Negotiating Agents

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Abstract

This reader serves as additional material for a course on Artificial Intelligence techniques, in which the development of automated negotiating agents serves as a practical assignment in which Artificial Intelligence techniques can be applied and students experience the power of distributed artificial intelligence to solve complex problems.

In this reader key concepts of negotiation and in particular key aspects of automated negotiation are defined and briefly explained. The concepts are first introduced as part of an explanation of negotiation, and then briefly defined in a kind of glossary, with occassionaly some references for further reading. In the spirit of open science and team work we would appreciate help to further develop this document.

1 Negotiation

Negotiation is a form of interaction in which two (or more) parties, with conflicting interests and a desire to cooperate, try to reach a mutually acceptable agreement. Negotiating is an important aspect of professional and personal life [52]. Sometimes we conduct explicit negotiations; when buying a car or in case of a career interview for example. We resolve most of daily life negotiations without even thinking of them as such, e.g. when going out for drinks or booking a holiday. Negotiations is a multidisciplinary field of interest. It is actively being researched in artificial intelligence (AI) [25], as well as other disciplines such as economics [5, 49, 51], game theory [49, 48], and psychology [56]. AI focuses on the automation of negotiations; using automated agents to negotiate on peoples behalves such as in e-commerce systems [39, 41]. This can improve the outcome and reduce the time needed for negotiations[41]. It can also be used to improve the persons negotation skills [20].

Positive reasons for entering a negotiation is that the negotiation parties see the potential for reaching a win-win outcome, need a deal

A win-win negotiation is one in which all parties can get a good deal out of the negotiation. In cases of one-issue bilateral negotiations, the problem typically corresponds to a constant-sum game, in which gains for one are the loss of the other party.

Negotiation between parties can in many ways be modeled as a game, and game theory is useful to analyze the behavior of negotiating parties. Negotiation is, however, also different from many board games such as chess and reversi. One of the most important differences is that multi-issue negotiation typically is not a constant-sum game. That is, a typical negotiation does not have a winner who takes all and a loser who gets nothing. In order to start a negotiation, it is only reasonable for both parties to believe that there is a *win-win* situation where both parties can gain by obtaining a deal through negotiation. Another difference is that the domain of negotiation (what the negotiation is about) may be quite different from one negotiation to the other. Another important difference is that in negotiations the parties typically do not reveal their complete preference ranking of possible outcomes, and that the information you have about the negotiation is therefore, typically uncertain and incomplete.

This report is organized as follows. In Section 2 we roughly sketch the *phases of the negotiation process* of negotiation. The bidding phase of the negotiation is organized according to protocols for different types of negotiations, see Section 4. The rich literature on the art of negotiation contains plenty of guidelines and advice for human negotiators. A short description can be found in Section 5. After that we make the transition to add intelligent agents to the game. This starts with Section 5.2, and is followed by Section 6 on the different strategies and Artificial Intelligence techniques that intelligent agents should implement; Section 6.3 on Opponent Modeling Strategies, Section 6.1 on Bidding Strategies, and Section 6.2, on when to accept, reject, or walk away. When developing automated negotiating agents, one needs measures and techniques for analyzing how well the agents are performing, see Section 7. We conclude the document in Section 8 with some pointers to research questions that could do with the attention of research minded people. For your benefit, we constructed a glossary of the concepts used, see Section 9.

2 Negotiation Phases

Initially, in a *pre-negotiation phase* the negotiation domain and the issue structure related to the domain of negotiation are fixed. The issue structure tells you what issues are negotiable and what value-range that issue can take. Negotiation may be about many things, ranging from quite personal issues such as deciding on a holiday destination to strictly business deals such as trading orange juice in international trade. In this reader, the party domain serves as a predefined example. The party domain is about organizing a party together with some friends and negotiating what you want to spend the available money on. In other words, the pre-negotiation phase has been completed and you cannot redefine the domain anymore.

There are two tasks that are usually considered part of the pre-negotiation phase that you do need to consider before you can ask an negotiating agent to negotiate on your behalf. The first task involves creating a so-called *preference profile* that captures your own preferences with regards to the party domain. The result will be a formal preference function that maps each possible *outcome* of a negotiation to a *utility number* in the range of 0 to 1. The second task involves thinking about *strategies* used to perform the negotiation itself. In negotiation you need at least two strategies: a bidding strategy - sometimes called offering strategy - (what to bid when), and an acceptance strategy (when to accept or reject offers, and when to stop negotiating - walk away).

In negotiation the following phases are recognized: preparation, exploration, bidding, closing. Each of these phases are briefly described.

2.1 Preparation phase

In the preparation phase you identify what you would like to get out of the negotiation. You think about the issues you would like to negotiate about (also called the negotiation variables), and what values these issues can have in a possible outcome. For example, when negotiating about a second hand car, typically the price of the car is an issue, and the value range of that issue might be between 250 euro and 15.000 euro. Similarly, you might want to negotiate about a guarantee on its proper functioning, with a value range of say 0 to 12 months. Some aspects that are important to you might not be negotiable, for example, if you are negotiating about a specific car, then the age and mileage of the car are already given, and cannot be changed. If you are negotiating about the characteristics of the car that is still to be found, then you can take these issues into the negotiation. The process of thinking about the negotiable issues, and their value ranges is sometimes referred to as domain modelling.

While investigating the domain of negotiation it is good to consider some other factors. How urgently do you need a deal? What about the other negotiation parties? Is there a discount factor? The discount factor indicates the loss of value over time as the bargaining process evolves. Consider a transportation company negotiating with a grocery shop to transport a load of vegetables. In this case, the company is eager to reach an agreement about the costs and the dates of transportation: Trucks that stand still don't make money. The grocery shop is concerned about the decay of the vegetables: as soon as the vegetables are harvested they should start their journey to the shop. Suppose that the vegetables are already harvested and the trucks of the transportation company are currently not transporting good. The longer the bargaining process, the greater the cost of the lost opportunity. To conclude, not only is the time spent bargaining important, but also the degree of impatience.

While thinking about the issues and their value ranges, you also need to think about your preference profile, i.e., a preference ranking of the possible outcomes of the negotiation. A preference profile can be represented by a utility function that maps bids to numbers, or a CP net that compares bids using a preference relation. When thinking on that you also need to establish a reservation value, which is related to a BATNA (Best Alternative to a Negotiated Agreement). For example, keeping your current car a year longer might be a good BATNA for buying a car that is actually not much better than your current car. The reservation value is expressed the utility below which you will not accept bids. Logically, your reservation value should not be lower than the utility of your BATNA.

It pays off to also think about the preference profiles, and the BATNA and reservation values of the other negotiation parties before you start negotiating. In the preparation and exploration phase you can also investigate what you can find out about the negotiation strategies of the other negotiators.

2.2 Exploration phase

The exploration phase is used to get to know the other negotiating parties. The aim of this phase is to check and possible adapt the domain of negotiation and to establish an atmosphere in which an agreement has the best chance of succeeding. During your contact with the other parties you might discover that you need to add issues to the negotiation, maybe because one of the other negotiation parties insists on talking about that, or because you discover that you forgot some aspects. You might also come to realise that your preference profile, BATNA and / or your reservation value need to be updated.

By talking with the other parties you also try to get a better estimate of the preference profiles, BATNA's and reservation values of the other parties.

Finally, pre-negotiation is also part of the exploration phase. During the pre-negotiation together with the other negotiating parties you establish what issues will be under negotiation, and what mechanisms and protocols will be followed during the bidding phase. This is a kind of negotiation in itself.

2.3 Bidding phase

In the development of automated negotiating agents, traditionally most emphasis is placed on the *bidding phase* itself, i.e., the exchange of offers between you (or your software party) and an opponent, or a set of other negotiation parties. The exchange of offers can be only about the value of one or some of the issues (partial bids), or about all issues simultaneously (complete bids). Furthermore, such offer might be accompanied by all kinds of motivation or argumentation. Someone that puts all his cards on the table (reveals his complete preference profile) is said to be open about his preferences. Someone that only presents a bid consisting of values linked to issues is said to be closed in his negotiations. Typically humans tend to negotiate one issue at a time, and to add some additional motivation or argumentation with each bid.

In this phase the important strategies are the bidding strategy (what to bid when), the acceptance strategy (when to accept, reject or walk away), and the opponent modeling strategy. More information on these strategies can be found in Section 6. The bidding phase ends when the negotiating parties come to an agreement (all other parties accepting the offer made by one of them), when the negotiations run into a deadline of some sort, or when enough parties walk away from the negotiations. The exact rules for ending the negotiation, as well as what one is allowed to exchange when is governed by the negotiation protocol, see Section 4.

2.4 Closing Phase

The content of the closing phase of a negotiation is determined by how the bidding phase ended. If parties walked away, the closing phase might be completely void, but might also be used to express under what circumstances the parties would be willing to come back to the negotiation table (in which case it makes good sense to close with expressions of appreciation of the effort made by the parties to attend the negotiation in the first place). However, if the bidding phase ended in an agreement, the closing phase is the phase in which the negotiation parties confirm the agreement reached. This phase in human negotiations concludes the negotiations by signing a contract, congratulating all parties on the agreement achieved and, if appropriate, looking forward together on the future in which the contract will be jointly fulfilled. The protocols for automated negotiation as present in GENIUS and GENIUSWEB make short work of this phase.

3 Formalizing Bids and Utilities

This section presents the notation and definitions for bids, utilities and moves as used in the remainder of this article. Furthermore, we would like to point out that our work is inspired on the work by many in the Automated Negotiating Agents Competition (ANAC), as reported in e.g., [29].

Let P be a set of at least two negotiating parties. Without loss of generality assume that the names of the negotiating parties are $p_1, \ldots p_k$, where $k = |P|$. Variable $p \in P$ ranges over all negotiating parties.

Let S denote the space of all possible bids and let $b_p^r \in S$ denote the bid made by negotiator p in round $r \in \mathbb{N}$. Note that any negotiation is presumed to be finite, so that r_m denotes the final round of the negotiation. Let $u_n : S \mapsto [0,1]$ denote the utility function of negotiating party p. Let U denote the function that maps bids $b \in S$ to the P-dimensional utility space $[0,1]^P$ spanned by the utility functions of the negotiating parties:

$$U : S \longmapsto \Pi_{p \in P}[0,1]$$

which is defined by:

$$\forall b \in S : U(b) = \langle u_1(b), \ldots, u_k(b) \rangle$$

Note that the utility functions of the negotiating parties in real negotiations are typically not known, and so would have to be estimated by each agent that wants to reason about the utility function of another negotiating party. For any two negotiating parties $q, p \in P$, $q \neq p$, let e_q^p denote the utility function of negotiating party q as estimated by negotiating party p.

So far, we have not further elaborated on S, the space of all possible bids. In multi-issue negotiations, the objective is to reach an agreement over a finite number β of issues $\mathscr{I} = \{i_1, \ldots, i_\beta\}$. Each issue $i \in \mathscr{I}$ has its own range of possible values S_i So, in general, $S = \Pi_{i \leq \beta} S_i$. Thus

$$S = \langle S_1, \ldots, S_\beta \rangle$$

The utility functions of the negotiating parties are therefore also functions that take a multi-issue bid as input and map that to the range $[0,1]$; formally: $\langle S_1, \ldots, S_\beta \rangle \mapsto [0,1]$. These functions can complex nonlinear functions, or relatively simple linear additive functions. For more information on these aspects, see [43].

In this document we focus on linear additive utility functions that are build up out of simpler utility functions per issue, that are often called issue evaluation functions, or sometimes valuation functions, so that for all $p \in P$, we define:

$$u_p(\langle i_1, \ldots, i_\beta \rangle) = \sum_{j=1}^{\beta} w_{p,j} u_{p,j}(i_j)$$

where $w_{p,j}$ is the weight that p assigns to issue j, and $u_{p,j} : S_j \mapsto [0,1]$ is the p's utility function for issue j, such that $\sum_{j=1}^{\beta} w_{p,j} = 1$.

3.1 Normalisation

Note that when negotiating in arbitrary domains, the evaluation ranges of the issues under negotiation might not necessarily be provided to you in the range of $[0,1]$. In that case, you will have to normalize the evaluation and the utility functions to the range of $[0,1]$ yourself to be able to compare the proficiency of your agents over different domains.

We discuss it here only for discrete domains. You first need to normalize all evaluation functions for the issues. Pick the item of the issues range that has maximum value, the normalized evaluation function for that issue maps that item to 1. For all other items in the range normalize in proportion to the maximum value to determine its normalized value.

Formally: Given issue $j \in \mathscr{I}$ with range S_j, and a non-normalised evaluation function $v_j : S_j \mapsto \mathbb{R}$, we define the normalized evaluation function $u_j : S_j \mapsto [0,1]$ by:

$$u_j(x) = \frac{v_j(x)}{max_{y \in S_j} v_j(y)}$$

Note that if the weights of the utility function are not normalized, then you also have to normalize the weights.

4 Types of Negotiations and their Protocols

Negotiation protocols define the rules and regulations the negotiating parties agree to adhere to during the negotiation. In informal human negotiations people might not priorly agree on a protocol or other rules of encounter [55], or implicitly use some culturally defined protocol, e.g., some form of Alternating Offers Protocol AOP [57]. Negotiation comes in different flavours that depend on how many negotiating parties there are and how these are organized, whether or not there is a mediator, and how the negotiation protocol orchestrates it.

4.1 Types of Negotiation

Whereas bilateral negotiation is a term reserved for negotiations between just two parties, we use the terms of multiparty and multilateral interchangeably for any negotiation involving two or more parties, with bilateral negotiations as a special case. A negotiation engagement can be a one-to-one, one-to-many, many-to-one, and a many-to-many negotiation. More options exist, but are not treated in this document. When describing market situations of multiple buyers and multiple sellers, you can use the concepts of one-on-one (or bilateral) as well as multiparty negotiation. In marketplace settings there are multiple buyers and sellers which conduct bilateral negotiations among themselves, i.e., they only interact in pairs. Examples of a marketplace type negotiations can be found in [47, 59].

We define one-to-many negotiations as auction negotiations. In contrast to the many-to-many negotiations, in this setting not all negotiators have the same role. The same is true for many-to-one negotiations, which we define as mediated negotiations. In this case, multiple parties try to come to an agreement by interacting with some centralized entity.

The next interesting variant is called multi-thread negotiations, a variant of one-to-many negotiations in which one party is negotiating about the same good in several bilateral negotiations. Not considered good practice in the Netherlands, but nonetheless sometimes practiced, for example, in real estate negotiations. Consider 5 parties all interested in buying the same house. The current owner of the house can simultaneously negotiate with all 5 parties. The seller can use this to his advantage, using a good bid from one of them to entice the others to raise their bids as well.

Finally, we define many-to-many negotiations, or peer negotiations. In a peer negotiation setting all parties have similar roles in the negotiation and try to come to a joint agreement. An example of peer negotiations is a group of friends negotiating on their holiday.

In this document we focus on the many-to-many negotiation or peer negotiation setting.

4.2 Negotiation Protocols

A negotiation protocol describes the rules of the negotiation about who can can offer what and when to whom. In this course we mainly work with the so-called turn-taking protocols, but we also briefly discuss other protocols.

The turn-taking protocols are all variants of the Alternating Offers Protocol (AOP) as specified by Rubinstein [57]. According to this protocol, one of the negotiating parties starts the negotiation with an offer. The other party can either accept or reject the given offer. By accepting the offer, the negotiation ends with an agreement. When rejecting the offer the other party can either end the negotiation (walk away), or make a counter offer. This process continues in a turn-taking fashion.

Initially, the protocols proposed for multiparty turn-taking negotiations in the multi-agent community mostly used a mediator [2, 22, 17, 18, 37].

The Mediated Single Text Negotiation Protocol (MSTNP) Mediated Single Text Negotiation Protocol, which is based on [50]) uses a mediator to propose offers that all negotiating parties can vote on with either accept or reject. When an offer is accepted by all negotiating parties, then the mediator stores that as the most recently accepted bid. When time is up (or a predetermined number of offers has been offered), then the most recently accepted bid is taken as the agreement reached in the protocol. The mediator modifies the most recently accepted bid by arbitrarily changing the value of one of the issues and then asks the negotiating parties to vote again. The role of the mediator is to propose new ideas that are acceptable to all. Different strategies have been proposed to efficiently find agreements and to optimize the agreements found. One solution is to use a mediator that is trusted by all parties; the parties reveal the preference profiles to the mediator, who then can use multi-criteria optimization techniques to find the best agreement. However, this centralised solution is not always possible, as that amount of trust might not be available. In that case, other artificial intelligence techniques can be tries. Mechanisms proposed for this are, e.g., hill-climbing, or simulated annealing, [36]. In the adaptation of MSTNP, called Mediated Single Text Negotiation Hill-Climber Agent that [36] proposed, negotiating parties accept an offer only if it is better for them than the most recently accepted bid. One of the problems with this approach is that if the utility of initial bid is quite high for one of the agents, that agent may not accept other bids even though those bids might be better for the majority. In other words it depends heavily on where in the space of offers the mediator starts the process. This is a well-known limitation of the hill-climber algorithm of getting stuck in a local optimum, which is why simulated annealing was invented. In simulated annealing means are introduced to make the algorithm jump to other places in the outcome space to increase the chance of finding a global optimum, as variation this is also discussed in [36]. In this variation, the parties use an acceptance strategy that in the earlier stages of the negotiation process increases the chance of accepting the offer, while over time acceptance relies more and more only on the improvement in utility that the party sees when comparing to the most recently accepted bid. Formally, $P(accept(b)) = min(1, e^{-\Delta u(b)/T}$, where T denotes a virtual temperature that is initially high, but cools of over time. For more information on simulated annealing, see e.g., [64].

In later years variations on non-mediated alternating offers protocol have been proposed. The Monotonic Concession Protocol was introduced by Endriss [11]. This protocol enforces the agents to make a concession or to stick to their previous offer. The concession steps suggested in that protocol require knowledge of the other agents preferences, as the agent is expected to make a bid that is worse for itself.

The Sequential-offer Protocol as introduced by Zheng et al.[70] is a generalization of the alternating offers protocol. They show that agents using the protocol are incentivized to converge to a solution, which is typically a desired property of a protocol. The protocol supports only timebased deadlines, and has no walk-away option.

De Jonge and Sierra introduced a multilateral protocol inspired by human negotiations, called the Unstructured Communication Protocol (UCP) [10]. Unlike the other negotiation protocols discussed above, this protocol does not structure the negotiation process: any agent may propose an offer at any time and offers can be retracted at any time. Agents can accept a given offer by repeating the same offer. When all agents propose the same offer, this offer is considered an agreement. This protocol is the most flexible discussed here. For example, in UCP an agent can remain silent and wait for the other agents.

The flexibility of UCP comes at a price. Designing an agent having the intelligence to deal with the uncertainties in UCP is quite a challenge: how do you decide whether the agent should bid or remain silent? How do you know if another agent is still participating or whether it walked away? What does it mean if some of the agents are silent?

Although the UCP protocol is more natural from a human point of view, negotiating in an agent environment is different: the agents lack information that humans that are physically present in the same negotiation room would normally have, such as body language, tone of voice, and eye contact.

Our point of view is that if we would like to develop a multilateral negotiation protocol in which humans and agents are to engage each other, then we should get the protocol as close as possible to the human way of negotiating, like UCP, while realizing that developing agents that can fully understand and act in such a heterogeneous setting is still a Grand Challenge.

For that reason we focuses on multiparty turn-taking negotiations that are formalized to ease the participation of automated negotiating agents, in particular, some protocols that are based on the AOP, i.e., the Stacked Alternating Offers Protocol (SAOP), the Alternating Multiple Offers Protocol (AMOP), and the Multiple Offers Protocol for Multilateral Negotiations with Partial Consensus (MOPaC). In these protocols, the negotiating agents can only take action when it is their turn, the turn taking sequences are defined before the negotiation starts. SAOP allows negotiating agents when it is their turn to react only to the most recent bid. The allowed reactions are limited to accepting that bid, making a counter offer, or walking away. By contrast, in AMOP per round all agents bid sequentially and then, again sequentially, they vote on all bids. Allowed votes are accept or reject. Consequently, agents can see each agent's opinion on their bid. As a result, in AMOP the agents have a better overview of the outcome space. They get more information on which bids are acceptable to their opponents, and which are not. On the other hand, the communication costs are higher than in SAOP. For technical details on SAOP and AMOP the reader is referred to [1]. In MOPaC the parties get a chance to indicate with what kind of subset of the negotiating parties they would be satisfied if content-wise an offer is to their liking. That is, if there are no offers that all parties agree on, but there are offers that a subset of the parties agree on, the negotiation can still succeed with a partial consensus. To achieve this, in comparison to AMOP, when making a bid, the parties can indicate with a parameter what power a subgroup should have that accepts the content of the deal to be considered a partial consensus. In a first voting round the parties can see if such a partial consensus is reached. In a second voting round, the remaining parties can still change their mind and join that group. In that way coalitions can be formed. Technical details for MOPaC can be found in [45].

5 Human versus Automated Negotiators

In this section we provide you with a few pointers to the rich literature on human negotiations, but for the rest we focus on some guidelines for building automated negotiating agents.

5.1 Human Negotiators

The literature on human negotiations is rich on both theoretical and practical treatises on how to become an good negotiator. Excellent books and courses are available from the Harvard Business School and other universities, see e.g., [14, 13, 61]. However, on a yearly basis new books are published that can help you. If you focus on automated negotiation, as we tend to make you do in this report, you might loose track that when humans are part of the negotiation, you have to take into account that human negotiations tend to have only a few rounds (from approximately 3 in Anglo-Saxon countries, to about 30 in Northern African regions, so yes, there is clear influence of culture on negotiation), can last a long time (days, weeks, even years), are not perse economically rational, and that humans bring all kinds of additional background knowledge to the table on the domain of negotiation. A number of aspects that makes it difficult for humans to become good negotiators are the following.

- Humans tend to leave money on the table. With this we mean that they tend to reach outcomes that are sub-optimal for all parties.
- Humans have bounded rationality, basically meaning that their computational powers are not capable of creating a mental map of the outcome space. That space is generally simply too large and often too complex. This is an aspect in which humans are by now easily outperformed by computers.
- Humans slowly discover what they want. In particular, they find this out while negotiating. In the literature, see e.g., [61], this is called that preferences are constructive (constructed during the process, not upfront). Note that this makes preference elicitation both extremely important, but also difficult.
- Humans rationalise their intuitions. In decision making, the term satisficing applies, which means striving for adequate rather than perfect results. The term ”satisfice”, was coined by Herbert Simon (Nobel laureate), see [60].
- Humans tend to bargain from a position, instead of from an understanding of the underlying concerns. Practice shows that this is counter-productive, see e.g., [61].
- Humans tend to practice self-reinforcement, which means that certainly after a difficult negotiation process, they are proud of having reached an agreement in the first place or rationalise that it was only for the best that the negotiation failed. With this in mind they reinforce the own behaviour, instead of trying to analyse whether they indeed followed the best course of action.

- Humans tend to be rather lazy than tired, which means that most humans don't prepare well for a negotiation. They fail to think carefully on what the preferences are, they don't study the available information on the domain of negotiation, and they don't take enough time to find out as much as they can about the other negotiating parties (their preference profiles, what drives them, what are their underlying concerns).

- Finally, humans tend to have emotions during a negotiation, and those emotions (especially if they are intense), have a negative effect on rationality.

5.2 Comparing Humans and Intelligent Agents in Negotiation

In this section we present a SWOT analysis of humans with respect to negotiation from an artificial intelligence point of view that is based on [26, 19]. For an excellent treatise we refer the reader to [61]. If you want to focus on negotiation support systems (to help humans reach better negotiation deals, you can look e.g., at [28]). From the point of view of getting the best possible negotiation outcomes, and given the current state of the art in artificial intelligence and automated natural language understanding to a level of really understanding the messages given the context, and given the difficulties humans have in negotiation, the best one can do is to team up AI and Human negotiators in a way that the strengths of the one make up for the weaknesses of the other and vice versa. To sum up these strengths and weaknesses, see Table 1.

Topic	Human	NSS
Natural language understanding	Good	Bad
Calculating (bids)	Bad	Good
Memory of bids and overview	Bad	Good
Contextual background	Bad	Good
Knowledge level	General	Negotiation specific
Emotion recognition	good & allowed	good & ethically circumspect
Emotional attitude	influenced	unaffected

Table 1: Human versus Negotiation Support System (MSS)

6 Developing Automated Negotiating Agents

The guidelines we present here are based on our long experience in developing automated negotiating agents, as well as the experience of our colleagues that have participated in the Annual Negotiating Agents Competition (ANAC). The general guidelines on the whole negotiation process that you are advised to take into account when building your own negotiating software party are presented in Table 2.

These guidelines are also relevant for designing agents to support humans in reaching better negotiation deals. For more information, on that goal, see [28]).

A negotiating agent employs a negotiation strategy to determine its action in a given negotiation state. Examples of general agent negotiators in the literature include, among others: Zeng and Sycara [69], who introduce a generic agent called *Bazaar*; Faratin et al. [12], who propose an agent that is able to make trade-offs in negotiations and is motivated by maximizing the joint utility of the outcome (that is, the agents are utility maximizers that seek Pareto-optimal agreements); Karp et al. [33], who take a

Know your reservation value.
Orient yourself towards a win-win approach.
Create options for mutual gain.
Find out the preferences of the other negotiating parties.
Generate a variety of possibilities before deciding what to do.
Pay attention to the negotiation dance [21], see Section 7.2.
Develop a concrete strategy for bidding.
Develop a concrete strategy for accepting and rejecting bids.

Table 2: Negotiation guidelines

game-theoretic view and propose a negotiation strategy based on game-trees; Jonker et al. [30], who propose a a concession oriented strategy called *ABMP*; and Lin et al. [40], who propose an agent negotiator called *QOAgent*.

The ANAC competition brought forth multiple advanced negotiation strategies. Notable ANAC agent strategies include: *Agent K* [34, 35], which calculates its target utility based on the average and variance of previous bids and employs a sophisticated acceptance strategy; *IAMHaggler* [66, 67, 65], which uses Gaussian process regression technique to predict the opponent's behavior; *CUHK Agent* [15, 16], which adaptively adjusts its acceptance threshold based on domain and opponent analysis; *OMAC Agent* [8, 7, 9, 6], which models the opponent using wavelet decomposition and cubic smoothing spline; *The Fawkes*, which combines the best bidding, learning, and accepting strategy components; and finally, *Meta-Agent* [24, 23], which, for any given negotiation domain, tries to dynamically select the most successful ANAC agent to produce an offer. Recently, automated configuration has been applied to construct strategies, see [54].

The BOA framework has been designed to systematically explore the space of negotiation strategies [3]. In this modular approach you can pick a bidding strategy, an acceptance strategy, and an opponent modelling strategy and easily combine these in one agent. It is supported by the GENIUS and the GENIUSWEB framework.

6.1 Bidding Strategies

The *bidding strategy*, also called *negotiation tactic* or *concession strategy*, is usually a complex strategy component. Two types of negotiation tactics are very common: *time-dependent tactics* and *behavior-dependent tactics*. Each tactic uses a *decision function*, which maps the negotiation state to a *target utility*. Next, the agent can search for a bid with a utility close to the target utility and offer this bid to the opponent.

6.2 Acceptance Strategies

In every negotiation with a deadline, one of the negotiating parties has to accept an offer to avoid a break off. A break off is usually an undesirable outcome, unless the negotiating party sees no possibilities to achieve an agreement that is better than its BATNA, which corresponds to a utility equal to its reservation value.

However getting an offer that is better than its BATNA does not mean that the negotiating party should take that deal. Maybe, by rejecting that offer, an even better offer might come along later during the negotiations, therefore, it is important to consider under which conditions to accept. When designing such conditions one is faced with the acceptance dilemma: Accepting too early may result in suboptimal agreements, while on the other hand, accepting too late may result in a break off.

When designing an acceptance strategy, one has to strike a balance as the average utility that the negotiating party can score with its strategies depends both on the agreement percentage and the average utility of these agreements.

In literature and current agent implementations, we see the following recurring acceptance conditions: As said, we are primarily interested in acceptance conditions that are not specifically designed for a single agent. We do not claim the list is complete; however it serves as a good starting point to categorize current decoupled acceptance conditions.

$AC_{\text{const}(\alpha)}$ is a very simple acceptance criterion that only compares the opponents offer with a constant α. This a is the good enough threshold. Formally, for any bid b,

$$AC_{\text{const}(\alpha)}(b) = \text{accept iff } \ u(b) \geq \alpha$$

AC_{next} can be considered to be sort of default standard acceptance condition: it accepts when the opponent's offer is already better than the planned bid. Used by Trade-off, Boulware, Conceder, and many more. Let τ denote the target utility of the next bid that the negotiating party would make if it rejects the offer. Then

$$AC_{\text{next}}(b) = \text{accept iff } \ u(b) \geq \tau$$

$AC_{\text{time}(T)}$ is the fail safe mechanism: an agent may decide its better to have any deal if it is better than its BATNA than no deal at all and hence to blindly accept any offer after time T. This strategy was used by Agent Smith [62]. Let t_{now} denote the current time in a negotiation. Then

$$AC_{\text{time}(T)}(b) = \text{accept iff } \ t_{\text{now}} \geq T$$

6.3 Opponent Modeling Strategies

Opponent modeling is about finding the best possible estimates of the preference profile, reservation value, BATNA, and the negotiation strategies of the other negotiating parties. Although more techniques exist to model the opponent's profile, in this reader we describe only the basics of the popular Frequency Analysis method, see e.g., [62, 63].

Frequency models learn issue weights and value weights of the opponents preference profile separately. The weight of issue determines how much that issue impacts the utility of a bid. For example, in the domain of cars some buyers find the issue prize more important than the issue color. A very rich buyer might think differently. Knowing how important an issue is to a negotiator, is not same as knowing how much likes the different values that issue can have in a bid. For example, for the issue color some might prefer the color blue over the color red. The value weight of blue would be bigger than value weight of red. Issue weights are calculated based on the frequency that an issue changes between two offers. The value weights are calculated based on the frequency of appearance of that particular value in offers made by the opponent.

7 Analysis

The analysis of how people or agents negotiate, is important for improving your negotiation strategies. In the literature on automated negotiation you will find outcome analysis (see Section 7.1) and negotiation DANS analysis (see Section 7.2).

The outcome analysis compares the utilities of the negotiating parties, to determine how fair that outcome is for each party, or to what extend each party has been able to optimize the outcome with respect to his/her own preference profiles. For this outcome analysis important outcomes are Nash Product (Nash Bargaining Solution), Social Welfare, Kalai-Smorodynski, the distance to the Pareto Optimal Frontier important. The DANS analysis considers the negotiation moves that parties make during the negotiation.

7.1 Pareto optimality, individual and socially optimal bargaining solutions

When evaluating the strength and weaknesses of negotiation strategies, the quality of the outcome is of the utmost importance to the users of the strategies. The analysis of the outcomes makes heavy use of metrics based on Pareto Optimal Bids.

A Pareto Optimal Bidis an offer that lays on the Pareto Optimal Frontier, which is the set of all offers that are not strictly dominated by any other offer. A bid is a Strictly Dominated Bid if there exists another bid that is better for at least one party, while simultaneously not worse for any other party in the negotiation. The Pareto frontier can be found by process of elimination: Consider all possible offers and for each offer check if it is strictly dominated by any other offer. If that is the case, remove it. What remains is the Pareto frontier. Finding such a frontier is a NP-Hard problem [42].

Negotiating or bargaining is considered a non-cooperative game [57, 58]; there is something to gain for each party involved, but parties are uncertain of feasible solution vectors. Because of this, a negotiation might not come to an agreement. Such a situation can also occur if the partys BATNA is higher than the offer currently on the table. This BATNAis the worst utility a party can get, for most negotiations this is simply zero utility for all parties involved.

The Nash Equilibrium [46] is a competitive solution and thus requires no cooperation. For each party, given there is no cooperation by the other parties, what is the best utility one can get? This equilibrium is usually illustrated by the prisoners dilemma. In this case the Nash equilibrium strategy is the minimax strategy: Choose the maximum utility for yourself given that the opponent will choose the minimum for you.

7.1.1 Example: Prisoner's Dilemma

Looking at the prisoners dilemma as described in Table 7.1.1 from one of the prisoners perspective, you have to choose between betray or keep silent. When choosing keep silent, the opponent may choose to either betray or also keep silent with respective utilities 0 and 1 for them. Using the minimax strategy [58] you can assume that the opponent will choose the former which means you end up with a utility of 4. Going back and choosing the betray action yourself, the opponent gets to choose between betray with utility 2 or keep silent with utility 4. The opponent will choose the former in this case, giving you a utility of 2. This means that while there are 4 possible outcomes, there is only one Nash Equilibriumstrategy: The opponent will always betray in a competitive game. Therefore, if you want to maximize your utility, you have to betray as well, resulting in utilities of (2,2).

	betray	keep silent
betray	(-2,-2)	(0,-4)
keep silent	(-4,0)	(-1,-1)

Table 3: The prisoners dilemma; A crime has been committed in a prison. Two prisoners are offered a choice to betray one other. They have no way of communicating. If they both remain silent, each prisoner has to serve 1 year of extra jail time. If both betray one other, they both get 2 years of extra time. If only one betrays the other, but the other remains silent, that other gets 3 years of extra time. According to the Nash equilibrium both prisoners should betray one another.

BATNA is also known as the outside option, the point of disagreement, the threat point, the competitive solution or the reservation value in other work. This concept is known by so many names for a good reason: The starting position has a huge impact on the negotiation. We will see its influence on solutions that we will discuss next.

We consider the Nash bargaining Solution (NS), the Kalai-Smorodinsky bargaining Solution (KSS) and the Egalitarian social welfare bargaining Solution (ES), all of which are Pareto Optimal Bids. The associated points of agreement are called the Nash points, the Kalai-Smorodinsky point, and the Egalitarian point respectively.

We will now discuss each of the three solutions in detail. The Nash bargaining Solution is a bargaining solution proposed by John Nash [46] that maximizes the product of utility gain. Let P be the set of parties in the negotiation, and let S be the space of potential solutions. For all $p \in P$, let $u_p(a)$ denote the utility of party p at the agreement point a and r_p their reservation values. The Nash bargaining Solution tries to maximize the product of $u_p(a) - r_p$. Thus Nash points are those elements $a \in S$:

$$maxarg_{a \in S}(\Pi_{p \in P}(u_p(a) - r_p))$$

Note that when only two negotiation parties are involved, this is the same as maximizing the area under the rectangle bounded by the agreement point and the point of disagreement, as can been seen in Figure 7.1.1.

Depending on the shape of the Pareto Optimal Frontier between 1 and all Pareto Optimal Bids can be Nash bargaining Solutions and thus multiple Nash points can exist. In order to find the Nash point(s) consider each point on the Pareto frontier, subtract the utilities that each party would get when not coming to an agreement. This result is called the utility gain. Multiply the utility gains of each party for the specific other and find the maximum of these multiplications. This multiplication is referred to as the Nash Product. Please note that the Nash bargaining Solution is a cooperative solution to multi-issue negotiation, and should not be confused with the earlier explained Nash Equilibrium, which is a different concept describing a competitive strategy and not a Pareto optimal cooperative agreement.

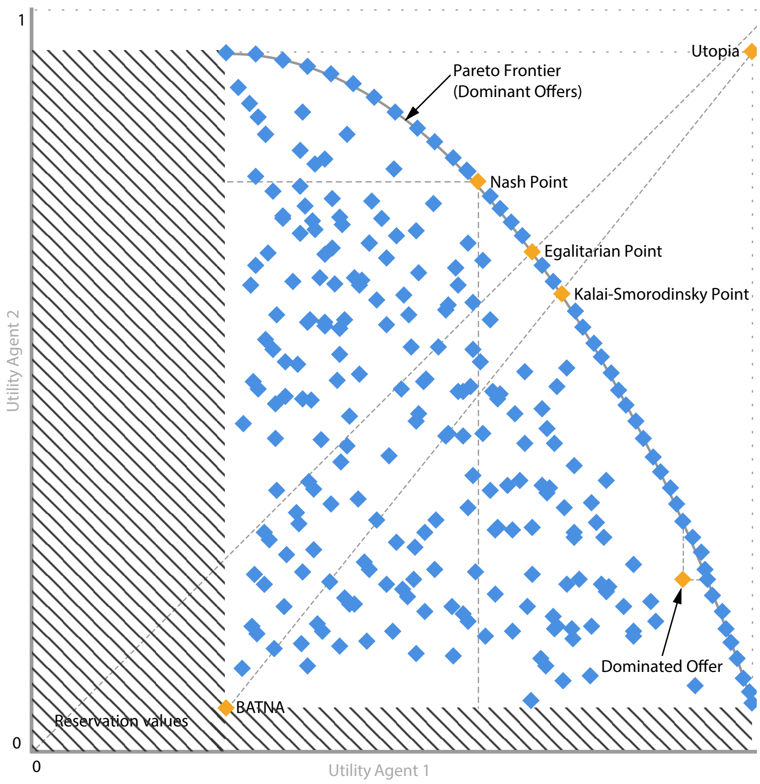

Figure 1: In picture the utilities of each possible solution are plotted for two agets. We see the offers corresponding to the Nash bargaining Solution, the Kalai-Smorodinsky bargaining Solutionand and the Egalitarian social welfare bargaining Solution.

The Kalai-Smorodinsky bargaining Solution, also known as the utilitarian social welfare bargaining solution, tries to maintain the ratio of maximum gains [32]. Intuitively, it tries to find the maximum sum of utility gains. For two players, this point can be found by calculating the ratio of maximum utility gain each party can get and comparing this to the ratio of each Pareto Optimal Bid. Suppose party p_1 has a maximum utility gain of m_1 and party p_2 that of m_2, then the ratio of equal gain is $r_{eq} = \frac{m_1}{m_2}$. For each point $a \in F$, where F is the Pareto Optimal Frontier, define the ratio

$$r_a = \frac{u_1(a)}{u_2(a)}$$

and compare to take the point on the Pareto Optimal Frontier that has the ratio which is the closest to r_{eq}. This point is the Kalai-Smorodinsky point.

$$KSP = minarg_{a \in F}(r_a - r_{eq})$$

The philosophy behind the Kalai-Smorodinsky bargaining Solution, is that of fair division [44], which states that when there is extra utility to be divided, no one should be worse off. This solution does that while maintaining bargaining positions; when a party has a better starting position, the Kalai-Smorodinsky bargaining Solution tends to favor that party.

The Egalitarian point or the Rawls point (after the philosophical theory of Rawls [53]) also known as the Kalai point (not to be confused with the Kalai-Smorodinsky point), is a lesser known bargaining solution. It was proposed by Kalai two year after the Kalai-Smorodinsky bargaining Solution [31]. Intuitively it tries to maximize the utility of the party with the lowest utility. The Egalitarian point can be found by choosing the point on the Pareto Optimal Frontier F with the highest minimum utility:

$$EP = argmax_{a \in F} argmin_{p \in P} u_p(a)$$

The philosophy behind this entails that in a cooperative environment, the utility of the individual that is the worst off, is the utility of a group. The group should therefore try to maximize its utility. The advantage of this bargaining solution, is that optimizing the minimum utility scales well into higher dimensions.

Each of the bargaining solutions previously discussed are based on a set of axioms. In this background chapter, we highlight the differences between the solutions. The Nash bargaining Solution does not adhere to resource monotonicity [68]. Resource monotonicity ensures that when there is a utility gain compared to the base situation, no party should be worse off. With the Nash bargaining Solution, a larger product could be found were some parties might strictly be worse off. The Kalai-Smorodinsky bargaining Solution adheres to resource monotoncity, but drops the Independence of Irrelevant Alternatives (IIA) axiom that the Nash bargaining solution adheres to [32]. Independence of Irrelevant Alternatives states that when a new solution is added to the domain, and this solution is not the agreement, it is irrelevant and should not influence the negotiation outcome. By substituting IIA for resource monotonicity, the Kalai-Smorodinsky bargaining Solution ensures fair division. Finally the Egalitarian social welfare bargaining Solution adheres to both the resource monoticity axiom as well as IIA, but drops the Scale Invariance axiom that both the Nash bargaining Solution and the Kalai-Smorodinsky bargaining Solution adhere to [31]. Scale Invariance states that if party p_1 can get a utility gain of $c \cdot u_1$ and player p_2 can get a utility gain of $c \cdot u_2$, the solution should remain the same for any positive real number c. It should be pointed out that this is based on the fact that we normalize all utilities to be between 0 and 1, and any computation consequently does not suffer from any Scale Invariance issues.

7.2 Negotiation Dance

The notion of a negotiation dance was first introduced by Raiffa [50] and refers to the dynamic pattern of the bidding. More formally, we follow [21], in defining it as the set of negotiation traces of negotiation moves made by each of the negotiating parties, where a negotiation move is defined as two subsequent bids made by a negotiating party, and a negotiation trace is defined as the sequence of moves made by negotiating party. In Figure 2, for the bilateral case, one can see the two traces of moves made by respectively agent A and agent B.

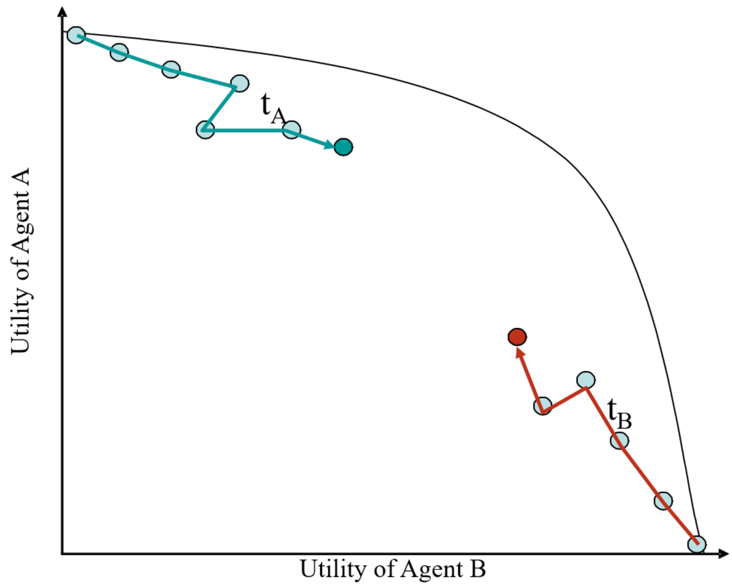

Figure 2: A negotiation dance consisting of two negotiation traces, each consisting of multiple negotiation moves

To analyse a negotiation dance as is done in the DANS framework introduced in [21], you need a way to analyse the negotiation moves made by the negotiators. Figure 3, graphically explains the types of moves from the DANS framework and is taken from [27]. Informally, we recognize and define the following move types.

silent move: the two subsequent bids made by the negotiating party have practically the same utility for all parties.

nice move: is a move that doesn't change things for the party making the bid, but it does make it better for the other negotiating parties.

concession move: is a move that makes things worse for the party making the bid, but better for the other negotiating parties.

selfish move: is a move that makes things better for the party making the bid, but worse for the other negotiating parties.

fortunate move: is a move that makes things better for all negotiating parties.

unfortunate move: is a move that makes things worse for all negotiating parties.

uncooperative move: is a move that is either unfortunate or selfish.

cooperative move: is a move that is not an uncooperative move[1].

For formal definitions for the bilateral case, the reader is referred to [21] or for a bit more general definitions to [27]. Note that these definitions were constructed for bilateral negotiations, and therefore need to be extended for the multi-lateral case, as the viewpoint on the classification changes with the set of negotiating parties whose utilities are considered in the classification.

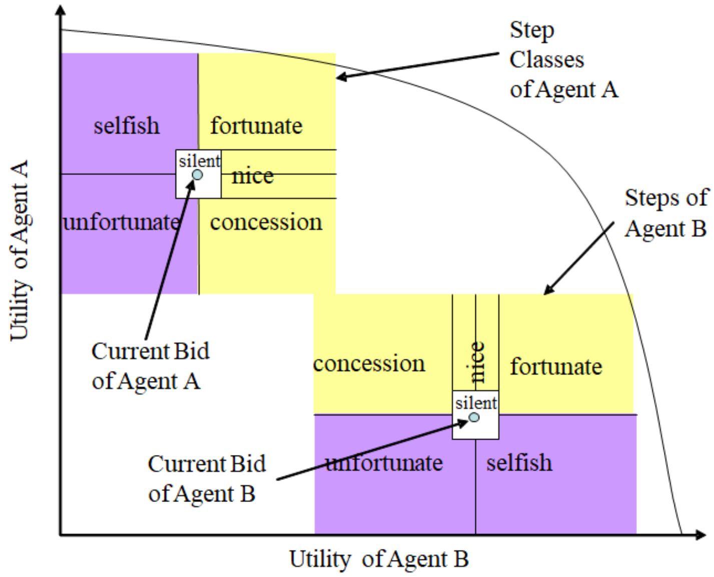

Figure 3: Moves

These move types make the classification of bidding strategies comprehensible, and by abstracting away from the specific utility functions of the negotiating parties, the move types can be used in machine learning approaches to classify negotiation strategies, see e.g., [38].

8 Directions for Research

For more information see [4]

9 Glossary of terms

Glossary

$AC_{\mathbf{const}(\alpha)}$ an acceptance strategy that accepts the opponents offer if its utility is at least constant α . 12

[1]Note that silent moves are considered to be cooperative.

$AC_{\mathbf{next}}$ an acceptance strategy that accepts when the opponents offer is better than the bid that the negotiating party would counteroffer. 12

$AC_{\mathbf{time}(T)}$ an acceptance strategy that accepts any offer after time T that is greater than its reservation value . 12

BATNA stands for Best Alternative To a Negotiated Agreement, and refers to the idea that in negotiation the BATNA is what you would have if the negotiations fail. The better your BATNA, the easier it is for you to insist on a negotiation outcome that is better than your BATNA, or to walk away if you can't get an outcome that is better than your BATNA. If the negotiation fails, this is what you can fall back on. The better your BATNA, the higher you can set your reservation value. The better your BATNA, the more relaxed you will be, the easier it will be creative, to think out of the box . 3, 4, 13, 14, 22

negotiation dance the dynamic pattern of the bidding, as defined by Raiffa [50]. It is the trace of negotiation negotiation moves made by the negotiators. 17

Egalitarian point The Egalitarian point is a Pareto Optimal Bid, that corresponds to the Egalitarian social welfare bargaining Solution. Synomyms are Kalai point, and Rawls point. 14, 16, 19

Egalitarian social welfare bargaining Solution The Egalitarian social welfare bargaining Solution is .... Its associated bid is a Pareto Optimal Bid, and called Egalitarian point. 14, 16, 19

Kalai point Synonym of Egalitarian point. 16, 19

Kalai-Smorodinsky point The Kalai-Smorodinsky point is a Pareto Optimal Bid, that corresponds to the Kalai-Smorodinsky bargaining Solution. 14, 16, 19

Kalai-Smorodinsky bargaining Solution The Kalai-Smorodinsky bargaining Solution is to maximize the sum of utility gains. Its associated bids are Pareto Optimal Bids, and called Kalai-Smorodinsky points. 14, 16, 19

Nash Equilibrium For the Nash Equilibrium we refer to the definition and explanations in [58]. 13, 14

Nash Product The Nash Product is defined as $\Pi_{p \in P}(g_p(a))$, where a is a Nash point. 14

Nash point The Nash point is a Pareto Optimal Bid, that corresponds to the Nash bargaining Solution. 14, 19

Nash bargaining Solution The Nash bargaining Solution is . Its associated bids are Pareto Optimal Bids, and called Nash points. 14, 16, 19

Pareto Optimal Bid A Pareto Optimal Bidor offer is a bid that is *not* strictly dominated by any other offer. See Strictly Dominated Bid. 13, 14, 19

Pareto Optimal Frontier The Pareto Optimal Frontier, or Pareto Frontier, is the set of all Pareto Optimal Bids. 13, 14

Rawls point Synonym of Egalitarian point, named after Rawls [53]. 16, 19

Strictly Dominated Bid A bid is a Strictly Dominated Bid if there exists another offer that is better for at least one party, while simultaneously not being worse for any other party in the negotiation. 13, 19

Alternating Multiple Offers Protocol (AMOP) In AMOPthe turn taking sequences are defined before the negotiation starts. Each round all agents get two turns. First all agents bid sequentially and then they sequentially vote on all bids either accept or reject. 8

Alternating Offers Protocol According to this protocol, one of the negotiating parties starts the negotiation with an offer. The other party can either accept or reject the given offer. By accepting the offer, the negotiation ends with an agreement. When rejecting the offer the other party can either end the negotiation (walk away), or make a counter offer. This process continues in a turn-taking fashion. 6, 7

bid is a set of $\langle$ issue,value$\rangle$ pairs. Synonym is offer. A bid can be a partial bid or a complete bid. 21, 23

competitive solution See reservation value. 14

complete bid is a bid in which every negotiation issue is associated with a value. To find the best possible outcomes, you are advised to only offer complete bids. 4, 20, 21

concession move is a move that makes things worse for the party making the bid, but better for the other negotiating parties. 17

cooperative move is a move that is not an uncooperative move. 18

CPnet Conditional Preference Network is a graphical model to represent user's preferences qualitatively. This model can capture mostly partial outcome ordering. 22

deal is a synonym of a negotiated agreement . 1

discount factor An essential feature of negotiations is that the agents' utilities decrease with time. Specifically, the decrease occurs as time progresses. This decrease is represented with a discount factor. For example, a load of bananas is worthless in a matter of a few weeks . 3

evaluation function a kind of utility function for one issue. It maps values of an issue to an evaluation. In normalised functions, it maps to $[0,1]$. Formally (for normalized functions), $\forall p \in P, all\, j \in \mathscr{I} u_{p,j} : S_j \mapsto [0,1]$. 5, 23

fortunate move is a move that makes things better for all negotiating parties. 17

issue something that the parties need to agree on for a successful negotiation. Common examples in trade are the prize of an object, and the delivery date of that object. 20, 21, 23

Mediated Single Text Negotiation Protocol (MSTNP) The MSTNP protocol uses a mediator to propose offers that all negotiating parties can vote on with either accept or reject. When an offer is accepted by all negotiating parties, then the mediator stores that as the most recently accepted bid. When time is up (or a predetermined number of offers has been offered), then the most recently accepted bid is taken as the agreement reached in the protocol . 7

Monotonic Concession Protocol This protocol enforces the negotiating parties to only makes concessions or to stick to their previous offer (which is a silent move), see [11]. A prerequisite for this protocol is that the parties know the preference ranking over bids for all negotiating parties . 7

Multiple Offers Protocol for Multilateral Negotiations with Partial Consensus (MOPaC) The MOPaC protocol is both a relaxation and and an enrichment of AMOP for Multilateral Negotiations in which the negotiation parties can reach an agreement with a subset of the participating parties, which is called a partial consensus. Whenever such a partial consensus is reached, all other parties still get a chance to join that group. The remaining parties, if there are enough of them, can continue the negotiation. 8

negotiated agreement is successful negotiation outcome that specifies what each party gets out of the negotiation, it is reached when the bid (cq. offer made by one of the parties is accepted by all other parties . 20

negotiation is a form of interaction in which two (or more) parties, with conflicting interests and a desire to cooperate, try to reach a mutually acceptable agreement. 1

negotiation move two subsequent bids made by a negotiator constitute a move by that negotiator. 17, 19, 21

negotiation party someone that has a stake in the outcome of the negotiation and is participating in the negotiation process by making bids. Other terms used for this are negotiator, party, opponent. A related term is stakeholder. 1, 3, 21–23

negotiation trace the sequence of negotiation moves made by a negotiating party. 17

negotiator Synonym for negotiation party. 21, 22

nice move is a move that doesn't change things for the party making the bid, but it does make it better for the other negotiating parties. 17

offer is a synonym for a bid. 21

opponent In the context of negotiations it is a synonym for negotiation party. 21, 22

outside option See reservation value. 14

partial bid is a bid in which some of the negotiatiable issues do not occur. For example, when negotiating about real estate, a partial bid might contain the price offered, but say nothing about the date of transition of the property. A related term is complete bid. 4, 20

party In the context of negotiations is is a synonym for negotiation party. 1, 21–23

point of disagreement See reservation value. 14

preference profile is a preference ranking of the possible outcomes of the negotiation. These preferences refer to the importance of issues, but also to the values per issue. Preference profiles can be qualitative or quantitative. A preference profile can be represented by a utility function that maps bids to numbers, or a CPnet that compares bids using a preference relation. 3

reservation value in terms of utility, it is a utility value below which bids are unacceptable. Each party should determine its reservation value. A related term is BATNA. 3, 4, 14, 19–23

resource monotonicity refers to the idea that when there is a utility gain compared to the base situation, no party should be worse off . 16

selfish move is a move that makes things better for the party making the bid, but worse for the other negotiating parties . 17, 22

Sequential-offer Protocol This protocol extends the AOP with timebased deadlines, and the lack of the option to walk-away. This provides an incentive to come to an agreement, see [70] . 8

silent move the two subsequent bids made by the negotiating party have practically the same utility for all parties. 17, 18

Stacked Alternating Offers Protocol (SAOP) In SAOPnegotiating agents have to await their turn to act, and the turn taking sequences are defined before the negotiation starts. In their turn an agent can only respond to the most recent bid by either accepting that bid, making a counter offer or walking away. 8

stakeholder in the context of negotiations, it is someone that has a stake in the outcome of the negotiation. Related terms are negotiator, party, opponent, or negotiation party. 21

threat point See reservation value. 14

uncooperative move is a move that is either an unfortunate move or a selfish move. 18, 20

unfortunate move is a move that makes things better for all negotiating parties. 17, 22

utility is short for utility value. 3

utility function Utility function: a quantitative representation of a preference profile. It maps bids to utility values. For easy of computation the range of utility values can be mapped to [0, 1]. Typically utility functions are only defined for complete bids. This notion is related to a preference profile in the sense that for all bids b and d such that b is preferred over d, also the utility of bid b is higher than that of bid d . 20, 22

utility gain Given an agreement $a \in S$, the utility gain of party p is defined as $g_p(a) = u_p(a) = r_p$, i.e., the utility of p for that agreement a minus p's reservation value. 14, 19

utility value is the amount of appreciation that someone has for a bid measured as a numeric value, typically set between 0 and 1. 22

valuation function another name for evaluation function. 5

value when referring to the value of an issue in a bid, it refers to the value associated to that issue in that bid. For example, €5 for the issue prize for a sandwich. 20

win-lose refers to win-lose negotiations, which are negotiations in which the winnings of one negotiation party are at the expense of another negotiation party. Related terms are win-win and zero-sum game. 23

win-win a win-win negotiation is a negotiation in which you think that all negotiation parties can reach a good negotiation outcome. Related terms are win-win strategy, win-win outcome, win-lose, zero-sum game. 1, 23

win-win outcome a negotiation outcome that is good for all parties. 23

win-win strategy a strategy that aims for getting a good negotiation outcome for all negotiation parties. 23

zero-sum game is a concept from game theory, referring to games in which the rewards of a game for all players always add up to zero. This implies, that my loss is your gain, and vice versa. 23

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