Conflicts Resolution with the SoDA Methodology

Nikolaos I. Spanoudakis[1], Antonis C. Kakas[2], and Pavlos Moraitis[3]

[1] Applied Mathematics and Computers Laboratory, Technical University of Crete, Greece
nikos@science.tuc.gr
[2] University of Cyprus, Cyprus
antonis@cs.ucy.ac.cy
[3] LIPADE, Paris Descartes University, France
pavlos@mi.parisdescartes.fr

Abstract. This paper studies the application of argumentation theory and methods from Artificial Intelligence to the problem of conflict resolution. It shows how the decision theories of each of the parties involved in a conflict can be captured and formalized within a framework of preference-based argumentation. In particular, it studies how the *SoDA* methodology and its support tool, *Gorgias-B* for developing argumentation software, facilitate the elucidation of each party's preferences over their available options for addressing the conflict, and, through this, the construction of appropriate argumentation theories corresponding to the decision theories of the parties involved. These argumentation theories are generated automatically and can be executed directly to find out the position of each party at any particular stage of the negotiation process. This connection between argumentation and conflict resolution is illustrated through a real-life example of conflict resolution between the US and China after a plane collision.

Keywords: argumentation, conflict resolution, decision making, software methodology, software tool

1 Introduction

Argumentation is an important area of AI, with a wealth of theoretical work over the last twenty years (see e.g. [2], [14]), addressing a variety of problems in AI and multi-agent systems. Several practical works exist, showing that argumentation is well suited for dealing with different kind of real life applications, such as finding interesting products in e-commerce [9], negotiating supply strategies [20], making credit assignments [13], managing waste-water discharges [1], deciding about an automatic freight process [4], improving the performance of transport systems in rural areas [19], emergency rescue [21], aggregating clinical evidence [10], smarter electricity [12], delivering clinical decision support services [6], evaluating debates on the social networks [18]. An interesting general study on the use of argumentation techniques for multi-agent systems can be found in [3].

Recently, we proposed the *SoDA* methodology, along with an argumentation tool called *Gorgias-B* [17], for modeling and developing application software, whose outputted source code is an argumentation theory for the problem at hand. *SoDA* helps developers structure their application knowledge at several levels. The first level serves for enumerating the different possible actions or decisions that can be considered under some satisfied conditions, while each higher level serves for resolving conflicts at the previous level, taking into account default and contextual knowledge. Conflict resolution at the higher levels is based on the definition of dynamic priority relations among conflicting decision policies of the previous level. The aim is to provide argumentation-based software solutions that are flexible to partial and conflicting information and that can be modularly developed.

In this paper, our aim is to show how *SoDA* and *Gorgias-B* can be used for dealing with conflict resolution problems. According to [8], a conflict has two or more decision makers, each of them having his/her own objectives. A possible resolution of a conflict depends on the strategic interactions of the decision makers during the evolution of the dispute. To apply conflict analysis to a particular problem we need the following information for developing a conflict model: a) the decision makers who are participating in the conflict, b) the options corresponding to the course of action available to each decision maker, and, c) the preferences expressing the relative importance of options as viewed by each decision maker. *SoDA* and *Gorgias-B* allow to take into consideration all the above requirements.

In the following we will briefly present *SoDA* and then we will use a real world use case, namely the United States-China plane collision negotiation scenario as it is presented in [16], to show SoDA's applicability for conflict resolution and analysis problems. We will present how the modeled theories based on the assumptions made in [16] of both USA and China have been implemented with *Gorgias-B* in order to generate the solution that had been mutually accepted.

2 Basics of Argumentation

In this section we review the basic theory of argumentation which we will use to model conflict resolution problems. The theory will be presented from a general point of view of applying argumentation to real-life (decision) problems.

In [11] a preference-based argumentation framework was proposed for representing multi-agent application problems via argumentation theories composed of different levels. **Object level arguments** represent the possible decisions or actions in a specific application domain and **first-level priority arguments** express preferences on the object level arguments in order to resolve possible conflicts. Then **higher-order priority arguments** are also used to resolve potential conflicts between priority arguments of the previous level.

Formally, an **argumentation theory** is a pair $(\mathcal{T}, \mathcal{P})$ whose sentences are formulae in the background monotonic logic, $(\mathcal{L}, \vdash)$, of the form $L \leftarrow L_1, \ldots, L_n$, where $L, L_1, \ldots, L_n$ are positive or negative ground literals. The derivability relation, $\vdash$, is given simply by the inference rule of modus ponens. The head literal L can also be empty. Rules in $\mathcal{T}$ represent the **object level arguments**, or denials when the head is empty. Rules in $\mathcal{P}$ represent **priority arguments** where the head L of these rules has the general form, $L = h\_p(rule1, rule2)$, where $rule1$ and $rule2$ are atoms naming two rules and h_p refers to an (irreflexive) *higher priority* relation amongst the rules of the theory.

The semantics of an argumentation theory are defined via the abstract argumentation framework $< Args, Att >$ associated to any given theory $(\mathcal{T}, \mathcal{P})$. The **arguments** in $Args$ are given by the composite subsets, (T, P) , of the given theory, where $T \subseteq \mathcal{T}$ and $P \subseteq \mathcal{P}$. An argument (T, P) **supports** its conclusions, of either a literal, L, or a priority (ground) atom, $h\_p(r, r')$, where r and r' are the names of two rules in the theory, when $T \vdash L$ or $T \cup P \vdash h\_p(r, r')$.

The **attack relation**, Att, allows an argument, (T, P), to attack another argument, (T', P'), when (i) these arguments derive contrary conclusions (i.e. derive L and $\neg L$, or $h\_p(r, r')$ and $h\_p(r', r)$) and (ii) (T, P) makes the rules of its counter proof at least "as strong" as the rules of the proof of the argument (T', P') that is attacked. The detailed formal definition of the attacking relation can be found in [11]. The **admissibility** of (sets of) arguments, Δ, is defined in the usual way [5], i.e. that Δ does not attack itself and that it attacks back any argument that attacks it.

It is important to note that typically for an argument (T, P) to be *admissible* its object level part, T, has to have along with it priority arguments, P (from $\mathcal{P}$), in order to make itself at least "as strong" as its opposing counter-arguments. This need for priority rules can repeat itself when the initially chosen ones can themselves be attacked by opposing priority rules. In that case the priority rules have to be made themselves at least "as strong" as their opposing priority ones.

2.1 An argumentation framework for conflict resolution problems

We will now further specialize this general argumentation framework to facilitate its use for conflict resolution problems. Following [8], a conflict has two or more decision makers, each of whom has his/her own objectives. A possible resolution of a conflict depends on the strategic interactions of the decision makers during the evolution of the dispute. As mentioned in the introduction, to apply conflict analysis to a particular problem we need the following information for developing a conflict model: a) decision makers who are participating in the conflict, b) options corresponding to the course of action available to each decision maker and c) preferences expressing the relative importance of options as viewed by each decision maker.

For modeling such problems with argumentation, we separate the language $\mathcal{L}$ of the theory into two ontological categories: **Options** and **Beliefs**, where the first refers to the properties that we are primarily interested, i.e. the solutions of the application problem, and the second refers to properties of the application problem environment. Beliefs can be decomposed, although not necessary, into *Defeasible and Non-Defeasible* beliefs and some of the defeasible beliefs can be designated as **abducible** beliefs, so that they can be hypothesized when needed. Furthermore, apart from the incompatibility relation that we have through negation, we can also have a **complementary** or **conflict** relation between the different options of the application.

In an argumentation theory representing an application problem, we can separate the object level statements, $\mathcal{T}$, into two parts, $\mathcal{T} = \mathcal{T}^{\mathcal{O}} \cup \mathcal{B}$, where $\mathcal{T}^{O}$ is the subset of rules that provide arguments for the various options, i.e. rules whose head refers to an option predicate, and B, called the **background theory**, is the subset of rules whose heads are belief predicates.

Definition 1. *An* **application (argumentation) theory,** T**,** *is an argumentation theory* $(\mathcal{T}, \mathcal{P})$ *where its object level rules are separated into rules for options and rules for beliefs and its priority rules part is partitioned into a finite set of levels,* $T = (\mathcal{T}^O \cup B, \mathcal{P}_1 \ldots \mathcal{P}_n)$*, such that all the rules in* $\mathcal{P}_1$ *are priority rules with head* $h\_p(r_1, r_2)$ *with* $r_1, r_2 \in \mathcal{T}^O$ *and, for any* $1 < k \leq n$*, all rules in* $\mathcal{P}_k$ *are priority rules with head* $h\_p(q_1, q_2)$ *s.t.* $q_1, q_2 \in \mathcal{P}_{k-1}$.

In general, the different levels in the priority rules relate to the granularity or **specificity** of the **context** in which we want to consider our application problem. Belief predicates are used to describe the various external problem environments, called **application scenarios**, under which we want to solve our problem. For simplicity, we are assuming that belief predicates are non-defeasible and hence their rules in the background theory are not prioritized.

When we are solving an application problem, we consider specific cases of application scenarios. Solutions to problems are then given through the admissible arguments of the given application argumentation theory extended with the application scenario of interest.

Definition 2. *Let* T *be an application argumentation theory and* S *an application scenario. Then a ground literal,* L*, is* ***credulously supported*** *by* T *under* S *iff there exists an admissible argument in* T'*, obtained from* T *by extending its background theory by* S*, that derives* L*. We say that* L *is* ***sceptically supported*** *by* T *under* S *iff it is credulously supported by* T *under* S *and all complements of* L *are not credulously supported by* T *under* S*. When the literal* L *refers to an option predicate then we will also say that* L *is a* ***credulous solution*** *or* ***sceptical solution*** *under* S*.*

Given the above theoretical notions of argumentation the link with conflict resolution problems rests on being able to capture the decision making process of the decision makers in the conflict in terms of argumentation theories expressing the options and, importantly, the preferences of the decision maker according to the high-level **values** that each decision maker has at the time of the conflict. These values may change as the resolution process unfolds. The main challenge in this, is, indeed, to be able to capture the high-level preferences of the decision makers, expressed in a natural manner by the decision makers (who are generally non-computing experts), in an executable argumentation theory. This theory should automate the preference-based decision making of the parties through the argumentative reasoning in them. Hence, the challenge is to cognitively and transparently extract the various options and preferences of the decision makers into rules and priorities, of the form given above, in an argumentation theory that automates the decision making.

3 The *SoDA* methodology

We will now present *SoDA*, a general software methodology for developing application software whose outputted source code is an argumentation theory for the problem at hand. This methodology defines a high level process requiring from the developer to consider questions about the requirements of the problem at various scenarios without

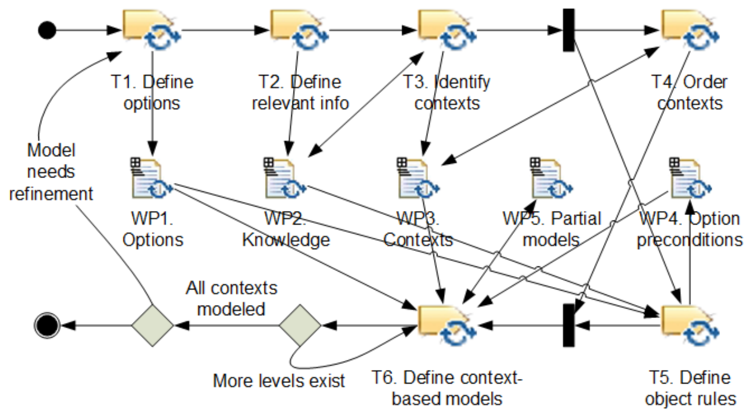

Fig. 1. The *SoDA* process

the need to consider the underlying software code that will be generated. Software is thus developed in a principled way with high-level declarative executable code.

Software development processes can be defined in a standard way by using the SPEM (Software Process Engineering Metamodel) 2.0 language[4]. A Software Process can be defined as a series of tasks (or activities) that produce Work Products (WPs). Work products can be textual models, which can be completely free (free text) or follow some specifications or grammar (a structured work product).

When drawing software processes in SPEM, each process contains yellow coloured tasks (or activities) connected with arrows showing flow of control. A black dot shows where the process starts and a black dot in a circle where it ends. A small black orthogonal can be used to fork control to more than one paths (that can be followed in parallel) or merge previously forked control. An activity has input and output work products. An arrow from an activity to a work product means that the product is created (or updated) by the activity. An arrow from a work product to an activity means that the product is an input to the activity.

Figure 1 presents the ***SoDA* process**. Let us explain the different tasks (T) and their input and output work products (WP):

T1: This task defines the different **options** of the application problem, given in predicate format with all the relevant parameters. The **conflict relation** between options is also defined here. For example, the option to deny access or to give partial access to a file is conflicting with the option to give full access. All this information is written in work product one (WP1).

T2: The second task is a knowledge engineering task required to identify the knowledge needed in order to describe the different application environments which can arise in the application problem domain. This knowledge is written in WP2 in the form of various **belief predicates**. WP2 also contains predicates that are used to type all object parameters of the problem that appear in the option and belief

[4] SPEM is a standard for defining software processes, http://www.omg.org/spec/SPEM/2.0/

predicates. Moreover, we define any background interrelationships that might exist amongst the belief predicates generating the **background theory**[5], which are also inserted into WP2.

T3: This task aims to separate the information in WP2 into two types: information that always exists for all instances of the problem and information that is **circumstantial**, which may be present in all instances of the problem. Circumstantial predicates are removed from WP2 and inserted in WP3. The next two tasks can be executed in parallel (T4 and T5)

T4: This task aims to sort the circumstantial information (predicates or groups of predicates) from the more general to the more specific application **contexts** in levels, starting from level one (more general contexts). Independent contexts (i.e. when the one is not a refinement of the other) can appear at the same level

T5: The four previous tasks were preparatory. This task begins the process of capturing the application requirements. It aims to define for each option, O_i, the different problem environments, i.e. the sets of **preconditions**, C_i, in terms of non-circumstantial predicates appearing in WP2, where the **option is possible**. Its output, WP4, contains all such sets of preconditions. Care must be taken to ensure that the parameters of the options are typed in the preconditions. It is possible for options, to be always possible, in which case they have the (only) precondition, $\{true\}$.

T6: This final task iteratively defines sequences of increasingly more specific **partial models or scenarios** of the world (stored in WP5) and considers how options might win over others. This starts with information from WP4 to precondition the world and iterates getting each time contextual information from the next level in WP3. At each **level** of iteration it defines which option is stronger over another under the more specific contextual information. In the final iteration, the winning options (if they exist) for each partial model are defined without extra information

4 Applying *SoDA* for the USA-CHINA plane collision negotiation

In this section we consider an example of conflict resolution, presented in [16], concerning the United States-China plane collision negotiation, in order to illustrate the suitability of our argumentation based approach for conflict analysis and resolution problems.

This conflict problem is described in [16] as follows, quoting directly from this paper:

> On April 1, 2000 an American surveillance plane and a Chinese fighter plane collided about 70 miles off the coast of China. China considers its airspace to extend 200 miles off its coast; international agreements specify 12 miles. The Chinese pilot parachuted out of his aircraft but was presumed dead; his

[5] For simplicity we will assume that the background theory is monotonic, i.e. contains strict information that is not defeasible. Otherwise, the same process needs to be followed for the defeasible belief predicates in analogy with the process for the option predicates that we are describing here.

> body was not found. The U.S. plane made as emergency landing at a Chinese military airfield on the island of Hainan without receiving China's permission. China thus had possession of the U.S. plane and crew. China said that the U.S. was responsible for the crash and should "apologize" and call off future surveillance flights. The U.S. expressed "regret" mentioning specifically regret that the Chinese pilot had died, but declared it had no apology to give as the fault lay with the Chinese pilot. After a while, the U.S. used the words "sorry" and then "very sorry" that can convey more emotion in referring to the loss of the Chinese pilot and the landing at the Chinese airfield without permission, but China still insisted on an apology.

So USA and China disagreed on the control action that should express the reconciliation statement. For satisfying the common goal "saving face", the pair "apology/dao qian" that was asked by China was rejected by USA while the pair "regret/yihan" that could be accepted by USA was rejected by China. Then, to these two alternatives the author in [16] added two other alternatives namely "regret/bao qian" and "apology/bao qian". He supported these two options by explaining that:

> A situation merits that a party A apologize to a party B for specific actions would appear to involve: (1) standards or norms and (2) departures from standards caused by actions of party A resulting in negative effects to party B. Because of disagreement about standards, departures, actions, causes and negative effects, any USA reconciliation statement, as expressed in both English and Chinese, had to be flexible enough for each side to interpret the statement as acceptable, i.e. for China the statement serving as a U.S. apology and for the USA as not constituting apology, a vacuous apology from the U.S.

The author explained in [16] how his suggestions reached the U.S. authorities. Subsequently, on April 11, an agreement between the U.S. and China was announced (for more details the reader can refer to [16]). In the agreement, the English version of the U.S. statement used the word "regret" (China droped its demand for apology), while the Chinese version of the U.S. statement used the word "bao qian" (expressing apology).

We will now use *SoDA* to model this conflict reconciliation problem by representing the possible decision policies of both USA and China as argumentation theories. In the following, we will use the above explanation of the author in order to model the USA and China argumentation theories that should capture this conflicting situation and its resolution. For this reason, we will first use the predicate $goal(saving\_face)$ for representing the common goal "saving face" of two parties. Then, we will use the predicate $violation\_of\_norms$ for representing the presumed by China violation of its airspace by the USA pilot, as China considers that its airspace is extended to 200 miles off its coast. Finally, we will use the predicate $disagreement\_on\_violation$ for representing the disagreement between USA and China on this Chinese consideration as international agreements specify 12 miles as the official airspace off a country's coast. We consider that these predicates represent the shared knowledge by both parties.

During the first task, T1, we identify the different options available in WP1. For the USA decision theory we have the three **options**:

propose*(regret_yihan)*

propose*(regret_bao qian)*
propose*(apology_bao qian)*

In task T2, we identify scenario information which is needed for the options to be enabled for possible consideration, and, during T3, we identify relevant circumstantial information and sort it in levels (from general to specific). In our example, WP2 can be considered empty, i.e. all three options are enabled from the start and constitute possible options, while WP3 would contain:

Level 1: *goal*(*saving_face*), *violation_of_norms*
Level 2: *disagreement_on_violation* (or *violation_in_special_circumstances*)

Note that these contexts are ranked from the more general to the most specific. For a more specific context to be valid, the previous level context must also be valid. Otherwise, they are independent contexts appearing at the same level. For example, if there is a *violation_of_norms* (level 1 context), there ***may*** be a *disagreement_on_violation* (level 2, more specific, context). The *goal*(*saving_face*) and *violation_of_norms* are independent contexts (thus are ranked at the same level).

In the next task, T5, we define, based on WP2, the different object level arguments that support each option by specifying the (eventual) preconditions from WP2 that must be satisfied for the option to be possible for consideration. Thus, in the case of the USA theory, as WP2 is empty, we have the following object level arguments for the three options:

Option 1: propose(regret_yihan) : true
Option 2: propose(regret_bao qian) : true
Option 3: propose(apology_bao qian) : true

Then, in WP5 we consider partial models as possible world models showing the various possibilities for the options as the model/world is extended with new (contextual) information according to the refinement levels in WP3. In these models we specify which of the (enabled) options can be possible, i.e. are (possibly) preferred over the other options. Note that these models are non-monotonic in the sense that as we refine the scenario conditions options may be dropped, i.e. options lose their preference over others.

In our example, following the analysis of [16], we have:

M1: {goal(saving_face)} : propose(regret_yihan); propose(regret_bao qian)
M2: {violation_of_norms} : propose(apology_bao qian)
M3: {goal(saving_face), violation_of_norms, disagreement_on_violation} : propose(regret_bao qian)

These express the following preferences on the options, from the USA point of view:

M1: Generally, prefer options that would serve the goal of "saving face".
M2: If we (USA) violate some norms then we would prefer options that are not "face saving", i.e. of apologizing as we (USA) have violated international standards.
M3: If we (USA) consider that there is no departure from the international standards, then we would prefer options that serve the goal of "saving face".

We will now consider how we can capture, through the *SoDA* methodology,the decision theory for China, following again the analysis of [16]. China has three possible options corresponding to possibly accepting the three proposals of USA. These are:

accept*(regret_yihan)*
accept*(regret_bao qian)*
accept*(apology_bao qian)*

As with the case of USA, we can consider that all these options are enabled, i.e. WP2 is empty, meaning that the object-level arguments for each of these options do not need any preconditions.

Hence for China the different options are the following:

Option 1: accept(regret_yihan) : true
Option 2: accept(regret_bao qian) : true
Option 3: accept(apology_bao qian) : true

Then, considering the application scenarios we identify in WP3 relevant circumstantial information and sort it in levels (from general to specific). Based on this we identify partial models that express the preferred options as the scenarios are made more specific. Following the analysis in [16] we may assume that China has the following preferences:

M1: Generally, prefer options that would serve the goal of "saving face" for China.
M2: If the other party (USA) violates some norms then we (China) would prefer options that are "face saving" in China i.e. the other party (USA) apologizing in China and in USA.
M3: If there is a disagreement on the violation of norms, we (China) can also accept the weaker option of USA expressing regret in USA but apologizing in China.

Then based on this the partial models generated in WP5 for the China theory are as follows:

M1: $\{$*goal(saving_face)*$\}$ *: accept(apology_bao qian); accept(regret_bao qian)*
M2: $\{violation\_of\_norms\}$ *: accept(apology_bao qian)*
M3: $\{$*goal(saving_face), violation_of_norms, disagreement_on_violation*$\}$ *: accept(regret_bao qian); accept(apology_bao qian)*

Note here that the condition *goal*(*saving_face*) is different from the analogous condition in the USA theory, referring now to China saving face. The other two conditions can be taken as being common to both theories.

4.1 Argumentation theories for USA and China

The specification for our real world case scenario modeled with the *SoDA* methodology, as analyzed above, is automatically translated into the following argumentation theories. Note that we restrict the attention here to the two options that according to [16] have been mainly considered for the final decision, namely *propose*(*regret_bao qian*) and *propose*(*apology_bao qian*).

For USA we have the argumentation theory:

$r_{1\_1} : propose(regret\_baoqian) \leftarrow true$
$r_{2\_1} : propose(apology\_baoqian) \leftarrow true$
$pr^1_{12\_1} : h\_p(r_{1\_1}, r_{2\_1}) \leftarrow goal(saving\_face)$
$pr^1_{21\_1} : h\_p(r_{2\_1}, r_{1\_1}) \leftarrow violation\_of\_norms$
$pr^2_{12\_1} : h\_p(pr^1_{12\_1}, pr^1_{21\_1}) \leftarrow disagreement\_on\_violation$

and for China we have the argumentation theory[6]:

$r_{1\_1} : accept(regret\_baoqian)) \leftarrow true$
$r_{2\_1} : accept(apology\_baoqian) \leftarrow true$
$pr^1_{21\_1} : h\_p(r_{2\_1}, r_{1\_1}) \leftarrow violation\_of\_norms$
$pr^1_{12\_1} : h\_p(r_{1\_1}, r_{2\_1}) \leftarrow violation\_of\_norms, disagreement\_on\_violation$

Then, under these two argumentation theories, as decision theories for the respective parties of USA and China in the final (negotiation) scenario where all conditions of, $\{goal^{USA}(saving\_face)$, $goal^{China}(saving\_face)$, $violation\_of\_norms$, $disagreement\_on\_violation\}$, hold, we get that the option $propose(regret\_baoqian)$ is sceptically entailed by the USA theory and $accept(regret\_baoqian)$ is credulously entailed by the China theory. Therefore, a resolution of the conflict can be reached with the action $regret\_baoqian$.

4.2 Conflict Resolution in Argumentation

We will now discuss how the treatment of the above case study example points towards a general way to capture conflict resolution problems within the preference based argumentation framework on which the *SoDA* argumentation software methodology is based. This is a preliminary investigation which merits further study, as we will discuss in the concluding section.

We will be concerned mainly with the conceptualization of the high-level general structure of the problem as followed by most approaches to conflict resolution (see e.g. [7, 15]). In the standard conceptualization of the problem we have a situation in which each one of two parties has a set of options or actions that it can carry out and wants to decide which option to adopt. The problem of conflict resolution, as a decision problem for the two parties involved, can be abstracted to have the following general form.

Definition 3 (Conflict Resolution Problem). *A conflict resolution problem consists of two parties, each of which has a decision theory D_1 and D_2 for selecting options from the set of (contradictory) problem options, $\{p_1, p_2, m_1, ..., m_k\}$, in any given state of the environment in which the problem is situated. Initially, option p_1 is the preferred option under D_1 for the first party and option p_2 is the preferred option under D_2 for*

[6] Note that the condition $goal(saving\_face)$ does not appear in this fragment of the China theory as this condition only plays a role in the default preference of the all the options over the first option of $accept(regret\_yihan)$ which we are not considered in this fragment.

the second (other) party. None of the other options, m_i *is preferred by either party in the initial state of the problem environment. The task is to find an option* m *amongst all possible options such that this is preferred under both* D_1 *and* D_2 *in possibly a new state of the problem environment.*

For simplicity of presentation, we will assume that there is only one middle position "*m*". In practice, there will be several middle options coming about as the process of resolution unfolds.

We see that the important ontological aspect of this definition is to capture the notion of **preferred option** under the decision theory of a party. This notion needs to be sensitive to the changing information in the problem environment as the negotiation process unfolds. We will now examine how argumentation can provide this kind of preference notion in a natural way.

In our example above $p_1 = regret\_yihan$ is the preferred option for USA, $p_2 = apology\_baoqian$ is the preferred option for China, and $m = regret\_baoqian$ is a possible middle position, on which they eventually resolve the conflict.

There are three central aspects of the general structure of problem of conflict resolution that we need to consider in a formalization of the problem in argumentation. These are:

- Capture the preferences that each party has for the various options based on the goals and/or desired values that each option (currently) serves for each party.
- Capture the special circumstances, normally arising through a negotiation process, that can affect or even overturn the general value-based preferences of a party.
- Formalize the notion of a **solution** to a conflict resolution problem in terms of the semantic notions of argumentation.

Let us consider these in turn. For the first aspect we note that we can associate to each option a value under some **valuation function** for each party. The valuation function could be based on a dominant value that the party is interested in, as in the case above, where for both the USA and China there is a dominant value of "saving face". As analyzed in [16], USA and China assign value 1 or 0 to the various options of the problem according to the degree that the option "saves face" for their country. Hence, the option $p_1 = regret\_yihan$ has value 1 for USA but value 0 for China, whereas the option $p_2 = apology\_baoqian$ has value 0 for USA and 1 for China.

The default preferences are then easily captured by preferring options whose valuation is higher over others whoe valuation is lower. This will provide to the argumentation theory first-level priority rules of the schematic form:

$$pr^1_{ij\_1} : h\_p(r_{i\_1}, r_{j\_1}) \leftarrow value(O_i, V_i), value(O_j, V_j), V_i \sqsupset V_j$$

where the valuation function, $value(Option, Value)$, and the order relation, $\sqsupset$, on the possible values, are defined (non-defeasibly) in the associated background theory of each party. Note that values do not need to be arithmetic and the order relation could in general be a partial multi-criteria one.

In the USA-China case example described above, we can see these default priority rules in a compiled form where, for example in the USA theory, the priority rule:

$$pr^1_{12\_1} : h\_p(r_{1\_1}, r_{2\_1}) \leftarrow goal(saving\_face)$$

is a compiled case of the general schema above as the condition $goal(saving\_face)$ captures the higher value, 1, given to the preferred option of $regret\_baoqian$.

The second aspect of formalizing conflict resolution through argumentation concerns the ability of the argumentation theory to capture exceptional circumstances of the problem environment, i.e. exceptional states, where the default value-based preferences are changed, possibly overturned. The argumentation framework adopted in this paper is well suited for such exceptions to default preferences (see [11]) by having its priority rules being conditional and by allowing higher-order priority rules, i.e. priorities over priorities, amounting to allowing statements that make the preferences vary as the information that we have about the problem case at hand changes.

We can see a case of this in the USA argumentation theory above with the following two priority rules in its theory:

$$pr^1_{21\_1} : h\_p(r_{2\_1}, r_{1\_1}) \leftarrow violation\_of\_norms$$
$$pr^2_{12\_1} : h\_p(pr^1_{12\_1}, pr^1_{21\_1}) \leftarrow disagreement\_on\_violation$$

where the first of these says that under its condition the option p_2 of apologizing is (possibly) preferred over the regret option, p_1, thus mitigating the default valued based preference which is in the opposite way (note that this alone does not overturn completely the default preference the other way but simply that it allows the apologizing option to be acceptable by the party). Then the second of these rules, which is a higher-order priority rule, has the effect of overturning this possibility and preferring the saving face option p_1, when $disagreement\_on\_violation$ also holds in the problem's environment.

The third aspect of formally capturing what is meant by a resolution or a solution to a conflict resolution problem in the argumentation formulation of the problem is given by the following definition.

Definition 4 (Conflict Resolution Solution(S)). *Let a conflict resolution problem between two parties D_1 and D_2 be given with options $\{p_1, p_2, m\}$. Then a **satisfactory resolution** of the problem, is reached in a state S of the problem environment when both argumentation theories, $D_1 \cup S$ and $D_2 \cup S$, corresponding to the two parties, credulously support the same option from the given set. We say that an **ideal resolution** is reached when $D_1 \cup S$ and $D_2 \cup S$, sceptically support the same option.*

In the example above, the resolution reached via the $m = regret\_baoqian$ middle option is a satisfactory resolution, but not an ideal one, as this option is only credulously supported by the China theory.

Note that the above definition allows for the solution of the conflict to be reached via any of the three options. In practice, it will be the middle option that would be reached as the common option decided by both parties. But, it is possible that in some cases the

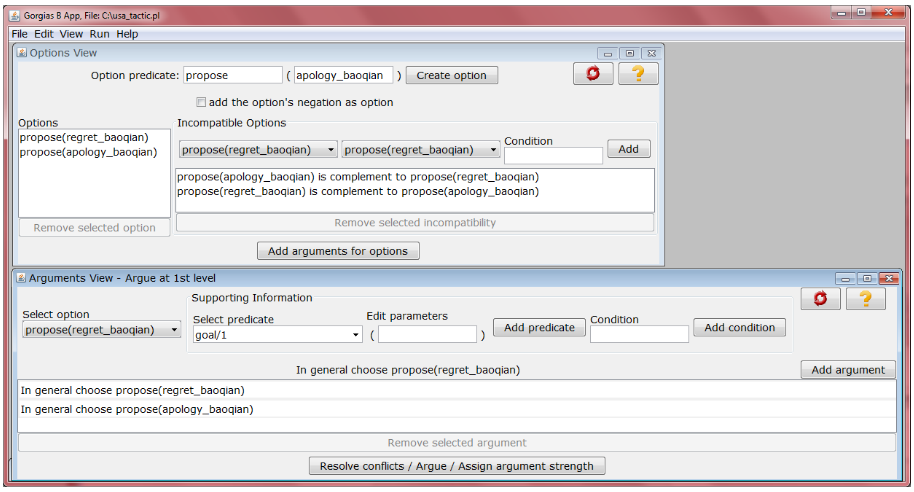

Fig. 2. A *Gorgias-B* screenshot showing the options view on top of the arguments view

reconciliation can come from an original position of one of the parties, i.e. when one party eventually manages to convince the other party of its position.

5 Solving the USA-China conflict with *Gorgias-B*

Herein we demonstrate the usage of the *Gorgias-B* tool[7] for developing the USA-China plane collision conflict decision policy for the USA. *Gorgias-B* supports the *SoDA* methodology and automatically generates the source code in the form of an application argumentation theory in the *Gorgias* framework.

When the user starts a new project in the *Gorgias-B* tool, a dialog prompts the user to enter the application options (see the *Options View* in Figure 2). The user inserts the option predicates and their conflicts (corresponding to WP1 of the *SoDA* methodology). The user can also insert background knowledge in similar views (WP2 and WP3). From the *Options View*, with the "Add arguments for options" button the user can edit preconditions (WP4) for options in the *Argument View* (Figure 2). This is how the user is building the (object-level) arguments for the various options.

The *Argue View* appears as soon as the user clicks the "Resolve conflicts" button. Here the user selects among scenarios with conflicting options more specialized cases (if they exist) where an option is preferred over another. When such specialized cases exist for both conflicting options, they are combined to a new more specific scenario and the user can then repeat the same process in the next level, which is always visible at the top of the dialog window.

[7] *Gorgias-B* is a Java application with a Graphical User Interface (GUI) that is freely downloadable from its web-site and can execute in a computer with the minimum requirements of a Windows OS, SWI-Prolog version 7.0 or later, and Java version 1.7 or later. Download it from http://gorgiasb.tuc.gr

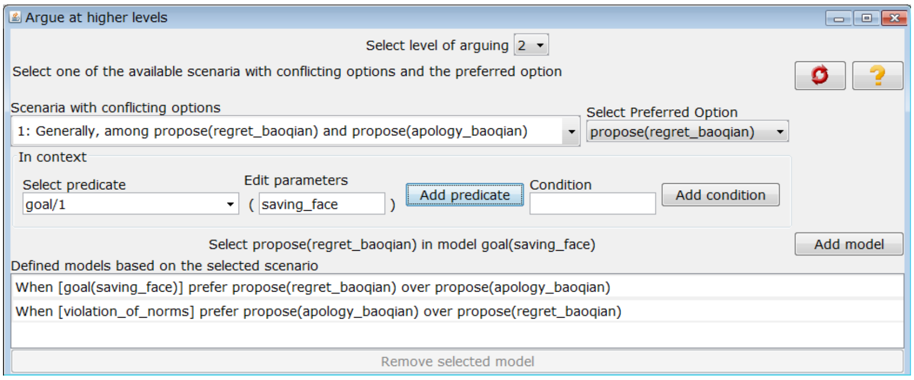

Fig. 3. An instance of the Argue view: Second level

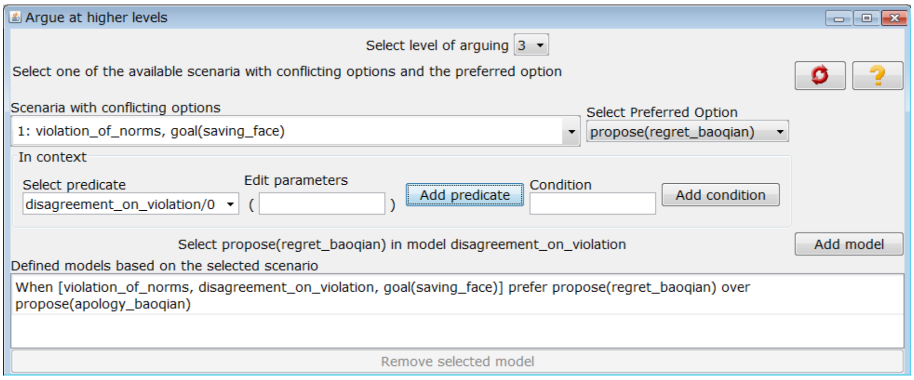

Fig. 4. Another instance of the Argue view: Third level

In Figure 3 we show the argue view at the second level, where we define two models, one that prefers *propose(regret_baoqian)* when *goal(saving_face)* and one that prefers *propose(apology_baoqian)* when *violation_of_norms*. Figure 4 shows the third level of arguing. Here, the scenario is the combination of *goal(saving_face)* and *violation_of_norms*. In this scenario we add the preference for *propose(regret_baoqian)* provided that *disagreement_on_violation*.

Finally, the decision maker can test the scenarios in the "Execute" View. He/she can instantiate as many facts as needed and then either search for specific options, or select the "Explore all options" button to see which of the options can be valid. In the case shown in Figure 5 we see that when *goal(saving_face)*, *violation_of_norms* and *disagreement_on_violation*, the only possible option (supported by *Argument #1*), a skeptical result, is *propose(regret_baoqian)*.

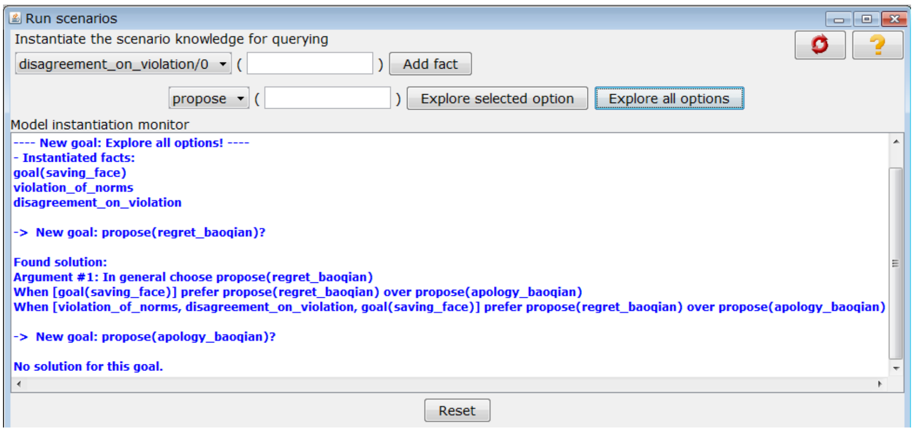

Fig. 5. The execution of a scenario for USA

6 Conclusions

We have presented an application of argumentation theory and methods from Artificial Intelligence to the problem of conflict resolution. We showed that the *SoDA* methodology, which we have briefly presented herein, helps to build in a natural way argumentation theories that can represent the decision policies of the parties involved in a conflict. We have also shown that its associated tool, namely *Gorgias-B*, allows the implementation of these theories in a transparent way, thus automating and simulating the decisions that the involved parties could/should made during the conflict resolution process.

In our future work, we aim to use techniques from the Natural Language Processing area to remove the requirement that users must be familiar with first-order logic in order to formulate their decision theories. A more natural way that allows the users to express their preferences in some structured form of natural language or graphical form will be examined. Visualizing the scenarios, contexts and options available will help us develop cognitive systems based on user decision policies. This, in turn, will help us study multi-party negotiations and how our systems can support the process of negotiation and the development of the conditions that would lead to the resolution of a given conflict.

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