. It is used for describing the negotiation objects and their dependences. They specify it as a language that conform to the following requirements (copied from [Bar01b]):

- Support for ontology and namespaces

- High degree of expressiveness

- Ability to express less than fully bound specifications

- Ability to express constrains over ranges of possible values as well as definite values of a specification

- Loose support for types and some degree of inheritance

- Support for complex queries

- Support for complex matching

This framework elaborates in detail the negotiation protocol. It proposes a general protocol and techniques for specifying it for particular cases. It proposes techniques for achieving interoperability among the participants. It is proposed as a solution at implementation level.

c. Framework three

The third framework discussed is the framework by K. Lee [Lee00]. This framework is also focused on the protocol side of negotiation process. More precise, the framework emphasizes the time involved in the negotiation process. The framework supposes that a system for exchange of messages already exists, as well as a protocol for the exchange of these messages. The framework proposes a time attribute to be attached to each message to represent the time period in which the message is valid.

The author proposes three different types of protocols depending on the time attribute attached to them. He gives the following example for illustration: Imagine a market with 3 agents. Agent P is a seller, agents X and Y are buyers. P has 7 units of something. In a certain moment P receives a request from X for 4 units. P answers to X 'Yes, I have 4 units.' Five minutes later, P receives request from Y for 6 units. Here the problems for P start. P needs additional information for determine an efficient strategy.

The first type is *Nothing-Guaranteed Protocol.* The time period of validity is zero. The protocol is valid only in the moment of generating the resulting message. The protocols without time attribute can be seen as Nothing-Guaranteed Protocols.

The second type is *Acceptance-Guaranteed Protocol.* This protocol represents the other extreme when the stated offer in a protocol remains valid for an unlimited time period.

The third type is *Finite-time Guarantee Protocol*. To every message in this protocol, a finite time period representing the relative time of validity of the message is attached.

The author shows that the optimal result for particular kind of negotiation can be achieved with the Finite-time Guarantee protocol with particular time period of validity.

d. Framework four

The forth framework, discussed in this section, is the framework by W. Y. Wong, D. M. Zhang and M. Kara-Ali [Won00]. This framework focuses on the decision making model. The framework proposes the Case Based Reasoning (CBR) as an approach to use past experience for choosing concrete strategy in every concrete situation.

The framework is build on top of a database with the following information in it. The core data is collection of cases of past negotiations. These example negotiations are rated and kept updated during the operation of the framework. The negotiation case maintenance process can be seen as a learning process. The negotiation cases are kept in the database in a form of clusters. These clusters are formed assuming the following criteria which are also part of the database. The criteria are profiles for every product, every customer and every seller. The negotiation process is divided into episodes. Before starting the negotiation process, customer's, seller's and product's profiles are known. For every step (episode) in the negotiation process, a matching procedure in the negotiation case database is performed. The results are rated and the best strategy for next step is chosen.

e. Summary

The following table shows comparison among the four frameworks.

	Negotiation protocols	Negotiation objects	Decision models
Fr1	X	X	X
Fr2	X		
Fr3	X – time		
Fr4			X - learning
Fr1	N.R. Jennings, S. Parsons, C. Sierra, P. Faratin, P. Noriega, A.R. Lomuscio and M. Wooldridge		
Fr2	C. Bartolini and C.Priest		
Fr3	K. Lee		
Fr4	W. Y. Wong, D. M. Zhang and M. Kara-Ali		

Table 3. Frameworks

The first framework covers the elements that can appear in the negotiation process. The description of the elements is kept abstract despite of the framework number two. The second framework is closer to the implementation level and proposes languages for describing and casting the protocols. The third framework is extension to the first two. It proposes time attribute attached to the protocol messages. The first

framework has a notion for negotiation object and decision models. They represent the objects that are subject of negotiation and the prescriptions for choosing a future action. The first framework covers the decision making model from argumentation-based, heuristic and game theory approaches. The fourth one proposes a decision model based on the Case Based Reasoning approach with element of learning despite of the first.

4. Q without A and future work

The motivation for this survey is the goal of building autonomous software agents that are able to negotiate. In order to satisfy this goal the following questions, listed in this section, need to be answered.

The first question that pops up, when software systems are developed, is the question about the architecture of the system. Logically, the first and main question is the following:

- What is the software architecture of an agent that can do negotiation?

This question generates a lot of other subquestion which themselves generate subquestions. The first one that comes up, is the question about the requirements:

- What are the requirements for a software system capable of doing negotiation?

- Where should these requirements be taken from?

The last question motivates the first part of this survey (section 2). The detailed investigation of the negotiation space aims to discover possible sources for requirements. The second part of the survey (section 3) is meant to answer the following question:

- What are the existing architectures?

Going further into details (sub question), the investigation of the negotiation domain generated the following questions:

- How is the agent's architecture influenced by the agents' relationships (1-1, 1-n, n-n)?

- What is the software architecture of a virtual market place?

- How is the virtual market place architecture influenced by the agents' relationships (1-1, 1-n, n-n)?

- How should the agents model the environment?

- How should the agents model the other agents?

- What kind of mental model should agents use?

- What are the criteria for evaluating software architecture?

The last group of questions is a motivation for the future work. The following sequence of steps should be taken in order to satisfy the main goal of building negotiation agents. First, the negotiation domain should be restricted to a reasonable set of elements with as small as possible number of combinations of attributes of elements. For example, the element of the domain 'cardinality of relationship' is part of the domain

and the possible values of its attribute 'cardinality' are 1-1 and n-n. The second step is gathering requirements from the restricted domain. Next is specifying architecture evaluation criteria. The fourth step is the design of an architecture. The last is comparison with existing architectures having in mind the same criteria in the same restricted domain.

5. Conclusion

This survey is an investigation of the negotiation domain. The motivation for this investigation is the goal of building a system that can do automated negotiation. This goal raises several research questions which are briefly stated in the beginning of the survey and are discussed in a separate section later. Reasons for the need of automated negotiation are given as well.

The main question that this survey attempts to answer is 'Where could the requirements for an automated negotiation system be taken?'. The answer is given in the second section where the results of the investigation of the negotiation domain are given. This survey gives a brief overview of existing negotiation frameworks. It summarizes them and makes a comparison among them. The survey concludes with putting forward some new research questions and sketching a plan for future work.

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