Requirements towards automated mediation agents

Simeon Simoff[1,3], Carles Sierra[2,3], Ramon López de Mántaras[2]

[1] School of Computing and Mathematics, University of Western Sydney,
NSW 1797, Australia
s.simoff@uws.edu.au
[2] Artificial Intelligence Research Institute (IIIA), Spanish Research Council (CSIC)
Campus Universitat Autonoma de Barcelona
08193 Bellaterra, Catalonia, Spain
{sierra, mantaras}@iiia.csic.es
[3] Faculty of Information Technology, University of Technology, Sydney
NSW 2007, Australia
simeon@it.uts.edu.au

Abstract. This paper presents a preliminary study of the issues on the way of developing an automated mediation agent. The work is conducted within the 'curious negotiator' framework. The work look from a knowledge perspective at mediation is an information revelation process. The introduced formalism is used to demonstrate how through the revealing of the appropriate information and changing the understanding of the disputes mediation can succeed. Automating mediation needs to take in account that mediation is a knowledge intensive process, where the mediators utilise their past experiences and information from negotiating parties for changing the positions of negotiating parties.

Keywords: automated mediation, mediation agent, information-based agency

1 Introduction

Negotiation is the process whereby two (or more) individual agents with conflicting interests interact, aiming at reaching a mutually beneficial agreement on a set of issues. Engaging in such interactions is a daily activity – from a simple negotiation of the price of a product we buy at the market to the complicated negotiations in dispute resolutions on the international arena. Whatever is the level of negotiation, during such interactions, participants may need to make concessions in order to reach an agreement [1].

Negotiation is goal-directed in the sense that individual agents involved in a negotiation may—probably will—have agendas of their own. But the agendas of the negotiating agents may be incompatible—there may be no solution that satisfies them all. Further the existence of a solution is unlikely to be known when the negotiation commences [2]. So it may not be useful to consider negotiation as a search problem because the solution space may be empty whilst the negotiating agents may believe that it is not so. If the negotiation is a multi-issue negotiation for which the issue set is

open [i.e. it can change at any stage in the negotiation] then the agendas of the individual negotiating agents must necessarily be at a higher level than the issues because the issues are unknown, and may even be issues that 'had never occurred' to one of the agents. So for multi-issue negotiation the agendas of the agents can not in general be an even high level goal such as 'to maximise profit on the deal' as the deal space is unknown. Environmental conflict resolution is a typical example, where conflicts involve many different types of parties, issues and resources [3].

As a result negotiations may reach a deadlock, taking prohibitively long time without reaching tangible outcomes, or be terminated. This is when in real life the intervention of a *mediator* can influence the process, facilitating it towards a mutual agreement.

The design of the 'curious negotiator' automated negotiation system, outlined initially in [4], is an attempt to address these issues. Fig. 1 shows an updated version of the overall design proposed in [4] and the progress of the work.

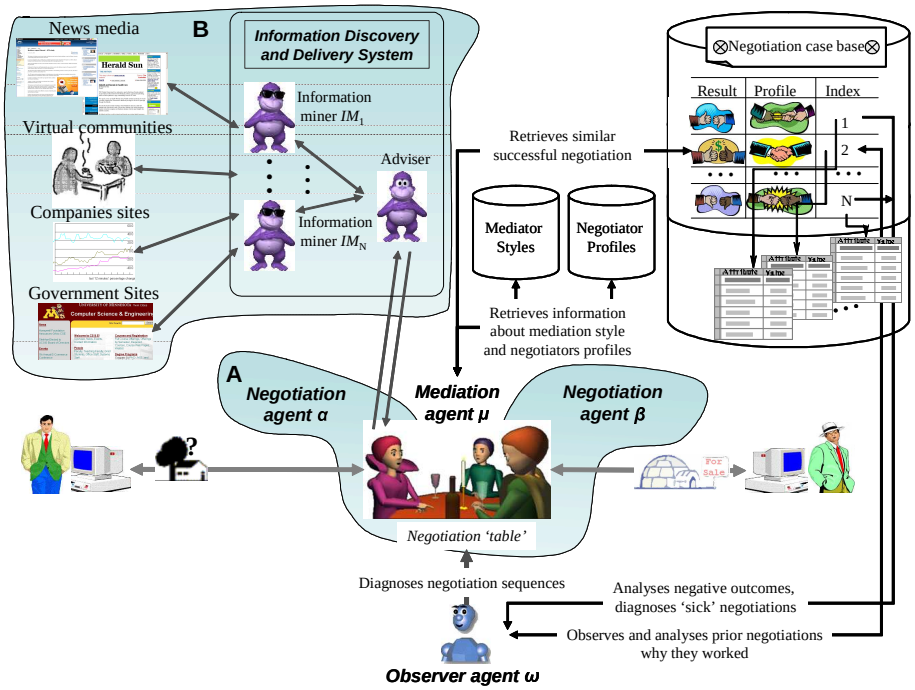

Fig. 1. The design of the 'curious negotiator' and the progress of the research

The 'curious negotiator' is founded on the intuition "it's what you know that matters" and investigates the use of information and information theory, including entropy-based (random worlds) inference, as a foundation for automated negotiation between agents with bounded rationality. The design presented in [4] aimed at exploiting the interplay between contextual information [5] and the development of offers in negotiation conducted in an electronic environment. This contextual information is derived from what happens at the bargaining table and away from it.

The work on the negotiation agent (shaded area A in Fig. 1) focused on identifying mechanisms and knowledge structures for utilisation information in the negotiation process. Negotiation agent α negotiates with agent β by sending illocutions which represent offers and counter offers. The illocutions are represented in communication language $\mathbb{C}$. An example of such language, where the kernel set of negotiation illocutions is extended with illocutions that enable persuasive negotiation and argumentation, is presented in [6] and [7]. Negotiation agent α also uses an internal language $\Im$ for it's reasoning.

Negotiation agent α negotiates from a stance that assumes nothing about her opponent's motivations and applies maximum entropy logic to that which it has observed. The basic feasibility of this approach was reported in [8] where an agent for multi-issue bilateral bargaining signs contracts if it is sufficiently confident that they are acceptable. This work is orthogonal to the utility-based approach, and treats negotiation as an *information discovery and revelation process*. The output from the work covering the shaded area A in Fig. 1 is known collectively as information-based agency [7].

The information that the agent utilises may come from at least two sources:

a. from the 'negotiation table', e.g. from the counter offers that the opponent provides (this is incorporated in the work presented in [8]) [in general, all utterances agents make during a negotiation give away (valuable) information];

b. from external sources, e.g. other deals, news, companies white papers, blogs of virtual communities, and other electronically accessible sources, all of which constitute part of the context in which negotiation happens.

The automation of the discovery, representation and delivery of the necessary information and knowledge to the agents has been the focus of the work on the information discovery and delivery system in the 'curious negotiator' (shaded area B in Fig. 1). Elements of the approach and different technical aspects of the embedded information mining system have been presented in several works. In [9] it has been presented one of its components in more details - an effective automated technique for extracting relevant articles from news web sites and their semi-structured representation, so that they can be used further by the information discovery and delivery system. In [10] it has been demonstrated how extracted unstructured or semi-structured news can be utilised to refine exchange rate predictions and provide the information to the negotiating agent. The choice of the application has been influenced by the literature indicators that daily economy news and political events influence the exchange rate daily movement [11, 12]. The mechanism includes news extraction algorithms, a quantitative process model based on the extracted news information, which is exemplified by an exchange rate prediction model, and a communication protocol between the data mining agents and negotiation agents. The predictive information about the exchange rate then can be utilised by agent's negotiation strategies. The system complements and services the information-based architecture in [7, 8]. The information request and the information delivery format is defined by the negotiation agent in the query. For example, if the topic of negotiation is buying a large number of digital cameras for an organisation, the shared ontology will include the product model of the camera, and some characteristics, like "product reputation" (which on their own can be a list of parameters), that are usually derived from additional sources (for example, from different opinions in a professional

community of photographers or digital artists). Information request can be formulated in a form that depends on the knowledge representation used by the agent, e.g. sets of possible values, value ranges, probability values. For example, if the negotiator is interested in high resolution cameras, and the brand is a negotiation parameter, the request for information to the information mining and delivery system can be formulated as a set of consisting of camera models and corresponding requests for preference estimates. These preference estimates then can be computed from the information about these models, available in various sources, including various communities of professional experts, prosumers and consumers. In [13] is presented a recommender mechanism that utilises text mining to extract opinions about the products from consumer reviews available in electronic from and convert those opinions into a recommendation that then can be utilised by a negotiation agent.

When the mechanisms for providing information and reasoning with such information, as well as the respective knowledge representation structures, have been developed, the mechanisms for dealing with negotiations that fail in reaching an agreement, or seemed to be leading to a failure, remain the undeveloped part of the 'curious negotiator' - the unshaded part in Fig. 1 includes the mediating agent μ, the observer agent ω and their supporting knowledge representation structures.

The paper presents an extremely preliminary work on the principles of building automated mediation agent within the 'curious negotiator' framework, consistent with the approach of the information based agency. It explores mediation as information revelation process. It specifies the requirements towards the knowledge representation structures supporting mediation, including case-based representation for storing the experience of past negotiations. Section 2 looks at mediation, as a knowledge-driven process and explores the changes that information revelation can make to the negotiation space and the outcomes of negotiation. It introduces the notion of 'mental model' of participants involved in the process and looks at mechanisms of how these model can be utilised in automated mediation. Section 3 considers some aspects in utilising past experiences and background knowledge in automated mediation. It looks also at the utilisation of information at the diagnosis stage.

2 Mediation as a knowledge driven process of information revelation.

Contemporary analysts in social and political sciences look at mediation as a process that enables conflict resolution. Mediators are often indispensable in the area of *dispute* (or *conflict*) *resolutions*, settling variety of disputes, spanning from conflicts between sovereign nations to conflicts between family members, friends, and colleagues. Successful mediation can make a dramatic difference to the outcome of a negotiation stalemate. For instance, on 14 January 1998 the President of United Nations Security Council issues statement demanding "that Iraq cooperate fully and immediately and without conditions with the Special Commission in accordance with the relevant resolutions."[1] As all UN weapons inspections in Iraq were frozen, during

[1] http://daccessdds.un.org/doc/UNDOC/GEN/N98/007/84/PDF/N9800784.pdf

the following month all direct negotiations between the US and Iraq did not reach any agreement and the military conflict seemed unavoidable. The following event sequence illustrates the mediation process: (i) the US authorised the mediation effort; (ii) the UN secretary (the mediator) achieved a possible deal with Iraq; (iii) the UN secretary passed it back to the US; (iv) the US reviewed and accepted the deal. Several months later the conflict escalated, but this time no mediation was sought and military actions started. The mediation made a huge difference in the first dispute resolution.

2.1 Necessary and sufficient conditions for mediation

This example illustrates that mediation as a process involves *information revelation* and part of mediator's strategy is guiding the process of information revelation. The following are the necessary (*C1*, *C2*) and sufficient (*C3*) conditions for a mediation to take place:

Condition C1: Negotiating agents α and β are willing to achieve a mutually beneficial agreement;

Condition C2: Negotiating agents α and β are seeking or will accept mediation (in the first case, the awareness about the conflict and the problem with the current state of the negotiation resides with the negotiating agents, in the second case either the mediator agent μ or, if present, the observer agent ω diagnoses the problem;

Condition C3: A mediating agent μ is available (this condition is by default embedded in the 'curious negotiator' paradigm).

In the example with the 1998 Iraq crisis, in the second case condition *C2* was not present. Conflicts may be a result of a contradiction of interests, as in the example with the 1998 Iraqi crisis, but can be also a result just of a different (but unknown to the disputing parties) perception of the disputed subject.

2.2 Mediation process within the 'curious negotiator' framework

Further we consider the following mediation process, illustrated in Fig. 2, where agents α and β are in a deadlock and direct exchange of offers between them has ceased. In a mediation session, α and β interact with messages *m* only with the mediating agent μ.

$M_{(\bullet)}(t)$ denotes a "mental model" at time *t*. We use the label "mental model" to denote the view (including related knowledge) of an agent about a dispute, about the views of the other parties on that dispute and the expected outcomes. This knowledge is internal to the agent. Each model is manifested to the other agents through the actions taken by the agent. Further in the text we use the term mental model without quotation marks.

$M_{\alpha}(t)$ and $M_{\beta}(t)$ denote the mental models of agents α and β, respectively. $M_{\alpha}(t)$ is not known by β and $M_{\beta}(t)$ is not known by α. None of them is known by the mediating agent μ. Each of these agents has own approximations of the mental

models of the other agents. $M_{agent(party)}(t)$ denotes the mental model that the agent has about another party. In particular, $M_{\alpha(\beta)}(t)$ is the mental model of α about β, i.e. about what β wants out of the negotiation; respectively, $M_{\beta(\alpha)}(t)$ is the mental model of β about α, i.e. the position of α in the dispute. Further, $M_{\mu(\alpha)}(t)$ and $M_{\mu(\beta)}(t)$ are the mental models of the mediating agent μ about the positions of α and β in the dispute, respectively. The actual formalism that expresses these models is beyond the scope of the paper.

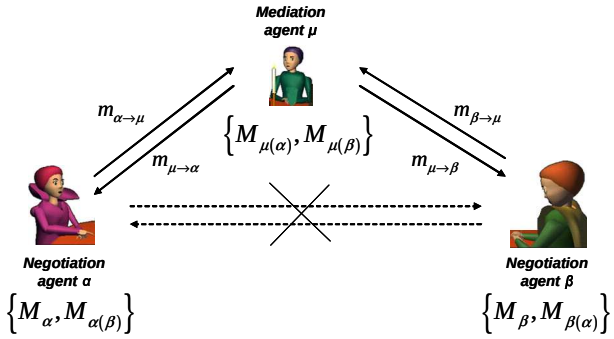

Fig. 2. The mediation agent within the 'curious negotiator' framework

2.3 Mediation process within the 'curious negotiator' framework

We use the above formalism to demonstrate some aspects of mediation that need to be taken in account when developing automated mediators. In the Orange Dispute [14], two sisters want the same orange. According to Kolodner [14] "MEDIATOR assumes they both want to eat it and solves the problem by having one sister cut the orange in two and the second chooses her half. When the second sister uses her peel for baking and throws away the pulp, MEDIATOR realises it made a mistake." [MEDIATOR [15] is one of the early case-based mediators. The focus of the work was on the use of case-based reasoning for problem understanding, solution generation, and failure recovery. The failure recovery ability is demonstrated with the Orange Dispute in [14]].

Further we present the two mediation attempts in terms of the agreements reached and the information that can be passed to the mediator. Lets our agent α represents the first sister who wants to have the orange as a desert and agent β represents the second sister who wants to have (only the peel of) the orange for cooking (the recipe requires the whole peel). If our mediation agent μ happen to be the case-based MEDIATOR, then the situation described in the Orange Dispute can be expressed through the mental models of the individual participants in Fig. 3, making explicit the wrong assumption (the shaded area in Fig. 3).

$M_{\alpha}(t) := '\alpha$ wants the orange as a desert'

$M_{\beta}(t) := '\beta$ wants only the peel of the orange for cooking'

$M_{\alpha(\beta)}(t_{break}) := '\beta$ wants an orange'

$M_{\beta(\alpha)}(t_{break}) := '\alpha$ wants an orange'

$M_{\mu(\alpha)}(t_{start}) := '\alpha$ wants the orange as a desert'

$M_{\mu(\beta)}(t_{start}) := '\alpha$ wants the orange as a desert'

Fig. 3. The wrong initial assumption of the MEDIATOR [15] in terms of our mental models. This initial assumption (which didn't change as there were no mechanisms for that) caused the failure of that mediator.

In these models t_{break}, and t_{start} indicate the time when negotiation broke and when mediation started, respectively (in the case of the MEDIATOR it has been a one step act). The results of the agreements in terms of the outcomes - Outcome (*agent*, *issue*, *result*) are presented in Table 1, where *result* values are denoted as follows: "+", "+/–" and "–" for a positive, acceptable, and negative results, respectively for the corresponding agents in terms of negotiated issue. In the original example [14], the result in the outcome for β should be "+/–" as the second sister still used the peel from her half. Here we added the constraint of the recipe in order to get negotiation about the orange to a halt with an unacceptable "–" result and generate a request for mediation.

Table 1. Outcomes of the Orange Dispute, based on mediation with initial assumption

Agent	**Agreement clauses**	**Outcome for α**	**Outcome for β**
α	Cuts the orange into halves	Outcome(α, have orange, +/–)	Outcome(β, have orange, –)
β	Chooses one half	Outcome(α, have orange, +/–)	Outcome(β, have orange, –)

The Orange Dispute can be considered an example of a dispute over resource scarcity. The resource in this case has a possible *component-based separation* (without change of the total amount of available resource) that allows to change the structure of the dispute through mediation, opening the space for a mutually beneficial solution. It exposes two aspects of mediation:

- The difference that a mediator can bring is in exploring the structure of the problem from a broader stance.
- An initial assumption by a mediator can lead to a failure of the mediation effort;

Consequently, we formulate the following postulates for the automated mediator:

Postulate P1: An automated mediator μ should start interaction with extracting more information about the position of the parties on the negotiation.

Postulate P2: An automated mediator should develop an independent "grand view" of the problem, which is more comprehensive than the individual views of α and β, respectively.

Postulate P3: An automated mediator μ should operate from the initial stance only of conditions *C1* and *C2*.

Starting mediation without initial assumptions means that μ either does not have a model for each of the negotiating agents α and β, or accepts the models $M_{\alpha(\beta)}(t)$ and $M_{\beta(\alpha)}(t)$ these agents have about each other at the point of requesting mediation. In the case of the Orange Dispute, μ starts mediation with the exit models of α and β:

- $M_{\mu(\alpha)}(t_{start}) := M_{\alpha(\beta)}(t_{break})$, i.e. $M_{\mu(\alpha)}(t_{start}) := '\alpha$ wants an orange', and
- $M_{\mu(\beta)}(t_{start}) := M_{\beta(\alpha)}(t_{break})$, i.e. $M_{\mu(\beta)}(t_{start}) := '\beta$ wants an orange'.

This information is not sufficient for mediation, e.g. the uncertainty in the mutual models of α and β, and the model μ has are the same. Research in conflict resolution in international relations demonstrates that if a mediator could credibly add information to the system of negotiators this alters the state of the system [16]. Consequently, μ takes steps in order to decrease this uncertainty. In addition, intuitively, it seems worth checking whether both parties have the same understanding of the issues in the dispute, i.e. technically, whether they operate with the same ontology or with compatible ontologies. In the Orange Dispute, μ obtains from each party what the orange is needed for. The Orange Dispute in terms of the mental models of the individual participants in the case of proposed mediation agent is presented in Fig. 4. In these models t_{break}, t_{start} and t_{end} indicate the time when negotiation broke and when mediation started and ended, respectively. Note the difference of $M_{\mu(\bullet)}(t_{start})$ for both α and β in Fig. 3 and Fig. 4. The steps taken by the mediating agent are described in Fig. 5 (we do not use a formal illocution based language, but the actions that the language should cater for are shown in italic).

$M_{\alpha}(t) := '\alpha$ wants the orange as a desert'
$M_{\beta}(t) := '\beta$ wants only the peel of the orange for cooking'
$M_{\alpha(\beta)}(t_{break}) := '\beta$ wants an orange'
$M_{\beta(\alpha)}(t_{break}) := '\alpha$ wants an orange'
$M_{\mu(\alpha)}(t_{start}) := '\alpha$ wants an orange'
$M_{\mu(\beta)}(t_{start}) := '\alpha$ wants an orange'
$M_{\mu(\alpha)}(t_{end}) := '\alpha$ wants the orange as a desert'
$M_{\mu(\beta)}(t_{end}) := '\alpha$ wants only the peel of the orange for cooking'

Fig. 4. The respective mental models of α, β and μ in the mediation session of the Orange Dispute with our proposed agent

The Orange Dispute illustrates also another important ability that an automated mediator should posses – the ability to refocus or restructure the dispute, based on the additional information about the models of each party. The outcomes of the restructured Orange Dispute are shown in Table 2

The ability to restructure the problem is crucial for developing successful automated mediators. The Sinai Peninsula Dispute in the area of international

relations shows similar properties to the Orange Dispute. The Sinai Peninsula is a piece of land of about 62,000 square km that separates Israel and Egypt. With its landscape Sinai has a *military value* for either side in terms of mechanised infantry transport or as a shelter for guerrilla forces. The perceived importance of the *territory* is evidenced that Israelis and Egyptians fought in or over the Sinai Peninsula in 1948, 1956, 1967, 1968-1970, and 1973. Since 1967 Sinai had been occupied by Israel. Fig. 6 shows a very simplified version of the models of the parties at the initial meeting in Jerusalem, when the negotiations started and halted and the change of the mediators models that lead to the outcomes. For the purpose of this paper we aim to emphasise the high level analogy with the Orange Dispute case (see Fig. 4), i.e. the need for a mediator to reframe the problem. In fact, the need for restructuring the problem in order for a mediator to get a "bigger picture" has been recognised in PERSUADER [1], to resolve labor-management disputes. In recent works [17] the mediator is expected to have a complete knowledge of the solution space.

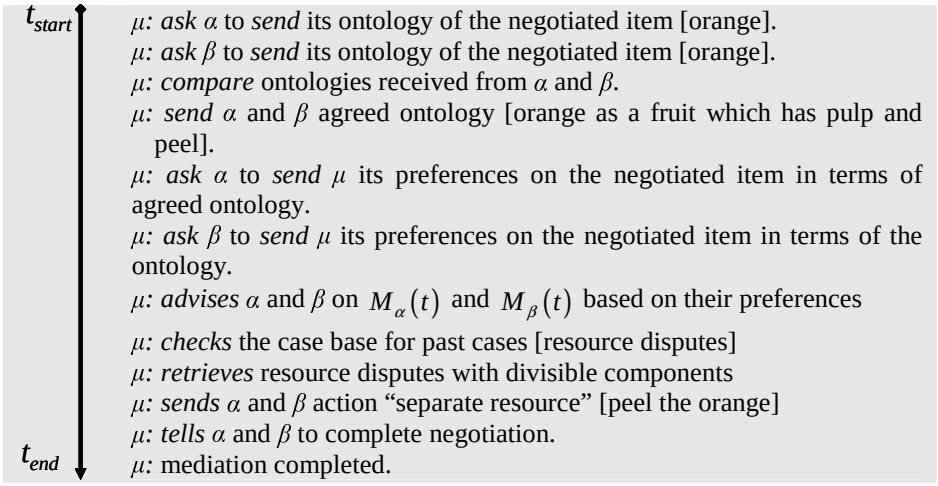

Fig. 5. Mediation as information revelation aiming at decreasing uncertainty within the negotiation system

Table 2. Outcomes of the restructured Orange Dispute

Agent	**Agreement clauses**	**Outcome for α**	**Outcome for β**
α	Peels the orange	Outcome(α, eat, +)	Outcome(β, cook, +)
β	Gets the whole peel	Outcome(α, eat, +)	Outcome(β, cook, +)

Following the initial interaction in Jerusalem, the US President Jimmy Carter initiated a *third-party mediation effort* that culminated in the Camp David accords. For the purposes of this paper we consider a simplified version of the second agreement of the Camp David accords on the future of the Sinai Peninsula. The items in the agreement are presented in Table 3, in a structure, similar to the presentation of the agreements in the Orange Dispute in Table 1 and Table 2. Without getting into the

details of the mediation steps, from Table 3 it is evidenced that the initial mutually perceived models $M_{\alpha(\beta)}(t)$ and $M_{\beta(\alpha)}(t)$ about the need for territory and strategic military advantage have been transformed by the mediation into a Security/Sovereignty trade-off, with economic benefits.

$M_{\alpha}(t) := '\alpha$ wants security, support for economy, recognition'

$M_{\beta}(t) := '\beta$ wants sovereignty (restored territory), support for economy, security)'

$M_{\alpha(\beta)}(t_{break}) := '\beta$ wants territory and strategic military advantage'

$M_{\beta(\alpha)}(t_{break}) := '\alpha$ wants territory and strategic military advantage'

$M_{\mu(\alpha)}(t_{start}) := '\alpha$ wants territory and strategic military advantage'

$M_{\mu(\beta)}(t_{start}) := '\beta$ wants territory and strategic military advantage'

$M_{\mu(\alpha)}(t_{end}) := '\alpha$ wants security, support for economy, recognition'

$M_{\mu(\beta)}(t_{end}) := '\beta$ wants sovereignty (restored territory), support for economy, security'

Fig. 6. The respective mental models of α, β and μ in the mediation session of the Sinai Dispute with our proposed agent

Table 3. The Sinai Peninsula Dispute. α denotes Israel; β denotes Egypt

Party	Agreement clauses	Outcome for α	Outcome for β
α	Withdraw its armed forces from the Sinai	Outcome(α, Military, –)	Outcome(β, Territory, +) Outcome(β, Sovereignty, +)
α	Evacuate its 4500 civilians	Outcome(α, Territory, –)	Outcome(β, Territory, +) Outcome(β, Sovereignty, +)
α	Restore Sinai to Egypt	Outcome(α, Territory, –)	Outcome(β, Territory, +) Outcome(β, Sovereignty, +)
α	Limit its forces within 3 km from Egyptian border	Outcome(α, Military, –) Outcome(α, Security, +)	Outcome(β, Security, +)
α	Lost the Abu-Rudeis oil fields in Western Sinai	Outcome(α, Economy, –)	Outcome(β, Economy, +)
β	Normal diplomatic relations with Israel	Outcome(α, Recognition, +)	Outcome(β, Security, +)
β	Guarantees freedom of passage through Suez Canal	Outcome(α, Economy, +) Outcome(α, Security, +)	Outcome(β, Security, +)
β	Guarantees freedom of passage through nearby waterways	Outcome(α, Economy, +) Outcome(α, Security, +)	Outcome(β, Economy, +) Outcome(β, Security, +)
β	Restricted Egyptian forces in Sinai	Outcome(α, Security, +)	Outcome(β, Military, –) Outcome(β, Security, +)

The analogy with the Orange Dispute is in having the initial negotiation framed around a common resource Territory and a similar issue of having strategic military advantage as the main goals that can enable the security. Though both territorial and military components remain on the negotiation table, the mediator brought a background knowledge which changed the models of the parties: security and restoration may not necessarily be achieved with occupation of a territory or with expensive military presence.

The information injected by the mediator and proposed steps leads to decreasing the differences between perceived mental models $M_{\alpha(\beta)}(t)$ and $M_{\beta(\alpha)}(t)$, and the respective actual mental models $M_{\beta}(t)$ and $M_{\alpha}(t)$ agents β and α, respectively, i.e. the intervention of the mediator decreases the uncertainty in the negotiation system.

2.4 Operating with information in mediation

As the mediator utilises information to decrease the uncertainty in the dispute, an automated mediation would require a measure of uncertainty $H\left(M_{(\bullet)}(t)\right)$, allowing to quantify and compare the uncertainty coming from the incomplete knowledge of the mental models of the agents. In terms of the two party mediation in Fig. 2, this decrease of uncertainty in mental models should be observable, i.e. $H\left(M_{\mu(\alpha)}(t)\right) < H\left(M_{\beta(\alpha)}(t)\right)$ and $H\left(M_{\mu(\beta)}(t)\right) < H\left(M_{\alpha(\beta)}(t)\right)$. Within the framework of the information-based agency, which adapts information-theoretic approach, such measure should measure the "information gain", as the mediator adds such gain.

Viewing mediation as a dialogue system in Fig. 2, e.g. the mediator is engaged with a dialogue with each party, points also to the information-theoretic work in dialogue management strategies in conversational case-based reasoning [18]. In terms of an automated mediation system, the mediator should have the mechanism to determine the most informative question to ask at each stage of the interaction with each of the negotiating agents.

3 Utilising past experiences and background knowledge in automated mediation

The American Bar Association defines mediation as a process by which those who have a dispute, misunderstanding or conflict come together and, with the *assistance of a trained neutral mediator*, resolve the issues and problems in a way that meets the needs and interests of both parties.[2] This definition emphasises the key role of the past experience of the mediator and its unbiased nature. Further, we consider these two aspects, starting with mediator bias.

[2] http://www.abanet.org/cpr/clientpro/medpreface.html

3.1 Unbiased mediator

The *bias of a mediator* is defined as the presence of a preference towards one of the

- *outcomes* in the negotiation;
- *sides* involved in the negotiation.

Not having preference towards any of the outcomes of a negotiation means also to keep open all options. For instance, the peace-loving broker's bias towards peaceful solutions makes his or her claims less believable compared to a broker who is indifferent to war or peace [16]. Such bias as a result can decrease the effectiveness of the mediation effort. Protecting automated mediation from introduction of a bias is not seen as a problem.

3.2 Utilising past experiences

Experience is, perhaps, the distinct feature between successful and less successful mediators. Case-based reasoning (CBR) is an approach to problem solving that emphasizes the role of prior experience during future problem solving (i.e., new problems are solved by reusing and if necessary adapting the solutions to similar problems that were solved in the past) [see [19] for a recent review of the state-of-the-art in the CBR field]. From a machine learning point of view, updating the case base is a lazy learning approach (i.e. learning without generalisation). Some aspects of using the past experience by the tandem Mediation and Observation agents has been discussed in [4]. In terms of required case representation, a starting point is knowledge representation structure for representing negotiation cases, proposed in [20]. This structure needs to be updated for dealing with ontologies. For the mediation, the case based will be linked to the corresponding knowledge base of the mediation strategies used. The case structure now includes a negotiation case as its problem section and the collection of mediation steps, information used and other knowledge, as the solution part of the case.

Important from a computational perspective is the diagnosis stage of the mediation process [21]. The diagnostic function consists of monitoring the progress of negotiation or related interactions intended to settle or resolve disputed issues [Druckman and co-authors [21] refer to [22]]. Monitoring provides a long view of unfolding developments, including trends in escalating and de-escalating dynamics. Within the framework of 'curious negotiator' we consider this stage as a pre-mediation stage, which is executed by the observer agent ω. To some extent it resembles similarity with OLAP[3] – the pre-data mining steps in business intelligence, where summary statistics at different levels are generated and later provide guidance to the data mining strategies. Similar to OLAP, monitoring should be able to provide snapshots of the negotiation process at any moment of time at different levels of granularity. The mediator μ should be able to estimate the difference between $M_{\alpha(\beta)}(t)$ and $M_{\beta(\alpha)}(t)$ from the respective actual mental models $M_{\beta}(t)$ and $M_{\alpha}(t)$

[3] Online analytical processing.

in order to define the intervention time of mediating interventions [if we follow a proactive approach and intervene before negotiation fails].

Conclusions

Though there has been some interest in automated mediation [1, 15, 17, 23] during the years, the field requires a significant effort in research and development. This paper has presented an early work on the principles of building automated mediation agent. The mediation agent is part of the 'curious negotiator' framework, hence can utilise some of the machinery developed for it, in particular:

- the information-based agency [7, 21], which offers mechanisms that allow the interplay between argumentation and information;
- the information-mining system, [9, 10], which offer means for automated discovery and (to some extent) delivery of that information to negotiating agents;
- the electronic/virtual institutions environment [24, 25], which offers means not only for performing negotiation, but also for collecting the necessary data about the negotiation sessions in order to use it in mediation.

Mediation is an information revelation process. The Orange and Sinai disputes demonstrate how through the revealing of the appropriate information and changing the understanding of the disputes mediation can succeed. Computationally, the approach requires the specification of the introduced mental models of the agents and the definition of a measure of the difference between what is labelled as mental models. The aim of the mediation is to decrease the difference between what is a perceived model and the actual model. One possible way is by identifying alternative formulations of the dispute, demonstrated with the Orange dispute and Sinai dispute (the simplified version of the second agreement).

Case-based reasoning offers potential mechanism for the mediator for handling past experiences, though the structure of the case will be complex (in comparison to the usually assumed attribute-value structure), extending the already complex structure for representing negotiation cases [20]. Overall, from a knowledge perspective, automating mediation needs to take in account that mediation is:

- a knowledge intensive process, where the mediators utilise their past experiences;
- a process that utilises information from negotiating parties and uses information for changing the positions these parties have on the negotiation table.

As it may deal with confidential information, mediation requires trust in the mediator from the parties involved, as much of the information about their position negotiating parties would not reveal to the other side. Though this has been beyond the scope of the paper, we are aware of this issue.

In conclusion, we would like to stress that the importance of mediation has been recognised world-wide. It's interesting to note that nowadays mediation skills are taught to students at various levels and schools spanning from elementary schools to university schools, including the Harvard Law School. Hence, the development of an automated mediation system is on the top priority of the research agendas.

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