Computing negotiation update semantics in multi-issue bargaining dialogues

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Abstract

This paper presents a computational approach to modelling pragmatic and semantic aspects of multi-issue bargaining dialogues. The model accounts for actions that shape negotiation structure and actions that express negotiation strategies. The model also accepts a number of negotiation moves as specifications of the semantic content of the performed task-related dialogue acts. The designed dialogue context model specifies the creation, maintenance and transfer of participants' private and shared beliefs. A negotiation agent that operates on this basis was implemented and evaluated against human performance. The approach allows efficient interpretation and generation of negotiation behaviour according to different negotiation strategies.

1 Introduction

The fundamentals of human dialogue modelling are concerned primarily with the modelling of conversational goals and intentions, dialogue structure, grounding mechanisms and reasoning with the assumptions of rationality and cooperation. Dialogue models are important for interactive human-computer systems development. Most research in human-computer interaction modelling and dialogue systems design so far has been done in the area of task-oriented systems (TOS) with well-defined tasks in restricted domains.

Research efforts in dialogue modelling have recently been moving towards a world of smart environments seeking new ways of interfacing and engaging with technologies that more closely reflect rich natural human interaction in domains and settings of various complexity. The research community is targeting more flexible adaptable open-domain dialogue modelling driven by cognitive modelling of human dialogue behaviour. Existing two-party TOS dialogue models are undergoing changes to reflect advanced understanding and to allow efficient computation of phenomena specific to new domains, new ways of interacting, and novel user experiences. For instance, it has been acknowledged that the assumption that conversational agents act fully rationally and cooperatively does not hold in many conversational settings, see e.g. (Traum et al., 2008b) and (Asher and Quinley, 2011). In competitive games, debates, and negotiations participants may have not fully aligned preferences and may not adopt shared intentions or goals. This paper focuses on modelling negotiations in a multi-issue bargaining setting.

Human-computer negotiation dialogue is typically modelled as a sequence of offers. The offers represent participants' commitments to a certain negotiation outcome. Valuable work has been done on well-structured negotiations - interactions among a few parties with fixed interests and alternatives, see e.g. (Traum et al., 2008a), (Georgila and Traum, 2011), (Guhe and Lascarides, 2014), (Efstathiou and Lemon, 2015). In human negotiation, however, offers as binding commitments are rare and a larger variety of negotiation behavioural patterns is observed (Raiffa et al., 2002b). Participant actions are focused mainly on obtaining and providing preference information and can make this explicitly but also implicitly, see e.g. (Cadilhac et al., 2013). A negotiator often states his preferences without expressing (strong) commitments to accept an offer that includes a positively evaluated option, or to reject an offer that includes a negatively evaluated option.

To achieve more human-like system behaviour, we designed a model which accepts a large variety of dialogue acts representing different levels of commitment. We defined the semantic content of task-related dialogue acts in terms of *negotiation moves*. To model negotiation behav-

ior with respect to preferences, abilities, necessity and acquiescence, and to compute negotiation strategies as accurate as possible, we define several *modal relations* between the modality 'holder' (typically the speaker of the utterance) and the target which consists of the negotiation move (and its arguments). Additionally, to facilitate structuring the interaction and enable participants to interpret partner intentions, dynamically changing goals and strategies efficiently, we defined a set of *qualifiers* attached to offer acceptances or rejections and agreements, e.g. tentative or final.

The paper is structured as follows. Section 2 discusses the multi-issue bargaining setting specifying participant tasks, negotiation structure and procedures, actions and other task-related and interactive phenomena observed, and negotiation strategies. In Section 3 the specific data collection scenario is outlined. Section 4 specifies the dialogue act update semantics. A domain-specific negotiation semantics is discussed in Section 5. We present the performed semantic annotations, and provide corpus statistics and illustrative examples. We outline an approach to computing the semantics of negotiation actions. In Section 6 we describe the information state update process in multi-issue bargaining dialogue, leading to the creation of mutual beliefs and belief transfer using various negotiation strategies. Section 7 presents and evaluates the implemented negotiation agent. Section 8 summarises our findings and outlines future research.

2 Multi-issue bargaining

In negotiations, two or more parties have an interest in reaching one or several possible agreements, and their preferences concerning these agreements are not identical (Raiffa et al., 2002b). Three main types of negotiations can be distinguished: *distributive*, *joint problem-solving* and *integrative*[1]. Distributive negotiation means that any gain of one party is made at the expense of the other and vice versa; any agreement divides a fixed pie of value between the parties, see e.g. (Walton and McKersie, 1965). The goal of joint problem-solving negotiations is, by contrast, to work together on an equitable and reasonable solution: negotiators will listen more and discuss the situ-

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[1] A fourth type of negotiations is *bad faith*, where parties only pretend to negotiate, but actually have no intention to compromise. Such negotiations often take place in political context, see (Cox, 1958)
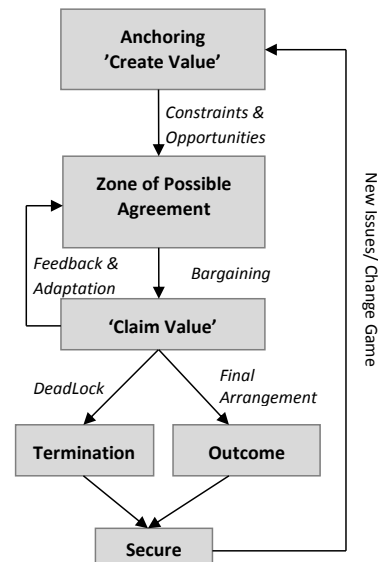

Figure 1: Negotiation phases associated with negotiation structure, based on (Watkins, 2003a; Sebenius, 2007).

ation longer before exploring options and finally proposing solutions. The relationship is important for joint problem solving, mostly in that it helps trust and working together on a solution (Beach and Connolly, 2005).

In many real-life negotiations pure distributive and problem-solving are rare, more often 'mixed-motive' negotiations take place (Lax and Sebenius, 1992). For instance, in sociopolitical and socio-economic contexts, parties are often interested to maintain good long-term relations with each other and therefore try to make trade-offs in order for both sides to be satisfied with the outcome. At the same time, however, they make competitive efforts to get a bigger share. This problem is often referred to as the 'Negotiator's Dilemma' (Lax and Sebenius, 1992). Negotiators may have partially competitive (adversarial, defensive), and partially cooperative goals. This often happens in integrative multi-issue bargaining, where parties usually have the possibility to simultaneously bargain over several goods and attributes, and to search for integrative potential (interest-based bargaining or win-win bargaining, e.g. see Fisher an Ury, 1981).

The different types of negotiation manifest mainly in how parties *create* and *claim values*. Negotiation starts with the **Anchoring** phase, in which participants introduce negotiation issues

SCOPE		TAXATION	
o	All outdoor smoking allowed	o	No change in tobacco taxes
o	No smoking in public transportation	o	5% increase in tobacco taxes
o	No smoking in public transportation and parks	o	10% increase in tobacco taxes
o	No smoking in public transportation, parks and open air events	o	15% increase in tobacco taxes
		o	25% increase in tobacco taxes

CAMPAIGN		ENFORCEMENT	
o	Flyer and billboard campaign in shopping district	o	Police fines for minors in possession of tobacco products
o	Anti-smoking posters at all tobacco sales points	o	Ban on tobacco vending machines
o	Anti-smoking television advertisements	o	Police fines for selling tobacco products to minors
o	Anti-smoking advertisements across all traditional mass media	o	Identification required for all tobacco purchases
		o	Government issued tobacco card for tobacco purchases

Figure 2: Preference card: example of values in four negotiated issues presented in colours.

and options. They also obtain and provide information about preferences, establishing jointly possible values contributing to the **Zone of Possible Agreement** (ZOPA, following the terminology of (Sebenius, 2007)). Participants may bring up early (tentative) offers, typically in the form of suggestions, including referring to the least desirable events - 'Create Value'. The actual bargaining occurs in the **'Claim Value'** phase, potentially leading to either adaptation, adjustment or cancelling the originally established ZOPA actions. Patterns of concessions, threats, warnings, and early tentative commitments are observed here. Distributive negotiations are more 'claiming values', while joint problem-solving negotiations are more 'value creating' interactions, and integrative negotiations are a mix of 'creating and claiming values' negotiations (Watkins, 2003a). In distributive negotiations the existence and size of the ZOPA is mostly determined by the 'bottom lines' of the opposite parties, which are formed by their respective *best alternatives to a negotiated agreement* (BATNA), see (Fisher and Ury, 1981). In integrative bargaining the ZOPA is mainly determined by the number of possible Pareto optimal (or efficient) outcomes. Pareto efficiency (or optimality) reflects a state of affairs when there is no alternative state that would make any partner better off without making anyone worse off.

After establishing the ZOPA, negotiators may still cancel previously made agreements and negotiations might be terminated. **Negotiation Outcome** is the phase associated with the "walk-away" positions for each partner. Finally, negotiators can move to the **Secure** phase summing up, restating reached negotiation agreements or termination outcomes. At this stage, strong commitments are expressed, and weak (mutual) beliefs concerning previously made commitments

and reached agreements are strengthened. Participants take decisions to move with another issue or re-start the discussion. Figure 1 depicts the general negotiation structure as described in (Watkins, 2003a; Sebenius, 2007) and observed in our data described in the next section.

The outcome of a negotiation depends on the plan (or agenda) each partner has (Tinsley et al., 2002). The most common tactic of novice negotiators observed is issue-by-issue bargaining (see data collection below). Parties may start with what they think are the 'toughest' issues, where they expect the most sharply conflicting preferences and goals, or they may start to discuss the 'easiest', most compatible options. Sometimes, however, negotiators bring all their preferences on the table from the very beginning. This increases the chance to reach a Pareto efficient outcome, since a participant can explore the negotiation space more effectively, being able to reason about each other's goals, see e.g. (Stevens et al., 2016b). Defensive behaviour, i.e. not revealing preferences, but also being misleading or deceptive, i.e. not revealing true preferences, results in missed opportunities for value creation, see e.g. (Watkins, 2003a; Lax and Sebenius, 1992).

All the aspects mentioned above may influence negotiators' strategies, which may also change within one interaction. For instance, (Traum et al., 2008a), who also consider a multi-issue bargaining setting, but viewed as a multi-party problem-solving task, define strategies as objectives rather than the orientations that lead to them. They distinguish seven different strategies: find issue, avoid, attack, negotiate, advocate, success and failure. Other researchers define negotiation strategies closely related to conflict management styles, i.e. the overall approach for conducting the negotiation. Five main strategies are observed:

Dialogue Act		Relative frequency (in %)	Dialogue Act		Relative frequency (in %)
Communicative function	Modality/Qualifier		Communicative function	Modality/Qualifier	
propositionalQuestion		2.0	suggest		10.0
checkQuestion		2.2	addressSuggest		1.4
setQuestion		10.3	acceptSuggest		2.0
choiceQuestion		0.6	declineSuggest		1.7
inform −>		30.3	offer −>		16.7
...	non-modalised	41.3	...	conditional	28.3
...	prefer	30.4	...	tentative	35.0
...	disprefer	3.1	...	final	36.7
...	acquiesce	3.0	addressOffer		0.6
...	need	2.0	acceptOffer −>		5.8
...	able	19.0	...	tentative	47.6
...	unable	1.2	...	final	52.4
agreement		10.3	declineOffer	tentative	2.0
disagreement		4.1			

Table 1: Distribution of task-related dialogue acts in the analysed multi-issue bargaining dialogues.

competing (adversarial), collaborating, compromising, avoiding (passive aggressive), and accommodating (submissive), see (Raiffa et al., 2002a; Tinsley et al., 2002). As in integrative negotiation, where the negotiators strive to achieve a delicate balance between cooperation and competition, (Lax and Sebenius, 1992), we defined two basic negotiation strategies: cooperative and non-cooperative.

Cooperative negotiators share information about their preferences with their opponents, are engaged in problem-solving behaviours and attempt to find mutually beneficial agreements, (De Dreu et al., 2000). A cooperative negotiator prefers the options that have the highest collective value. If not enough information is available to make this determination, a cooperative negotiator will elicit this information from his opponent. A cooperative negotiator will not engage in positional bargaining[2] tactics, instead, he will attempt to find issues where a trade-off is possible.

Non-cooperative (or sometimes called *adversarial, competitive*) negotiators prefer to withhold their preferences for fear of weakening their power in the negotiation by sharing too much, or the may not reveal true preferences deceiving and misleading the partner. These negotiators focus on asserting their own preferred positions rather than exploring the space of possible agreements, (Fisher and Ury, 1981). A non-cooperative strategy is characterized by a focus on positional bargaining. A negotiator agent using this strategy will rarely ask an opponent for preferences, and will often ig-

nore a partner's interests and requests for information. A non-cooperative negotiator, instead, will find his own ideal offer, state it, and insist upon it in the hope of making the opponent concede. He will threaten to end the negotiation or will make very small concessions. If the opponent makes a threat, the non-cooperative strategy will accept an offer only if the negotiator can gain a significant number of points from it.

All the discussed suggests that for adequate modelling we need to take into account that negotiators may perform several types of actions: (1) dialogue acts expressing various levels of commitment; (2) negotiation moves specifying events and their arguments; (3) qualified ('modalised') actions expressing participants' negotiation strategies; (4) communicative actions to control the interaction.

3 Data Collection

For adequate modelling of human dialogue interactions a systematic analysis of a variety of dialogue phenomena is required. A common procedure of such analysis is human-human data collection and its semantic annotation. The specific setting considered in this study involved a real-life multi-issue bargaining scenario about anti-smoking legislation in the city of Athens passed in 2015-2016. After the new law is enacted, many cases of civil disobedience were reported. Different stakeholders came together to (re-)negotiate and improve the legislation. The main negotiation partner was the Department of Public Affairs of the City Council who negotiates with representatives of small businesses, police, insurances, etc.

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[2]Positional bargaining involves holding on to a fixed preferences set regardless of the interests of others.

Dialogue Act	Relative frequency (in %)	
	Task Management	Discourse Structuring
propositionalQuestion	1.8	-
checkQuestion	1.8	-
choiceQuestion	1.8	-
setQuestion	3.5	-
inform	22.8	1.9
answer	7.0	-
(dis-)agreement	10.5	1.9
suggest	22.8	16.8
request	7.0	-
addressSuggest	-	0.9
acceptSuggest	15.8	7.5
declineSuggest	1.8	0.9
offer	1.8	-
addressOffer	1.8	-
interactionStructuring	na	46.7
closing	na	2.8
opening	na	3.7

Table 2: Distribution of Task Management and Discourse Structuring dialogue acts in the analysed multi-issue bargaining dialogues.

The anti-smoking regulations were concerned with four main *issues*: (1) smoke-free public areas (smoking ban scope); (2) tobacco tax increase (taxation); (3) effective anti-smoking campaign programs (campaign); and (4) enforcement policy and police involvement (enforcement), see Figure 2. Each of these issues involves four to five most important negotiation *values* with preferences assigned representing parties negotiation positions, i.e. preference profiles. Nine cases with different preference profiles were designed. The preferences strength was communicated to the negotiators through colours. Brighter orange colours indicated increasingly negative options; brighter blue colours increasingly positive options. The use of colour rather than numbers introduces a form of uncertainty in the exact value of a given agreement, which is closer to real-life negotiations.

Each participant in the experiment received the background story and instructions, as well as their preference profiles for each scenario. Their task was to negotiate an agreement which assigns exactly one value to each issue, exchanging and eliciting offers concerning ⟨*ISSUE*;*VALUE*⟩ option. Participants were randomly assigned their roles. They were advised to start with the highest possible values according to their preference information. Participants were not allowed to show their preference cards to each other. No further rules on the negotiation process, order of discussed issues or time constraints were imposed. They were allowed to withdraw or re-negotiate previously made agreements within one session, or terminate a negotiation.

16 unique subjects (aged between 19 and 25)

participated in the experiments. The resulting data collection consists of 50 dialogues of a total duration of about 8 hours, comprising about 4.000 speaking turns (Petukhova et al., 2016). The human-human negotiation behaviour was evaluated with respect to the number of agreements reached, the ability to find Pareto optimal outcomes, and acceptance of negative outcomes, see Table 6 for results and comparison with human-agent performance. The data was segmented and annotated with dialogue acts information following the ISO 24617-2 standard (ISO, 2012).

4 Dialogue Acts and Update Semantics

In order to model all relevant phenomena, we specified a set of dialogue acts stipulating different levels of commitment with respect to the targeted negotiated outcome. For this purpose the ISO 24617-2 dialogue act taxonomy[3] and its superset DIT^{++}[4], were used. We distinguished five levels of commitment: (1) zero commitment for offer elicitations and preference information requests; (2) the lowest non-zero level of commitment for informing about preferences, abilities and necessities; (3) an interest and consideration to offer a certain value; (4) weak (tentative) or conditional commitment to offer a certain value; and (5) strong (final) commitment to offer a certain value.

Actions at zero level of commitment are used by negotiators to gather information about partner's preferences, mostly in the form of questions. For example, a *Set Question* of participant *A* addressed to *B* with the goal to elicit *B*'s preference concerning the smoking ban scope, e.g. 'Where do you think we should ban smoking?', can be represented as $SetQuestion(A, B, offer(ISSUE = 1; ?VALUE))$. To describe the intended update effects of an action a number of formal concepts - semantic primitives - are used that specify an agent's beliefs, goals, and commitments. A set of semantic primitives is defined in (Petukhova, 2011). Bunt (2014) provides a detailed specification of the update semantics of dialogue acts. For instance, the primitive *Bel* expresses the possession of information and the *KnowVal* primitive serves to represent the availability of information. For example, *A* believing that *B* has certain preferences for the 'scope' issue is represented as $Bel(A, KnowVal(B, offer(ISSUE =$

Negotiation Move	Relative frequency (in %)
Offer	75.0
CounterOffer	12.4
Exchange	6.6
Concession	1.2
BargainIn	0.4
BargainDown	1.2
Deal	2.4
Withdraw	0.8

Table 3: Defined negotiation moves and their relative frequencies in the annotated multi-issue bargaining corpus.

$1;?VALUE)))$.[5] The primitive *Want* is used to capture a participant's goal to achieve a certain situation. Thus, A's goal to obtain information about B's negotiation preference can be represented as $Want(A,KnowVal(A,offer(ISSUE = 1;?VALUE)))$.

Negotiators may *Inform* each other about their preferences. These actions also include various types of *Answers*. A's goal to inform B about his negotiation preferences can be represented as $Want(A,KnowVal(B,Bel(A,offer(ISSUE = 1;VALUE = 1C))$. Negotiators do not just provide information about their preferences, but also communicate their evaluation and estimation of the probability of events and their beliefs about what is possible, necessary and desirable in the current context, e.g. $Bel(A,\Box offer(ISSUE = 1;VALUE = 1C))$, $Bel(A,\neg \Diamond offer(ISSUE = 1;VALUE = 1C))$.

Suggestion acts express considerations to offer certain values, and assumptions about the opponent's abilities and interests to offer the same, i.e. $ConsidDo(A,offer(X;Y))$; $Bel(A,CanDo(B,offer(X;Y)))$; $Bel(A,Interest(B,offer(X;Y)))$.

At a higher level of commitment, *Offer* acts are observed, expressing commitments to offer (or not to offer) a certain value, e.g. $CommitDo(A,offer(X;Y))$ and $CommitRefrain(A,offer(X;Y))$. Weak and strong commitments to *Accept* or *Reject* an *Offer* (but also a *Suggestion*) may dependent on a condition specified in the semantic content of a dialogue act. When annotating, a *conditional* qualifier is attached to action-discussion communicative functions. Additionally, all offers and responses to them at all negotiation stages except the *Secure* phase are modelled as weak commitments, e.g. $WBel(A,CommitDo(A,offer(X;Y)))$, indicating that they are *tentative*, and can eventually be strengthened or cancelled. At the highest level of

commitment are *final offers* and responses to them in the *Secure* phase. Annotations contain tentative and final communicative function qualifiers. Table 1 presents the observed distribution of task-related dialogue acts in the annotated data.

To structure a negotiation task, *Task Management* acts are used. These dialogue acts explicitly address the negotiation process and procedure. This includes utterances for coordinating the negotiators' activities (e.g., "Let's go issue by issue") or asking about the status of the process (e.g., "Are we done with the agenda?"). Task Management acts are specific for a particular task and are often similar in form but different in meaning from Discourse Structuring acts, which address the management and monitoring of the interaction. Examples of the later are utterances like "To sum up", and "Let's move to a next round". Table 2 presents the distribution of these dialogue acts.

5 Negotiation Semantics

Semantically, dialogue acts correspond to update operations on the information states of the dialogue participants. They have two main components: (1) the *communicative function*, that specifies how to update an information state, e.g. Inform, Question, and Request, and (2) the *semantic content*, i.e. the objects, events, situations, relations, properties, etc. involved in the update, see (Bunt, 2000). Negotiations are commonly analysed in terms of certain actions, such as offers, counter-offers, and concessions, see (Watkins, 2003b), (Hindriks et al., 2007). We considered two possible ways of using such actions, also referred to as 'negotiation moves', to compute the update semantics in negotiation dialogues. One is to treat negotiation moves as task-specific dialogue acts. Due to its domain-independent character, the ISO 24617-2 standard does not define any communicative functions that are specific for a particular kind of task or domain, but the standard invites the addition of such functions, and includes guidelines for how to do so. For example, a negotiation-specific kind of $Offer_N$ function should be introduced for the expression of commitments concerning a negotiation value.[6] Another possibility is to use negotiation moves as the semantic content of general-purpose dialogue acts. For example, a negotiator's statements con-

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[5]Additionally, the strength of A's beliefs is represented by the parameter σ, which can have the values 'firm' and 'weak', or numerical values expressed, for example, by confidence scores computed elsewhere.

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[6]Negotiation 'Offers' may have a more domain-specific name, e.g. *Bid* for selling-buying bargaining.

Context	num	source	Agent (A)context		num	source	Council (C) context
LC					u001	*prec*	$Bel(C,Next\_Speaker(C))$
LC	s1		$Bel(A,Current\_Speaker(C))$		u1		$Bel(C,Current\_Speaker(C))$
	fs_1	*latest*	$\langle verbatim \rangle$		fs_1	*latest*	$\langle verbatim \rangle$
	da_1	*D;CF*	Task; Suggest		da_1	*D;CF*	Task; Suggest
		sem_content	$p2 = offer(ISSUE = 1;VALUE = 1b)$			*sem_content*	$p2 = \langle offer(ISSUE = 1;VALUE = 1b)$
			Speaker:C; Addressee: A				Speaker:C;Addressee: A
CC	s2	exp.und:da_1	$Bel(A,MBel(\{A,C\},WBel(C, Interpreted(A,du_1))))$		u2	exp.und:da_1	$Bel(A,MBel(\{A,C\},WBel(C, Interpreted(A,du_1))))$
SC	s01a	exp.und:da_1	$Bel(A,MBel(\{A,C\},WBel(C, Bel(A,Bel(C,Interest(A,p2))))))$		u01a	exp.und:da_1	$Bel(C,MBel(\{A,C\},WBel(C, Bel(A,Bel(C,Interest(A,p2))))))$
	s01b	exp.und:da_1	$Bel(A,MBel(\{A,C\},WBel(C, Bel(A,Assume(C,CanDo(A,p2))))))$		u01b	exp.und:da_1	$Bel(C,MBel(\{A,C\},WBel(C, Bel(A,Assume(C,CanDo(A,p2))))))$
	s01c	exp.und:da_1	$Bel(A,MBel(\{A,C\},WBel(C, Bel(A,Want(C,ConsidDo(A,p2))))))$		u01c	exp.und:da_1	$Bel(C,MBel(\{A,C\},WBel(C, Bel(A,Want(C,ConsidDo(A,p2))))))$
	s02a	exp.ad: da_1	$Bel(A,MBel(\{A,C\},WBel(C, Bel(A,Interest(A,p2)))))$		u02a	exp.ad:da_1	$Bel(C,MBel(\{A,C\},WBel(C, Bel(A,Interest(A,p2)))))$
	s02b	exp.ad: da_1	$Bel(A,MBel(\{A,C\},WBel(C, Bel(A,CanDo(A,p2)))))$		u02b	exp.ad:da_1	$Bel(C,MBel(\{A,C\},WBel(C, Bel(A,CanDo(A,p2)))))$
	s02c	exp.ad: da_1	$Bel(A,MBel(\{A,C\},WBel(C, Bel(A,ConsidDo(A,p2)))))$		u02c	exp.ad:da_1	$Bel(C,MBel(\{A,C\},WBel(C, Bel(A,ConsidDo(A,p2)))))$
SC	s03a	und:da_1	$Bel(A,Bel(C,Interest(A,p2)))$				
	s03b		$Bel(A,Assume(C,CanDo(A,p2)))$				
	s03c		$Bel(A,Want(C,ConsidDo(A,p2)))$				
SC	s3	*prec*	$Bel(A,\diamond p2)$				
	s04a	ad:da_1	$Bel(A,Interest(A,p2))$				
	s04b		$ConsidDo(A,p2)$				
	s04c		$Bel(A,CanDo(A,p2))$				
SC	s4	*prec*	$CommitDo(A,p2)$				
LC	da_2	*plan:s4*	Task; AcceptSuggest				
		sem_content	$p2 = offer(ISSUE = 1;VALUE = 1b)$				
LC	s001	*prec*	$Bel(A,Next\_Speaker(A))$				
LC	s5		$Bel(A,Current\_Speaker(A))$		u2		$Bel(C,Current\_Speaker(A))$
	fs_2	*latest*	$\langle verbatim \rangle$		$fs_2 : du2$	*latest*	$\langle verbatim \rangle$
	da_2	*D;CF*	Task;AcceptSuggest		$fs_2 : da_2$	*D;CF*	Task;AcceptSuggest
		sem_content	$p2 = offer(ISSUE = 1;VALUE = 1b)$			*sem_content*	$p2 = offer(ISSUE = 1;VALUE = 1b)$
			antecedent: da_1				antecedent: da_1
			Speaker:A; Addressee: C				Speaker:A;Addressee: C

Table 4: Example of context update for cooperative negotiation behaviour. (LC = Linguistic Context; CC = Cognitive Context; SC = semantic context; prec = preconditions; da = dialogue act; fs = functional segment; D = dimension; CF = communicative function; exp.und = expected understanding; und = understanding; exp.ad = expected adoption; ad = adoption; Bel = believes; MBel = mutually believed; WBel = weakly believes)

cerning his preference to a certain option can be represented as $Inform(A,B,\diamond offer(X;Y))$.

We specified 7 basic negotiation moves, whose distribution in the analysed data is shown in Table 3.

Negotiators often communicate their cooperativity by using modal utterances expressing preference and ability. Non-cooperative behaviour, by contrast, may be articulated by expressing inability and dislike. Modality expressions are mainly observed in *Inform* and *Answer* acts, see Table 1.

The proposed approach allows for flexibility in the interpretation and generation of negotiation strategies and accounts for a richer set of task-related actions.

6 Belief Transfer and Negotiation Strategies

We compute the meaning of negotiation dialogue contributions in terms of their effects on the participants' information states as proposed by the Information State Update (ISU) approach, (Poesio and Traum, 1998; Bunt, 1989) and the computational model of grounding and beliefs transfer proposed by (Bunt et al., 2007).

Negotiators produce their contributions aiming at the understanding by others. Understanding that a certain dialogue act is performed means creating the belief that the preconditions hold which are characteristic for that dialogue act. Using the ISU machinery and procedures for incorporating beliefs and expectations shared between speaker and hearers, we can compute *expected understanding effects* modelled as *weak* beliefs. When evidence about successful understanding arrives weak beliefs are *strengthened*, otherwise they may be *cancelled*.

Negotiators also expect that their opponent will share some of their preferences and will accept some of their offers (*expected adoption effects*). The strength of such expectations depends on the available knowledge about their opponents, on their common and individual goals, and on the knowledge concerning the opponent's negotiation strategy. When the negotiator states identical preferences, agrees with the opponent's preferences, or accepts his suggestions and offers, he adopts the opponent's beliefs as beliefs of his own. Consider the following example:

(1) Council(human): *What do you think if we do not allow smoking in public transportation at least?*

Information type	Explanation	Source
Strategy	The strategy associated with the instance	negotiationMove, modality
My-bid-value-me	The number of points the agent's bid is worth to the agent	
My-bid-value-opp	The number of points that the agent believes its bid is worth to the user	
Opp-bid-value-me	The number of points the users bid is worth to the agent	
Opp-bid-greater	*true* if the users bid is at least as much as the agent's current bid, *false* otherwise	Preference profile
Next-bid-value-me	The number of points that the next best option is worth	
	The next best option is defined as the option closest in value to the current one	
	(Not including those that are worth more than the current option.)	
Overall-value	The total value of all options that have been agreed upon so far.	
	This is a measure of how the negotiation is going.	History
	If it is negative, negotiation is likely to result in an unacceptable outcome.	
My-move	The move that the agent should take in this context.	Planned future

Table 5: Structure of an instance in the Negotiation Agent, adopted with extensions from (Stevens et al., 2016a).

Business(agent): *Well, I think we can live with that* Council (*C*) produces a ⟨*Task*;*suggest*⟩ dialogue act with the semantic content *p2*. Weak mutual beliefs concerning expected understanding and adoption effects are created, the dialogue context model is updated with *s01a − s02c* and *u01a − u02c* updates as shown in Table 4. Business representative *A* understands *C*'s *da₁* as a suggestion and accepts it following the cooperative negotiation strategy. *A*'s understanding means that *A* believes that *C* wants *A* to consider to do *p2* because *C* believes that *p2* would be interesting for *A*, and *A* is able to do *p2*. In *A*'s preference profile, *p2* is a possible offer. This enables *A* to accept *C*'s suggestion, see precondition in *s3*. *A* acting as a cooperative agent is considering to offer the discussed value and commits to perform this action. Thus, beliefs about expected and actual understanding and adoption together with the negotiator's preferences give rise to the generation of one or more relevant dialogue acts. Similarly, additional updates are performed in other contexts. For instance, the Linguistic Context (LC) is updated with respect to beliefs concerning the speaker role management, and in the Cognitive Context (CC) concerning processing successes and failures. This triggers the generation of dialogue acts in multiple dimensions, e.g. here in the Turn Management and Feedback dimensions, respectively.

The example in (2) shows non-cooperative negotiation behaviour. It may be noted that negotiation partners always cooperate at a linguistic level, as they try to understand each other's contributions and respond to perceived intentions.[7] A rational agent may show non-cooperative behavior

at the level of perlocutionary actions (see (Attardo, 1997)), when cancelling of expected adoption beliefs occurs.

(2) Council(human): *What do you think if we do not allow smoking in public transport at least?*
Business(agent): *It's not possible for me*

The dialogue context model is updated in this case as follows. *A* understanding *C* means that *A* believes that *C* wants *A* to consider to do *p2* because *C* believes that *p2* would be interesting for *A* and *A* is able to do *p2*. According to *A*'s preference profile, *p2* is not a possible offer, resulting in the precondition in *s3* as $Bel(A, \neg \Diamond p2)$. This leads to cancelling *C*'s expected adoption beliefs. Acting as a non-cooperative but rational agent, *A* refuses to commit to *p2*. Alternatively, *A* may offer another value more preferable for him, i.e. performing a counter-offer move when $Bel(A, Interest(A, \neg p2))$ but $Bel(A, Interest(A, p3)); Bel(A, CanDo(A, offer(p3)));$ $ConsidDo(A, offer(p3))$ where *p3* stands for example for $offer(ISSUE = 1; VALUE = 1c)$.

7 Negotiation Agent

The implemented Negotiation Agent produces counter-move based on the estimation of partner's preferences and goals. The Agent adjusts its strategy according to the perceived level of the opponent's cooperativeness. Such meta-strategies are observed in human negotiation and coordination games, see (Kelley and Stahelski, 1970), (Smith et al., 1982). Currently, the Agent distinguishes three strategies: cooperative, non-cooperative and neutral. The agent starts neutrally, requesting the partner's preferences. If the Agent believes the opponent is behaving cooperatively, it will react with an

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[7]Consider also the definition of cooperative communicative behaviour proposed by Allwood et al., 2000. Communicative agents are considered cooperative at least in trying to recognise each other's goals, and the recognition of a goal

may be sufficient reason for the participant to form the intention to act.

cooperative negotiation move. For instance, it will reveal its preferences when asked for, it will accept the opponent's offers, and propose concessions or cross-issues trade-offs. It will use modality triggers of liking and ability. If the Agent experiences the opponent being non-cooperative, it will switch to non-cooperative mode. It will stick to its preferences and insist on acceptance by the opponent. It will repeatedly reject the opponent's offers using modal expressions of inability, dislike and necessity. It will not make concessions and will threaten to withdraw reached agreements and/or terminate negotiation.

The Agent's negotiation moves and their arguments are encoded as instances represented as a set of slot-value pairs corresponding to the Agent's preference profile concerning beliefs about Agent's and partner's preferences (state of the negotiation and conditions), and Agent's and estimated partner's goals (actions), see Table 5. The Agent assumes that the partner's preferences are comparable, but values may differ. At the beginning of the interaction, the Agent may have no or weak assumptions (guesses) about the partner's preferences. As the interaction proceeds the Agent builds up (learns) more knowledge about his partner's choices. Agent's decisions are made by finding a prior experience (an instance) that is most 'active' (based on history, e.g. frequency and recency, and on similarity, e.g. how similar the instance is, given the context) in the current context, see (Gonzalez and Lebiere, 2005). Negotiation Agent is based on the Instance-Based Learning (IBL) model as implemented in ACT-R cognitive architecture, see () for the later.

Having computed the 'best' negotiation move as a response, the Agent will pass it to the Dialogue Manager for updating the dialogue context model and producing an appropriate task-related dialogue act. Thus, the Negotiation Agent is integrated in a spoken dialogue system as a Task Agent of its Dialogue Manager which operates on a structured dynamic dialogue context, see (Malchanau et al., 2015) for the proposed multi-threaded DM architecture.

We evaluated the Negotiation Agent's performance, comparing it with human performance on the number of agreements reached, the ability to find Pareto optimal outcomes, the degree of cooperativeness, and negative outcomes, see Table 6. For this evaluation, 28 sessions involving 28

Evaluation criteria	Human-human	Human-computer
Mean dialogue duration (min)	5:51	9:37
Agreements (%)	78	66
Pareto optimal (%)	61	60
Negative deal (%)	21	16
Cooperativeness rate (%)	39	51

Table 6: Comparison of human-human and human-agent negotiation behaviour.

participants aged 25-45 (all professional politicians or governmental workers) were analysed. We found that the participants reached a lower number of agreements when negotiating with the Agent than when negotiating with each other. This could in most cases be attributed to the imperfect recognition and interpretation by the dialogue system of spoken participant behaviour. Overall task effectiveness in terms of proportion of successfully completed dialogues was found to be 76.8% (human-human pairs were 100% successful). Of the reached agreements, the participants made a similar number of Pareto optimal agreements when negotiating with the Agent as when negotiating with each other. Human participants show a higher level of cooperativity when interacting with the Agent, measured in the number of cooperative actions given the total number of the task-related actions performed. This may mean that humans were more competitive when interacting with each other. A lower number of negative deals (i.e. agreements on bright 'orange' options in Figure 2) was observed for human-agent pairs.

8 Conclusions and Future Research

In this study we proposed, implemented and evaluated an ISU-based model of multi-issue bargaining dialogue behaviour. A real-life complex negotiation scenario was used for data collection, with a rather comprehensive pragmatic and semantic analysis of negotiation phenomena. The model accounts for specific multi-issue bargaining dialogue structure, for actions that express different degrees of commitment to targeted negotiation outcome, as well as for the strategic actions to achieve this outcome. The model is flexible in that it can be extended with other domain-specific event-based semantics. We showed how the participants' beliefs are created when a speaker's behaviour is understood and how it leads to the adoption or cancellation of beliefs when participants have overlapping and conflicting preferences. The model supports the generation of dialogue contributions in multi-

ple dimensions accounting for task-related negotiation actions as well as for actions that are used to control the overall interaction.

The evaluation of human-human and human-agent performance shows that the relevant negotiation aspects and interactive phenomena are adequately modelled, resulting in plausible and effective negotiation behaviour.

Future efforts will be undertaken to refine the model with respect to the negotiation moves semantics. We also plan to extend the model to account for attitudinal meaning aspects of multi-modal dialogue contributions to compute sophisticated negotiation strategies with respect to co-operativity and dominance. A user-based within-subject evaluation (e.g. in repetitive negotiation rounds) will be performed to analyse participant's negotiation behaviour change over time, and to incorporate user models into the adaptive human-computer negotiation system.

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