Mixed-Initiative Argumentation: A Framework for Justification Management in Clinical Group Decision Support

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Abstract

This paper identifies ways in which traditional approaches to argumentation can be modified to meet the needs of practical group decision support. A framework for outcome-driven decision rationale management is proposed that permits a novel conception of mixed-initiative argumentation. The framework is evaluated in the context of group decision support in medicine.

1. Introduction

The use of argumentation for decision support is not new, with a long history of studies such as (Amgoud and Prade 2009; Amgoud and Vesic 2009; Amgoud, Dimopoulos, and Moraitis 2008; Fox et al. 2007; Amgoud and Prade 2006; Atkinson, Bench-Capon, and Modgil 2006; Rehg, McBurney, and Parsons 2005; Karacapilidis and Papadias 2001). The use of argumentation for decision support suffers from two key problems. Firstly, the background knowledge required (for instance, to determine inconsistency, or attack relations, between arguments) is often hard to come by and needs to be manually encoded (often an expensive proposition). Secondly, the bases for decision making often end up being inconsistent over a series of decisions (e.g. arguments X is preferred to argument Y in obtaining a given decision, but Y is preferred to X in obtaining the next). There is a clear need for a formal framework for the management of justifications (or rationale) in decision support. In this paper, we propose an approach to *mixed-initiative argumentation* that address these problems. Several different levels of mixed-initiative are presented in (Allen 1999). Our mixed-initiative argumentation framework falls into the "Sub-dialogue initiation". As the name suggests, the "initiative" in the problem solving process can come in equal measure from the "system" and the "user".

We present a framework that permits the interleaving of steps of the former kind (*decision generation* steps) with steps of the latter kind (*decision justification* steps). Decision generation steps involve classical argumentation, where the "winning" argument(s) are identified. Decision justification steps are more complicated, and require an "inversion" of the machinery for decision generation. The user selects the "winning" arguments, and is then prompted to *justify* the decision by updating the background knowledge that is brought to bear in decision generation. The principle of *minimal change*, that has a long history in philosophy and in AI approaches to theory change, needs to underpin this process. In devising the machinery for decision justification, we are interested in answering the following question: how might we minimally modify the argumentation system (specifically the background knowledge) in order to obtain one that would generate the (user-specified) "winning" argument(s) when used in the decision-generation mode? In the remainder of the paper, we motivate our approach by using a group decision making setting in clinical oncology, present a formal framework, and procedural basis for mixed initiative argumentation and finally describe a clinical group decision support system that implements this framework.

1.1 Motivation

Let us look at an extract from a medical group decision session taken from (Chang, Miller, and Ghose 2009). The discussion is on a patient with early stage superficial unilateral larynx cancer. The discussion involves several medical specialists (Surgeons S_1,S_2,S_3), Radiation Oncologists RT_1,RT_2) debating on the best treatment for the disease. In general, the patient's physician will have the final say. In this scenario, although the physician did not partake nor was privilege to the discussion, the ultimate decision still lies with him/her.

Disease Definition: Larynx Cancer Early Superficial Unilateral	
S_1	: (A_1) My opinion is to take out the patient's larynx. This is has the best cure rate of 99%.
S_2	: (A_2) I agree, taking out the patient's larynx would provide the best cure potential.
S_3	: (A_3) I also agree, taking out the patient's larynx would provide the best cure potential.
RT_1	: (A_4) But if taking out the patient's larynx, the patient will have no voice.
RT_1	: (A_5) However if you use radiotherapy, there is a 97% cure rate from the radiotherapy and about 97% voice quality, which is very good. The 3% who fail radiotherapy can have their larynx removed and most of these will be cured too.

Arguments A_1 … A_5 illustrates several important issues. Firstly, the need for accrual in argumentation. Within argumentation, "accrual" generally refers to the grouping of arguments to support or refute a particular opinion. It is recognised (Verheij 1995; Prakken 2005; Lucero, Chesñevar, and Simari 2009) that "accrual" of arguments is an issue that requires attention. To highlight our point, let us focus on three key arguments. A_4 forms the basis of an attack on the argument A_1. When just considering these two arguments alone, it maybe difficult to determine which course of action is the most appropriate. Now, let us consider the argument: A_1 in conjunction with the argument A_5. Again, it maybe difficult to determine which choice is a more appropriate action to take. However, when we consider all three arguments together, it is clear that the best course of action is to perform radiotherapy before taking out the patient's larynx. Secondly, the ability to strengthen arguments by repetition. To highlight our point, let us focus on the arguments: A_1, A_2, A_3. Although these three arguments do not enlighten the discussion with any additional information, it is conceivable that in a human debate situation, the number of arguments is sufficient enough to overwhelm any suggestion of the contrary. However, we are not advocating that we should always strengthen a position simply by providing multitude of identical arguments. Performing such tasks should be informed by some additional information such as source's expertise or credibility. Finally, the importance of the information sources during argumentation. If we consider the accrual of identical arguments as a reflection of the norms of a community, then it is conceivable that the first course of action would be to take out the patient's larynx. However, if the specialist RT_1 has special insight or knowledge not shared with the other specialists (e.g., the specialist is the ONLY radiation oncologist in the group), therefore might occupy a somewhat privileged position, it is then possible that the arguments made by this particular specialist may carry more weight. In this example, we motivate that the credibility of the individual presenting the argument is important. Using this notion of credibility, we can infer a preference ordering on the arguments.

S_2	: (A_6) My opinion is also that the patient should have a hemi-laryngectomy. This will give a cure rate is as good as radiation therapy.
S_3	: (A_7) I agree, performing a hemi-laryngectomy would give a cure rate as good as radiotherapy.
RT_1	: (A_8) Yes, I have performed many hemi-laryngectomies, and when I reviewed my case load, the cure rate was 97%, which is as good as that reported internationally for radiotherapy.
RT_2	: (A_9) I agree, however you fail to take into account the patient's age. Given the patient is over 75, operating on the patient is not advisable as the patient may not recover from an operation.
RT_1	: (A_{10}) Yes, however in this case, the patient's performance status is extremely good, the patient will most likely recover from an operation. (i.e. the general rule does not apply)

Arguments $A_6 \ldots A_{10}$ illustrate an interesting phenomenon. In this particular instance, the specialist RT_1 did not disagree with the correctness of the presented facts and conclusion in the argument presented by RT_2, but rather the applicability of the underlying inference rule that is used to construct the argument. This phenomenon is defined by (Pollock 1987; Prakken and Vreeswijk 2002) as "undercut". In this situation, the argument presented by RT_1 is more specific. This indicates that there exist some exceptions to the general decision rules that are context dependent and a revision on the attack relation is required.

S_2	: (A_{11}) Reviewing our past case decisions, evidence suggest that the we have always performed a hemi-laryngectomy, hence my preference is to do the same.
S_3	: (A_{12}) I agree, however, there is some new medical literature reporting that the voice quality after a hemi-laryngectomy was only 50% acceptable and the reporting institution was the North American leaders in hemi-laryngectomy, hence we should perform radiotherapy.

Arguments A_{11} and A_{12} illustrate an attack on the user preference. Similar to the previous example, attacks on the user preference are generally context sensitive and may indicate a revision on the general attack relation. These two examples illustrate that an argumentation system should evolve over time, accumulating past decision as justification for future decisions. However, it is also clear that in some instances, we wish to overrule past precedent. In most argumentation and decision support systems presented in the literature, the systems are relatively static. Most systems are open to new facts however have difficulties handling changing rules and preferences.

Furthermore, let us now assume that the patient's physician decided to perform a hemi-laryngectomy. He/She will now have to justify the decision. If we assume that the above discussion did not occur (i.e. empty knowledge base), then the physician only requires to presents arguments for the hemi-laryngectomy decision. However, if the knowledge base consists of the arguments, attack relations and preferences captured from the discussion, then the physician will be required to not only present arguments for the hemi-laryngectomy decision but also address all attack on his/her decision. One can view the sequence of interaction captured in the discussion as "decision generation" mode, if all the arguments, attack relation and preferences exists in the knowledge base (in other words, the knowledge base is complete) and we requested the argumentation system to present us with a decision. Alternatively, if the knowledge base is incomplete, erroneous or an undesired decision generated, a decision can be introduced and modification performed on the knowledge base in the "decision justification" mode.

In spite of these shortcomings, these examples reinforce the view that argumentation is a prime candidate for such a group decision support situation. In the next section, we will present an abstract mixed-initiative argumentation framework. Section 3 will present the decision generation and decision justification procedures. Section 4 will present the use of this framework in a medical group decision system. In section 5, we present the conclusions.

2. Formal Framework

Most argumentation systems generalise to that of (Dung 1995) which we use as our point of departure. However, Dung's formulation does not address preferences. It is generally accepted by (Modgil 2009; Kaci, van der Torre, and Weydert 2006; Bench-Capon 2003; Doutre, Bench-Capon, and Dunne 2005; Amgoud and Cayrol 1998; 2002; Amgoud and Parsons 2001; Amgoud 1998; Amgoud, Cayrol, and Berre 1996; Amgoud and Cayrol 1997; Kaci, van der Torre, and Weydert 2006) that preferences play an important role in an argumentation system. Recent studies such as (Bench-Capon 2003; Doutre, Bench-Capon, and Dunne 2005) recognise that the acceptability of arguments is subjective, and is contingent on agreements between the participants. Their notion of acceptability is derived from social values obtained from the participants and audience. We view these social values as the aggregated preferences from a society or community.

Definition 1 *An* ***argumentation theory*** *is a triple* $\langle AR, Conf, Pref \rangle$ *where:*

- AR *is a set of arguments* $\{\alpha_1, \ldots, \alpha_i, \ldots, \alpha_n\}$
- $Conf$ *is the conflict theory consisting of relations/assertions of the form* $conf(\alpha_i, \alpha_j)$ *where* $\alpha_i, \alpha_j \in AR$
- $Pref$ *is the preference theory consisting of non-transitive assertions of the form* $A_i \leq A_j$ *where* $A_i, A_j \subseteq AR$

Given $A_i, A_j \subseteq AR$, we will denote $A_i \leq A_j$ to mean A_i is preferred to A_j. The assertion $conf(\alpha_i, \alpha_j)$ denotes that argument α_i conflicts with argument α_j. Note that given a language L with an associated entailment relation $\models_L$, any theory T composed of sentences in L induces a consistency theory. In the absence of a background theory, such sentences need to be explicitly (user-) defined. Preference assertions are always explicitly user-defined.

Definition 2 *Given an* $AT = \langle AR, Conf, Pref \rangle$ *and a set of arguments* S, S *is an* ***extension*** *if and only if it satisfies the following:*

- *(Absences of conflict) There does not exists any argument* $\alpha_i, \alpha_j \in S$ *such that* $conf(\alpha_i, \alpha_j) \in Conf$.
- *(Admissibility) For all arguments* $\alpha_i \in S$*, if there exists an argument* $\alpha_j \in AR$ *and* $conf(\alpha_j, \alpha_i) \in Conf$ *then there exists an argument* $\alpha_k \in S$ *such that* $conf(\alpha_k, \alpha_j) \in Conf)$.
- *(Maximality) There is no set* S' *such that* $S \subset S' \subseteq AR$ *and* $S' \leq S$.

In the following section, we will use Ext_{AT} *to denote the set of all extensions of an argumentation theory* AT.

Note that the preferred extension defined in (Dung 1995) is a special case of the extension definition given above. They coincide if the preference theory is empty.

Definition 3 *Given* $\mathcal{AT}$*, the class of all argumentation theories, and* $\mathcal{AR}$*, the universe of arguments, a* ***mixed-initiative argumentation system*** *is defined as* $\langle A_{gen}, A_{just} \rangle$ *where:*

1. A_{gen} *is a* ***decision generation function*** *such that* $A_{gen} : \mathcal{AT} \longrightarrow 2^{\mathcal{AR}}$. *Intuitively,* A_{gen} *selects the "winning" extension, given that an argumentation theory may in general support multiple extensions.*
2. A_{just} *is a* ***decision justification function*** *such that* $A_{just} : \mathcal{AT} \times 2^{\mathcal{AR}} \longrightarrow \mathcal{AT}$. *Intuitively,* A_{just} *takes an argument theory* AT *and a user-specified set of arguments, and generates a revised argumentation theory* AT'*, such that the input set of arguments is the "winning" extension if* A_{gen} *were to be applied to* AT'

We use the term "winning" extension in the definition above (as opposed to "preferred" extension, for instance) mainly because our definition of an extension already incorporates the application of the preference theory. We admit the possibility of multiple extensions, hence the identification of a unique "winning" extension must involve the application of criteria (such as user choice) extraneous to those encoded in an argumentation theory. The main objective of a mixed-initiative argumentation system is to perform group decision support activities. A_{just} is used to construct the rationale for supporting a selected decision. The user-specified extension is externally provided. We will refer to the *user-specified extension* as a *decision*.

Definition 4 *Given* $AT = \langle AR, Conf, Pref \rangle$ *and a decision* S, AR *is* S***-complete*** *if and only if* $S \subseteq AR$

Definition 5 *A decision justification function* A_{just} *is a* ***conflict-modifying*** *decision justification function if and only if for every argumentation theory* $\langle AR, Conf, Pref \rangle$ *and every decision* S, $A_{just}(\langle AR, Conf, Pref \rangle, S) = \langle AR, Conf', Pref \rangle$ *where* $Conf \neq Conf'$*, provided that* AR *is* S*-complete.*

Definition 6 *A decision justification function* A_{just} *is a* ***preference-modifying*** *decision justification function if and only if for every argumentation theory* $\langle AR, Conf, Pref \rangle$ *and every decision* S, $A_{just}(\langle AR, Conf, Pref \rangle, S) = \langle AR, Conf, Pref' \rangle$ *where* $Pref \neq Pref'$*, provided that* AR *is* S*-complete.*

3. Procedure

In a mixed-initiative argumentation system, user interaction with the system over a period of time can viewed as an interaction sequence $\langle i_1, i_2, i_3, \ldots, i_n \rangle$ consisting of interleaving interactions of two types: decision generation process and decision justification steps.

We note that the definition for an extension above directly provides a decision generation procedure. A range of approaches to optimizing such a procedure are possible, but we do not consider these here due to space restrictions (however, some of these have been utilized in the implementation of the tool described later in this paper). For instances, the procedure of (Doutre and Mengin 2001) could be extended to account for a preference theory to suit our requirements.

We will now describe the decision justification process informally. During the decision justification interaction, any combination of three categories of change may occur: the addition of new arguments, the modification of the conflict theory or the modification of the preference theory. Given $AT = \langle AR, Conf, Pref \rangle$, a set of extensions Ext_{AT} generated from A and a decision S, if $\{S\} = Ext_{AT}$ then the decision justification phase terminates. Otherwise, we check if AR is S-complete. If it is not, we set $AR \leftarrow AR \cup S$. In

(Cayrol, de Saint-Cyr, and Lagasquie-Schiex 2008), the authors addressed the issue of revising the set of arguments, hence in situations where no conflict theory or preference theory revision is required, the techniques they described can be deployed.

If AR is S-complete, we determine if $S \in Ext_{AT}$. This provides useful information to assist in determining which of the two categories (conflict theory or preferences theory) of modification to perform next. If $S \in Ext_{AT}$, this informs us that a change in ordering such that there is no extension $S' \subseteq AR$ and $S' \leq S$ is in the preference theory. If $S \notin Ext_{AT}$, we modify the conflict theory to ensure that there are no cycles.

We will now present this procedure in detail. Firstly, let us focus on the modification of the preference theory. A **preference-modifying** decision justification procedure is as follows:

1. For all $A_i \in (Ext_{AT} \setminus S)$ and $A_i \leq S \in Pref$, $Pref' \leftarrow (Pref \setminus \{A_i \leq S\}) \cup \{S \leq A_i\}$

In the situation that $S \notin Ext_{AT}$, we will need to also consider the modification of the conflict theory. Given $AT = \langle AR, Conf, Pref \rangle$, Ext_{AT} and a decision S, a **conflict-modifying** decision justification procedure execute as follows:

1. Identify an extension $E \in (Ext_{AT} \setminus S)$ for which $E \cap S$ is maximal with respect to set inclusion i.e. there exists no $E' \in (Ext_{AT} \setminus S)$ such that $E \cup S \subset E' \cup S$. Note that maximality can also be defined with respect to set cardinality. This alternative intuition would leave much of our machinery unchanged, but we do not explore it any further in this paper due to space restrictions. If $E \cap S = \emptyset$, then we will need to perform the following; for all $\alpha_i \in E$ and for all $\alpha_j \in S$, if $conf(\alpha_i, \alpha_j) \in Conf$ then we set $Conf' \leftarrow (Conf \setminus \{conf(\alpha_i, \alpha_j)\}) \cup \{conf(\alpha_j, \alpha_i)\}$. If there exists many $E_i \in Ext_{AT}$ for which $E_i \cap S$ is maximal, then non-deterministically select one.

2. Determine which of the elements of $Conf$ requires modification. This can be achieved by considering a combination of the following two strategies:

   - Demoting elements of $E \setminus S$: We modify $Conf$ such that all $\alpha_i \in (E \setminus S)$ are excluded. This can be achieved by performing the following: for each $\alpha_i \in E \setminus S$, identify an $\alpha_j \in E \cap S$ such that $conf(\alpha_i, \alpha_j) \notin Conf$ and set $Conf' \leftarrow Conf \cup \{conf(\alpha_j, \alpha_i\})$. If there does not exists any $\alpha_j \in E \cap S$ such that $conf(\alpha_i, \alpha_j) \notin Conf$, then $Conf' \leftarrow (Conf \setminus \{conf(\alpha_i, \alpha_j)\}) \cup \{conf(\alpha_j, \alpha_i)\}$
   - Promoting elements of $S \setminus E$: We modify $Conf$ such that all $\alpha_i \in (S \setminus E)$ are supported. This can be achieved by performing the following: for each $\alpha_i \in E \cap S$ and $\alpha_j \in S \setminus E$, if $conf(\alpha_i, \alpha_j) \in Conf$ then $Conf' \leftarrow Conf \cup \{conf(\alpha_j, \alpha_i)\}$.

We can now apply the preference theory modification procedure or repeat the conflict theory modification procedure for all $E_i \in (Ext_{AT} \setminus S)$. Note that conflict theory modification procedure can be used (in an iterative fashion) as an alternative to preferences theory modification in the situation where $S \in Ext_{AT}$ mentioned previously.

Theorem 1 *Given $AT = \langle AR, Conf, Pref \rangle$ and a decision S such that AR is S-complete, if S is not the unique extension of AT, then there exists at least one conflict-modifying decision justification function such that S is the unique decision of $A_{just}(\langle AR, Conf, Pref \rangle, S)$*

Theorem 2 *Given $AT = \langle AR, Conf, Pref \rangle$ and a decision S such that AR is S-complete, if S is not the unique extension of AT, then there exists at least one preference-modifying decision justification function such that S is the unique decision of $A_{just}(\langle AR, Conf, Pref \rangle, S)$*

Definition 7 *Given an argumentation theory $AT = \langle AR, Conf, Pref \rangle$ and a (user-specified) decision $S \subseteq AR$, a conflict theory $Conf'$ is a minimally modified conflict theory with respect to AT and S if and only if:*

1. *S is the unique extension of $\langle AR, Conf', Pref \rangle$.*
2. *There exists no $Conf''$ such that $Conf \ominus Conf'' \subset Conf \ominus Conf'$ and S is the unique extension of $\langle AR, Conf'', Pref \rangle$. Note that $\ominus$ denotes symmetric set difference.*

Note that a minimal change to a conflict theory can also be expressed with respect to set cardinality by using $|Conf \ominus Conf''| < |Conf \ominus Conf'|$. From the definition above, we can assume that starting with $conf(\alpha_i, \alpha_j)$, both removing $conf(\alpha_i, \alpha_j)$ from $Conf$ and replacing $conf(\alpha_i, \alpha_j)$ with $conf(\alpha_j, \alpha_i)$ represents the same "quantum of change".

Definition 8 *Given an argumentation theory $AT = \langle AR, Conf, Pref \rangle$ and a (user-specified) decision $S \subseteq AR$, a preference theory $Pref'$ is a minimally modified preference theory with respect to AT and S if and only if:*

1. *S is the unique extension of $\langle AR, Conf, Pref' \rangle$.*
2. *There exists no $Pref''$ such that $Pref \ominus Pref'' \subset Pref \ominus Pref'$ and S is the unique extension of $\langle AR, Conf, Pref'' \rangle$.*

Note also that a minimal change to a preference theory can also be expressed with respect to set cardinality by using $|Pref \ominus Pref''| < |Pref \ominus Pref'|$.

Definition 9 *Given an argumentation theory $AT = \langle AR, Conf, Pref \rangle$, and a (user-specified) decision $S \subseteq AR$, $\langle AR, Conf', Pref' \rangle$ is a minimally modified argumentation theory if and only if:*

1. *S is the unique extension of $\langle AR, Conf', Pref' \rangle$*
2. *There exists no $Conf''$ and $Pref''$ such that $Conf \ominus Conf'' \subset Conf \ominus Conf'$, $Pref \ominus Pref'' \subset Pref \ominus Pref'$ and S is the unique extension $\langle AR, Conf'', Pref'' \rangle$*

Theorem 3 *Given an argumentation theory $AT = \langle AR, Conf, Pref \rangle$ and a (user-specified) decision S such that AR is S-complete and S is not the unique extension of AT, the conflict-modifying decision justification procedure generates a conflict theory $Conf'$ that is a minimally modified conflict theory with respect to AT and S. As well $\langle AR, Conf', Pref \rangle$ is a minimally modified argumentation theory with respect to AT and S.*

Theorem 4 *Given an argumentation theory $AT = \langle AR, Conf, Pref \rangle$ and a (user-specified) decision S such that AR is S-complete and S is not the unique extension of AT, the preference-modifying decision justification procedure generates a preference theory $Ponf'$ that is a minimally modified preference theory with respect to AT and S. As well $\langle AR, Conf, Pref' \rangle$ is a minimally modified argumentation theory with respect to AT and S.*

4. Medical Group Decision Support System

Following a Web 2.0 philosophy, we have constructed a web enabled medical group decision support system utilising Asynchronous JavaScript and XML (AJAX) with a back-end repository. HyperText Mark-up Language (HTML) and Javascript are used to build the user interface and controls the interaction with the web server. Hypertext Pre-processor (PHP) is used to build the reasoning engine to perform back-end computation of the arguments. MySQL is used as the database repository. The benefits of this approach are platform independence, portability, scalability and accessibility.

The prototype was presented to several medical oncologists and a "head-and-neck" session was simulated. A "head-and-neck" session is where groups of medical oncologists meet to discuss treatment therapy for cancer cases in the head to neck region. During this session, a typical larynx cancer case was discussed. Treatment analyses are performed over 6 categories. These categories (in order of importance) are as listed: survival, control, physical toxicity, psychological toxicity and clinician's choice. These categories are addressed in stages starting from the most important to the least. Argumentation is performed at each stage and final recommendation is based on the accrual of all arguments over all the stages. Each stage can be viewed as a decision-making cycle where decision made affects the available choices for the next cycle. Given a case description, the system presents a possible recommendation (if one exists). Specialists are then asked if the recommendation is acceptable. If the recommendation is not acceptable, the system asks the specialist to select a recommendation and justify it with arguments, with which the system then recomputes a new recommendation. If the recommendation does not coincide, the system presents its findings and asks for more justifications. This process is iterated until the recommendation of the system coincides with the specialist's choice. In Figure 1, we present the user interface. In the left column, pertinent details of the case definition are presented. In the right column, the users are presented with a list of possible treatment recommendations appropriate for the case profile. These treatment recommendations are extensions. Figure 2, illustrates the argument modification interface. The arguments and clinician specific preferences associated with the decisions and the generic case information are retained for future reuse. Any changes require that the clinician provide the strength of the evidence and a literature references if used. In essence, by associating the argument with the treatment choice, the user has provided justification for the particular treatment. The "Aspect" column represents associated facets for each argument. There exists several facets with different level of priorities. These facets represents preferences. In Figure 3, we present the

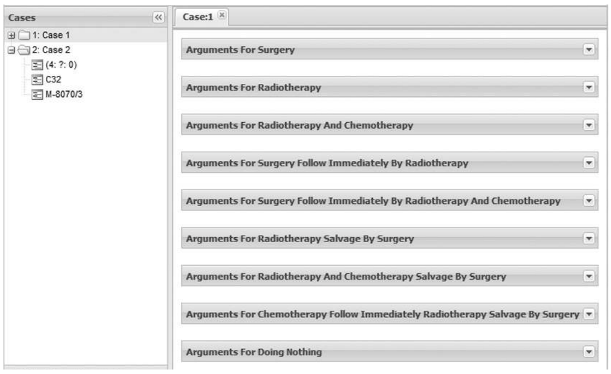

Figure 1: Treatment Choices

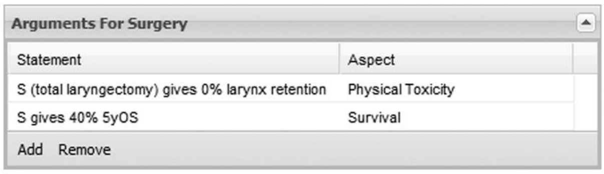

Figure 2: Arguments

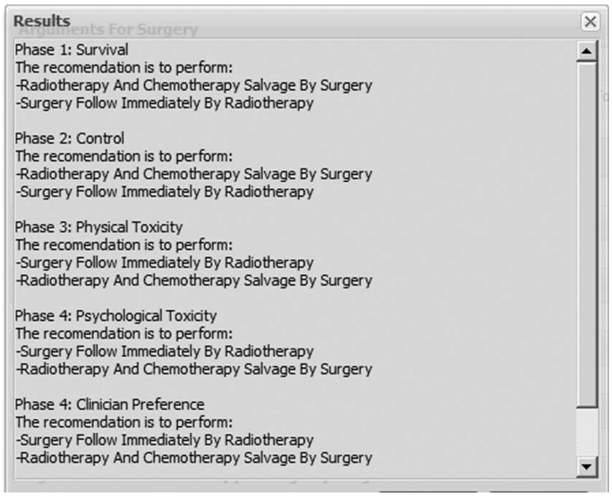

Figure 3: Recommendations

resulting output, which illustrates the recommended decision for each facet of a given sequence of decisions. Each facet has different priority (if two treatments have identical cure and control rates, the one with lower physical toxicity is preferred) and the final treatment choice is computed using these preferences.

5. Conclusion

In this paper, we have identified ways in which traditional approaches to argumentation can be modified to meet the needs of practical group decision support. We presented a framework for mixed-initiative argumentation and procedures for performing decision generation and decision justification. Finally, we presented a tool for use in the context of group decision support for medical oncology.

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