An Interactive System for Documentation and Analysis of Clinical Discussions

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Abstract. This paper gives an overview of my PhD research that aims to support the clinical decision making scenario by providing a tool that allows documenting and structuring clinical discussions in all the steps of the decision making process, by means of argumentation-based techniques. The goal is to highlight contradicting opinions, to recognize invalid reasoning steps, to discover hidden assumptions, or to identify missing evidences. Indeed, in a clinical discussion, participants make important pieces of knowledge explicit, by presenting different opinions, providing evidences that support hypotheses, and possibly arguing about clinical guidelines. However, this knowledge is often lost after the meeting is closed, since only the final decisions are written in patient records. The approach proposed in this paper aims at overcoming these limitations.

Keywords: clinical discussions, argumentation schemes, logical analysis, support system, knowledge management.

1 Introduction

Multidisciplinary clinical discussions are becoming a routine activity in hospitals and healthcare structures in general. Clinical discussions provide the forum for specialists of various medical disciplines to focus on critical cases, debate about the diagnostic hypotheses, therapeutic protocols or follow-up of patient conditions, and to devise the most appropriate treatment. Unfortunately, as witnessed by many physicians we have interviewed, most of this knowledge just exists during the discussion and is lost after the meeting is closed. Only the final decisions that determine the specific actions to perform - such as further examinations, surgical operations, or therapeutic treatments - are reported in medical records [1][2]. When a discussion is resumed after certain time, the participants hardly remember what was going on in the previous meeting; therefore, they often go through old reasoning paths without realizing they have been explored already; sometimes it can also happen that physicians reach conclusions that contradict those proposed in the former meeting.

My research aims to investigate how we can support the decision making scenario by providing a tool that allows documenting and structuring a clinical discussion in all the steps of the decision process, and monitoring and revising the decisions. In this context, the exigency arises to design an interactive computer-based tool to help physi-

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cians manage clinical discussions effectively and efficiently and to support their decision making activity. This tool could be useful for simplifying the work flow, improving the quality of healthcare service and reducing costs ; since time costs money, especially when several medical specialists are involved, it is important to keep the team meetings as short as possible, without reducing the quality of the discussion. A clinical discussion support tool should focus on two main objectives:

1. *Documentation*: it is fundamental to record and document a clinical discussion in an informal yet well structured way. The representation language adopted should account for the logical and temporal structure of a discussion, but at the same time, it should be easily understandable by physicians. Discussion documentation will serve as a memory support for the following meetings and as a justification record for the decisions made.
2. *Logical analysis*: once a discussion has been properly documented, it can then be interpreted from a logical point of view, on the basis of a set of reasoning patterns (formalized as argumentation schemes [3] in the following) that are considered valid in the specific medical domain. This analysis should be able to highlight contradicting opinions, to recognize invalid reasoning steps, to discover hidden assumptions, or to identify missing evidences.

On the basis of these objectives, we have decided to design a new interactive software tool, called ArgMED, structured in three components; the first component for the documentation of discussion; the second component for logical analysis of discussion; the third component for the creation of argumentation schemes. The paper is organized as follows: Section 2 presents background and related works; Section 3 introduces our research methodology; Section 4 and 5 describe the proposed approach; finally, Section 6 concludes the paper and outlines future research issues.

2 Background and Related Works

In order to investigate the research problem of documentation and visualization of the discussion, and the problem of analyzing the discussion, we have analyzed many existing formal and informal approaches, and tools for argument visualization and clinical decision support. Most of interactive tools are based on argumentation theory. Argumentation theory is a framework for practical and uncertain reasoning viewed as a process of arguments production and evaluation. Arguments are entities including a supported conclusion and a set of premises that represent not necessarily deductive reasons to believe the conclusion itself [4]. In general, different arguments may be in conflict, i.e. for each argument there may be one or more arguments representing its counterarguments, and the theory explicitly manages these contradictions by selecting justified arguments according to a given argumentation semantics [5].

To resolve the visualization problem several tools have been proposed in the literature. For instance, Van Gelder [6] proposes the argument map notation, a “box and arrows” diagram in which nodes correspond to claims and links indicate their evidential relationships. In the approach of Cyra and Gorski [7] an argument structure is represented as a left-to-right hierarchy (similar to file directories), which allows for effective representing, traversing, and managing large collections of arguments. Other well-

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known systems in this research area – like ArgVIS [8], Araucaria [9], Rationale [10], SEAS [11], and Carneades [12] – also provide specific diagrammatic representations of arguments; however, most of them require that the user is familiar with argumentation concepts, such as "premise", "conclusion", "counterargument", "support", "attack", and that he/she is familiar with formal reasoning systems.

In medical domain, a variety of Clinical Decision Support Systems (CDSSs) based on argumentation theory have been proposed to help medical personnel solve conflicts and deepen the motivations underlying decisions, such as: REACT [13], CAPSULE [14], CARREL [15], and CREDO [16]. These proposals provide a valid solutions to clinical decision support based on argumentation; however, they are unable to manage free clinical discussions and/or collaborative decision making. Furthermore, they are not intended to keep track of the decision making processes for subsequent assessment and revision, but rather to provide instant solutions to specific problems.

There are also several informal approaches (mainly based on ethnographic studies) that have been proposed to document and visualize clinical discussions. Frykholm and Groth [17][18] have proposed an approach to improve collaboration on, and visualization of, patient information in medical multi-disciplinary team meetings. For this purpose, they have developed a tool that presents information from different medical systems to be used as a support for the decision process. Kane and Luz [2] have proposed an approach based on a shared visual display to facilitate data entry and validation of an electronic record during multi-disciplinary team meeting discussions, where specialists discuss patient symptoms, test results, and image findings. These proposals provide valid solutions for documenting and visualizing the medical data in a structured way; however they do not provide the possibility to analyze the discussion in order to highlight contradicting opinions, recognize invalid reasoning steps, discover hidden assumptions, or identify missing evidences.

3 Research Methodology

The methodology applied in this research is composed of the following steps:

1. analysis of the current state of the art in medical contexts, with respect to: (i) existing approaches and tools for argument and visualization; (ii) existing approaches and tools for clinical decision support; (iii) informal approaches and ethnographic tools; (iv) argumentation theory and argumentation schemes;
2. analysis of real clinical discussions to understand the structure and how clinical discussions take place, and to identify a minimal set of argumentation schemes;
3. proposal of solutions to overcome the limitations of existing proposals, e.g., models and technology solutions;
4. definition of user requirements and functional requirements of the proposed system;
5. design, prototyping, and implementation of the proposed system;
6. validation of the system through user experiments;
7. refinement through iterations of the system.

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4 The Proposed Approach for Documenting Clinical Discussions

4.1 Issues and Requirements

The first issue that we have investigated, is the clinical discussion structure. For this issue, we have analyzed several real cases. A clinical discussion is usually constituted by a set of sessions (or meetings), taking place in a strict temporal sequence. Each session is based on a set of facts shared by all participants (for example, the general state of the patient, the results of clinical tests, the effects of the on-going treatment, etc. [17]) and includes all the statements asserted by the participants, expressing their personal opinions. In the discussion there are different types of participants : medical staff, such as, physicians and nurses, and a chairman (a senior specialist), is responsible for keeping the structure and discussion relevant, and for reaching a decision at the end. Each session evolves in general through three stages:

1. The session begins with the medical staff introducing the patient and providing detailed information about present and earlier diseases, subjective symptoms, and general health status. Objective observations and results of clinical tests are also reported. Such general facts and observations are assumed to be shared by all participants and are not disputable.
2. After the presentation, the participants in the meeting assert their proposals about possible diagnosis or treatment and support them through their own experience, literature cases, or clinical guidelines. During the session, participants may attack the assertions posted by colleagues or may support them.
3. At the end, participants identify a set of acceptable conclusions and then decide for one of them.

In particularly critical cases such as a difficult diagnosis, a rare pathology or a new treatment, several meetings are necessary before a valid and shared conclusion is reached, thus giving rise to an articulated clinical discussion.

The second issue about discussion documentation, is concerned with the acquisition and representation of a clinical discussion in a structured but at the same time intuitive way that can be understood and validated by the participants and serve as memory support for the following meetings. The analysis of real cases and the feedback we directly got from potential users on the represented discussions allowed us to identify some basic requirements to achieve this objective:

- Representation of a discussion according to the way the discussion has been carried out: physicians require a structured representation of a previous discussion in a way that somewhat adheres to the way the discussion has been carried out. In particular, they do not accept to structure the information according to a predefined scheme if this does not reflect the order in which information has been pointed out. For instance, if a hypothetical diagnosis has been proposed before looking for symptoms, they do not accept a discussion representation where this order is reversed, e.g. presenting the symptoms first and then a diagnosis as a possible cause.
- Free and no discussion protocol: physicians are not willing to follow any discussion protocol, but they want to feel free to participate in the discussion according to their usual habits. For instance, sometimes they want to point out all of a patient's symp-

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toms, other times they want to focus on a subset of them to identify a diagnosis, other times they tentatively reason about a diagnosis and look for the corresponding symptoms.

- No specific informative need: observations, symptoms and results of diagnostic tests are directly collected by the practitioners in charge of the clinical case at hand and more information is generally not necessary.
- No abstract representation of propositions: physicians adopt a specific medical terminology with a shared meaning, and do not accept to characterize their propositions in abstract ways, e.g. identifying a major premise or distinguishing between data and general rules.
- No willingness to make argument structure explicit: even though physicians interact by pointing out arguments and counterarguments, they are not willing to make the relevant structure explicit during the discussion, let alone conform to a predefined scheme.
- Clear and easy language: the language used to document the clinical discussion must be clear, easy to understand and specific to the medical domain.

4.2 A Sample Discussion

To illustrate our approach, we focus on a literature example concerning a breast cancer case [19]. The discussion is on a patient with localised breast cancer. The discussion involves several medical specialists (MD1, MD2, MD3) debating on the best treatment for the disease. Fig. 1 shows the transcript of a portion of the discussion session reported by Chang et al [19].

MD1(A1): Given the type of cancer, I believe that we should undertaken a lumpectomy.
MD2 (A2): Agree.
MD1 (A3): I have undertaken a lumpectomy with clear margins and an auxiliary lymph node dissection, with no positive nodes, therefore I believe that there is no need of other treatment.
MD1(A4): No radiotherapy required. Given her age, tumour size, grade, margin status, the local recurrence risk is 1.3% with radiotherapy and 4.5% without radiotherapy, and no benefit in overall survival. The local control benefit is not large enough to justify the offer of treatment.
MD2 (A5): Agree.
MD1 (A6): No chemotherapy required, her 10 year death rate will only reduce from 5% to 4% with chemotherapy and has only a small effect on the local recurrence rate (now 3.2%).
MD3 (A7): I disagree. I think she should have chemotherapy, because while the death rate is similar, her 10-year relapse rate will fall from 25% to 11% with chemotherapy, meaning there is more life without cancer.

Fig. 1. The breast cancer case.

4.3 The Clinical Documentation Tool

The part of the tool to be used for tracking and managing clinical discussions has been developed through an iterative approach, including the design of paper-based and interactive prototypes, and various interviews with representative users (students in medicine and physicians). This activity has led to define the terminology to be used in the

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system and to understand how to support the creation and modification of a discussion. The idea is structuring each discussion about a clinical case as a tree diagram, somewhat resembling the IBIS-like notation of Rationale [10], but adopting a specific medical ontology. More specifically, the tree diagram will include different kinds of nodes corresponding to the different medical concepts that physicians use during discussions (diagnosis, symptom, examination result, and so on). Each node represents a participant's statement and can be connected to any other node through an arc, graphically denoting that a relation holds between the two nodes. Therefore, users are not forced to use terms not familiar to them, such as "argument", "counterargument", "support", "attack", even though they will implicitly express such kinds of concepts and relations during tree construction.

The documentation activity can be performed by a domain expert user e.g. a member of the medical staff, in real-time during the discussion, or after the discussion, with the help of a video recording and written notes. Figure 2 shows a screenshot of the resulting system with an example (breast cancer case). Here, there are one diagnosis node and 3 hypothesis nodes. Each hypothesis is supported by motivation *pro* or attacked by motivation *con* node. For example the first hypothesis "Should surgery be performed?" is supported by the motivation "Given the type of cancer, I believe that we should undertaken a lumpectomy". In [20][21] we have explained in details our approach to the documentation of clinical discussions.

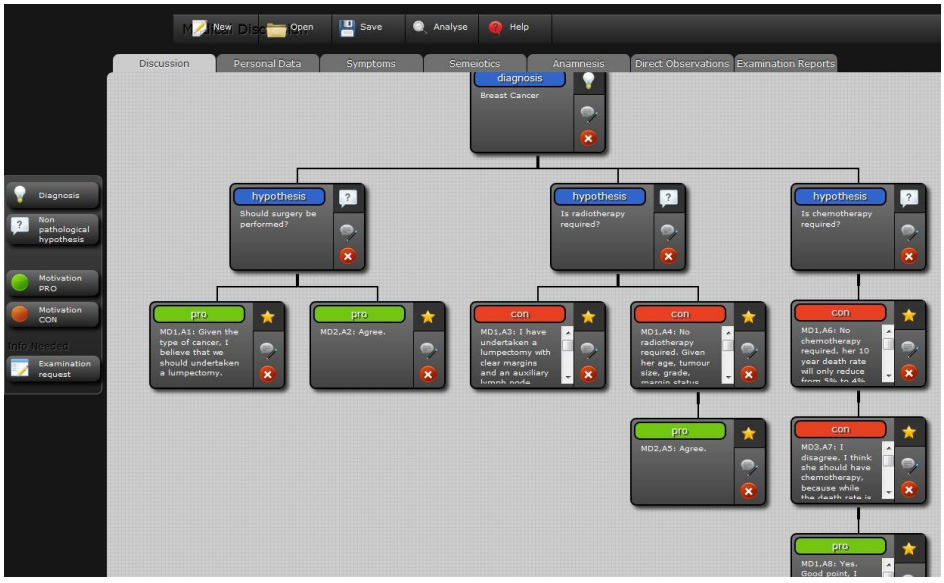

Fig. 2. The part of the tool devoted to the documentation of clinical discussions.

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5 The Proposed Approach to Logical Analysis of Clinical Discussions

After the documentation of the discussion it should then be possible to post-process this first representation and produce a more logically sound formalization including, for example, identification of missing data, need for verification activities, existence of hidden conflicting opinions, etc. In order to investigate this issue, it is useful to regard clinical discussions as argumentation processes. We have decided to rely on argumentation schemes [3], in order to translate the tree diagram representation of a discussion into a structured logical representation according to a suitable formalism.

An argumentation scheme represents a reasoning patterns consisting in the statement of a presumption in favor of a given conclusion. All argumentation schemes share the same basic structure; namely, a name, a set of premises, a conclusion, and a set of critical questions. The conclusion is considered to be true if all premises are true and all critical questions receive a positive answer (are satisfied). Critical questions are indeed intended to challenge the validity of an argument and provide a sieve to make sure that the reasoning pattern is applied in the correct way. Premises, conclusion, and critical questions contain variables that allow the instantiation of the argumentation scheme to a particular case, thus yielding an argument.

5.1 Argumentation Schemes for the Medical Domain

Walton identified twenty-five argumentation schemes in the legal field [3]. Inspired by this work, in the first phase of our research, a variety of literature case studies have been analyzed in order to identify the most frequent argumentation schemes in the medical field. We have identified a set of argumentation schemes sufficient to analyze a discussion, such as: Argument for Treatment Efficacy, Argument for Better Treatment, Argument for Treatment Risk, Argument for Risk Containment, Argument for Preference from Side Effects, Argument from Medical Expert Opinion (see [22] for more details). Figure 3 shows an example of argumentation scheme.

Argumentation schemes must result from a deep knowledge acquisition activity, where knowledge engineers and domain experts work together to define the set of accepted reasoning patterns. To support this task an editor of argumentation schemes (see fig. 4) has been developed, which allows easy manipulation of the components of an argumentation scheme and supports the definition of an argument-relation graph used to define the relations among argumentation schemes.

Argument from Medical Expert Opinion (AMEO)

Variables: Physicians <PH1, PH2, PH3, ... >, Domain <DOM>, Assertion <A>.

Premise 1: Physicians <PH1, PH2, PH3, ...> are specialists in domain <DOM>.

Premise 2: Physicians <PH1, PH2, PH3, ...> assert <A>.

Conclusion: <A>.

CQ1: Is <A> inconsistent with other experts' assertions?

CQ2: Is <A> inconsistent with recent studies?

CQ3: Is there no evidence that substantiates assertion <A>?

CQ4: Is the assertion <A> not in domain <DOM>?

Fig. 3. An example of argumentation scheme for the medical domain.

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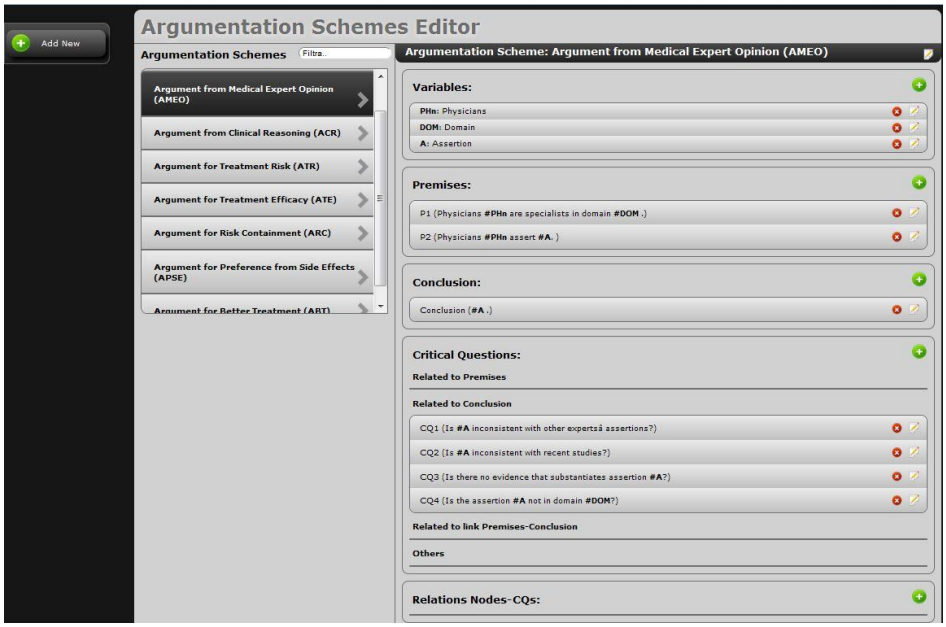

Fig. 4. The editor of argumentation schemes.

5.2 The Clinical Discussion Logical Analysis Tool

Discussion analysis consists in the iteration of two interrelated activities:

- A discussion statement is examined and a suitable argumentation scheme is selected for its formal representation. The argumentation scheme is then instantiated into an actual argument by substituting variable terms with the corresponding linguistic items extracted from the statements being considered. Arguments are stored in a data base compatible with the Argument Interchange Format (AIFdb) [23].
- After instantiation, critical questions are considered. If all of them receive a negative answer (answered with no), then the conclusion is assumed to be true. If one question receives a positive answer (answered with yes), then the system, on the basis of the argument-relation graph inserted through the editor of argumentation schemes, instantiates another argumentation scheme, giving arise to a new argument that attacks the previous one. Questions that remain open - and therefore denote possible lacks or bugs in the logical structure of the discussion - will be proposed to the experts in the next discussion.

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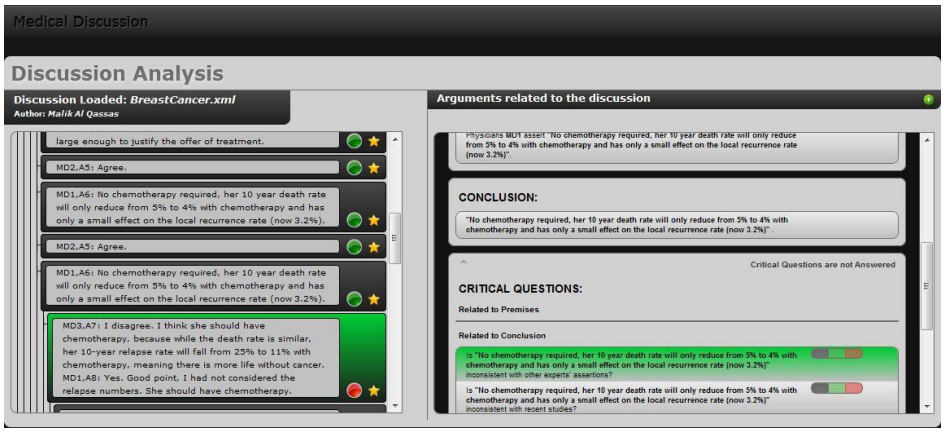

Fig. 5. The part of the tool devoted to the analysis of clinical discussions.

5.3 Discussion Analysis through Argumentation Schemes: An example

After the documentation of the discussion using the first component (see Fig. 2), the user can analyze the discussion. Figure 5 shows a screenshot of the part of the tool devoted to the analysis of a discussion. Here, each archived discussion is visualized as a multi-level list in the left part of the screen and the user may create a set of arguments related to the discussion by means of argumentation schemes, which will be visualized, one at a time, in the right part of the screen.

When the user creates a new argument by selecting the button "New Argument", a popup window will be activated (see Fig. 6) asking him/her the argument name, to select the type of argument, the relation type, and related argument (if it exists). There are 3 types of relation: attack, support and neutral.

In our case, considering for example the statement A6 "No chemotherapy required, her 10 year death rate will only reduce from 5% to 4% with chemotherapy and has only a small effect on the local recurrence rate (now 3.2%)", the user has selected the argumentation scheme "Argument from Medical Expert Opinion" (see Figure 3), with the purpose of instantiating a new argument. To this end, the user has selected the attack type. The new argument attacks the argument related to the hypothesis "Is chemotherapy required?". After that, the user can instantiate premises by associating them with propositions appearing in the beginning of the discussion, so the variables <PHn> assumes the value "MD1", <DOM> assumes the value "chemotherapy" and <A> assumes the value "No chemotherapy required, her 10 year death rate will only reduce from 5% to 4% with chemotherapy and has only a small effect on the local recurrence rate (now 3.2%)". As a consequence, also the conclusion and critical questions are instantiated. Moreover, each premise can be connected by the user to the discussion statements that refer to the premise itself, and the same can be done for the conclusion and critical questions. In the case at hand, the user links the conclusion of the new argument to the statement A6, and the first critical question ("Is "No chemotherapy required, her 10 year death rate will only reduce from 5% to 4% with chemotherapy and has only a small effect on the local recurrence rate (now 3.2%)" inconsistent with other experts' assertions?") to the statement A7 ("I disagree. I think she should have chemo-

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therapy, because while the death rate is similar, her 10-year relapse rate will fall from 25% to 11% with chemotherapy, meaning there is more life without cancer").

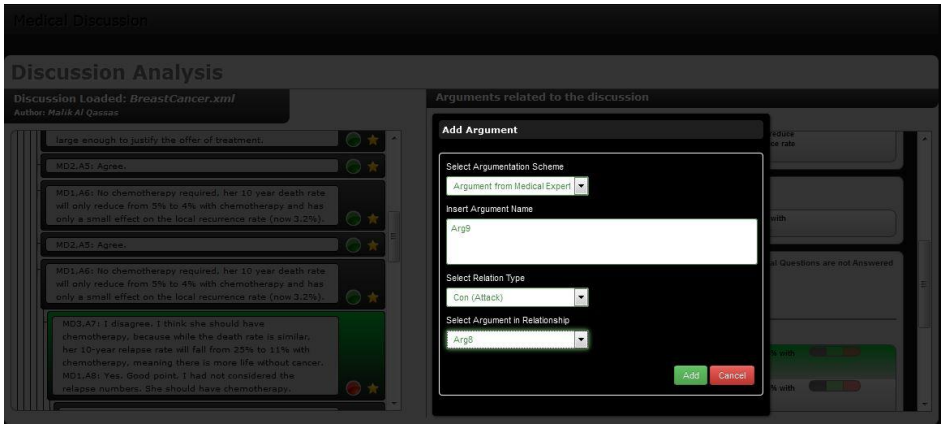

Fig. 6. The user is creating an argument by instantiating an argumentation scheme.

After the linkage of the critical question to a discussion statement, the user can answer it with a positive or negative answer. In the case at hand, the first critical question received a positive answer. Then the system, on the basis of the argument-relation graph, instantiates another argumentation scheme (type of "Argument from Medical Expert Opinion"), giving arise to a new argument that attacks the previous one. This means that the new argument (related to the statement A7) attacks the argument related to the statement A6. After that, the user can instantiate the variables of the new argument with suitable values. The variables <PHn> assumes the value "MD3", <DOM> assumes the value "chemotherapy" and <A> assumes the value "she should have chemotherapy, because while the death rate is similar, her 10-year relapse rate will fall from 25% to 11% with chemotherapy, meaning there is more life without cancer".

Considering the statement A8 "Yes. Good point, I had not considered the relapse numbers. She should have chemotherapy", the user may create a new argument. To this end, the user selects the support type. The new argument supports the argument related to the statement A7.

Doing the same thing to all statements will give rise to a set of arguments (Arg1, Arg2,...,Arg11). On the basis of the set of arguments created, the system is able to create the argument graph. In case at hand, the resulting graph is shown in Fig. 7. This graph can be processed by a standard conflict resolution algorithm to determine the set of arguments (corresponding to physicians' assertions) that, according to a specific argumentation semantics [5], can be considered as justified. In this case, it turns out that according to the relevant conclusions of arguments Arg2 and Arg10, which are justified, lumpectomy should be performed followed by chemotherapy.

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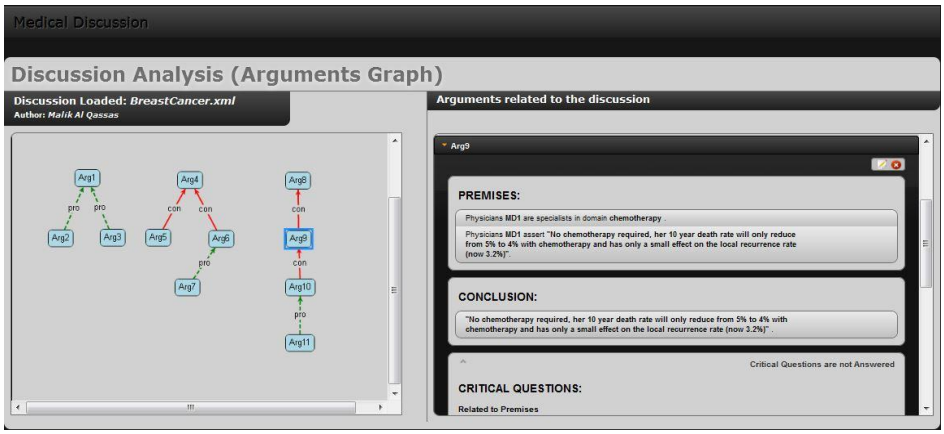

Fig. 7: The argument graph representing the discussion example.

6 Conclusions

In this paper, we have presented our approach to support clinical discussions based on argumentation schemes. We are currently completing the development of the interactive system ArgMED, in order to better investigate the visualization and human-computer interaction aspects of the tool. In particular future work will be focused on the experimentation of our tool and the validation of the identified argumentation schemes with physicians, and on the definition of new argumentation schemes from other discussions. The experimentation will mainly consist in two activities: the participation in several meetings in the hospital ward to collect data and formalize further argumentation schemes, and the experimentation of the system with medical staff to gather information about the usefulness and usability system.

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