Web-based collaboration and decision making support: A multi-disciplinary approach

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Abstract: *Arguing that a varying level of formality needs to be offered in systems supporting argumentative collaboration, this paper proposes an incremental formalization approach that has been adopted in the development of CoPe_it!, a web-based tool that complies with collaborative principles and practices, and provides members of communities engaged in argumentative discussions and decision making processes with the appropriate means to collaborate towards the solution of diverse issues. According to the proposed approach, incremental formalization can be achieved through the consideration of alternative projections of a collaborative workspace.*

1. Introduction

Designing software systems that can adequately address users' needs to express, share, interpret and reason about knowledge during a session of argumentative collaboration has been a major research and development activity for more than twenty years (de Moor and Aakhus, 2006). Designing, building, and experimenting with specialized argumentation and decision rationale support systems has resulted to a series of argument visualization approaches. Technologies supporting argumentative collaboration usually provide the means for discussion structuring, sharing of documents, and user administration. They support argumentative collaboration at various levels and have been tested through diverse user groups and contexts. Furthermore, they aim at exploring argumentation as a means to establish a common ground between diverse stakeholders, to understand positions on issues, to surface assumptions and criteria, and to collectively construct consensus (Jonassen and Carr, 2000).

When engaged in the use of these technologies, through a software system supporting argumentative collaboration, users have to follow a specific formalism. More specifically, their interaction is regulated by procedures that prescribe and - at the same time - constrain their work. This may refer to both the system-supported actions a user may perform (types of discourse or collaboration acts), and the system-supported types of argumentative collaboration objects (e.g. one has to strictly characterize an object as an idea or a position). In many cases, users have also to fine-tune, align, amend or even fully change their usual way of collaborating in order to be able to exploit the system's features and functionalities. Acknowledging that the above are necessary towards making the system interpret and reason about human actions (and the associated resources), thus offering advanced computational services, there is much evidence that sophisticated approaches and techniques often resulted to failures (Shipman and McCall, 1994). This is often due to the extra time and effort that users need to spend in order to get acquainted with the system, the associated disruption of the users' usual workflow (Fischer et al., 1991), as well as to the "error prone and difficult to correct when done wrong" character and the prematurely imposing structure (Halasz, 1988) of formal approaches.

As a consequence, we argue that a varying level of formality should be considered. This variation may either be imposed by the nature of the task at hand (e.g. decision making, joint deliberation, persuasion, inquiry, negotiation, conflict resolution), the particular context of the collaboration (e.g. legal reasoning, medical decision making, public policy), or the group of people who collaborate each time (i.e. how comfortable people feel with the use of a certain technology or formalism). The above advocate an incremental formalization approach, which has been adopted in the development of CoPe_it!, a web-based tool that is able to support argumentative collaboration at various levels of formality (http://copeit.cti.gr). CoPe_it! complies with collaborative principles and practices, and provides members of communities engaged in argumentative discussions and decision making processes with the appropriate means to collaborate towards the solution of diverse issues. Representative settings where the tool would be useful include medical collaboration towards making a decision about the appropriate treatment of a patient, public policy making involving a wide community, collaboration among students in the context of their project work, organization-wide collaboration for the consideration and elaboration of the organization's objectives, web-based collaboration to enhance individual and group learning on an issue of common interest, etc.

According to the proposed approach, incremental formalization can be achieved through the consideration of alternative *projections* (i.e. particular representations) of a collaborative workspace, as well as through mechanisms supporting the switching from one projection to another. This paper focuses on the presentation of this approach. More specifically, Section 2 comments on a series of background issues related to reasoning and visualization, as well as on related work. Section 3 presents our overall approach, illustrates two representative examples of different formality level and sketches the procedure of switching among alternative projections of a particular workspace. Finally, Section 4 discusses advantages and limitations of the proposed approach and outlines future work directions.

2. Background issues

The representation and facilitation of argumentative discourses being held in diverse collaborative settings has been a subject of research interest for quite a long time. Many software systems have been developed so far, based on alternative models of argumentation structuring, aiming to capture the key issues and ideas during meetings and create a shared understanding by placing all messages, documents and reference material for a project on a "whiteboard". More recent approaches pay particular attention to the visualization of argumentation in various collaborative settings. As widely argued, visualization of argumentation can facilitate problem solving in many ways, such as in explicating and sharing representations among the actors, in maintaining focus on the overall process, as well as in maintaining consistency and in increasing plausibility and accuracy (Kirschner et al., 2003).

Generally speaking, existing approaches provide a cognitive argumentation environment that stimulates reflection and discussion among participants (a comprehensive consideration of such approaches can be found in (Karacapilidis et al., 2005)). However, they receive criticism related to their adequacy to clearly display each collaboration instance to all parties involved (usability and ease-of-use issues), as well as to the structure used for the representation of collaboration. In most cases, they merely provide threaded discussion forums, where messages are linked passively. This usually leads to an unsorted collection of vaguely associated positions, which is extremely difficult to be exploited in future collaboration settings. As argued in (van Gelder, 2003), “packages in the current generation of argument visualization software are fairly basic, and still have numerous usability problems”. Also important, they do not integrate any reasoning mechanisms to (semi)automate the underlying decision making processes required in a collaboration setting. Admittedly, there is a lack of consensus seeking abilities and decision-making methods.

Taking the above into account, we claim that an integrated consideration of visualization and reasoning is needed in an argumentative collaboration context. Such an integrated consideration should be in line with incremental formalization principles. More specifically, the above integration should efficiently and effectively address problems related to formality (Shipman and Marshall, 1994). As discussed in (Shipman and McCall, 1994), “users want systems be more of an active aid to their work - to do more for them; yet they already resist the low level of formalization required for passive hypertext”. Existing work on incremental formalization argues that problems related to formality have to be solved by approaches that (i) do not necessarily require formalization to be done at the time of input of information, and (ii) support (not automate) formalization by the appropriate software.

At the same time, the abovementioned integrated consideration should be also in line with the *information triage* process (Marshall and Shipman, 1997), i.e. the process of sorting and organizing through numerous relevant materials and organizing them to meet the task at hand. During such a process, users must scan, locate, browse, update and structure effortlessly knowledge resources that may be incomplete, while the resulting structures may be subject to rapid and numerous changes.

3. Our approach

The research method adopted for the development of the proposed solution follows the Design Science Paradigm, which has been extensively used in information systems research (Hevner et al., 2004). Having followed this paradigm, our main contribution lies in the development of a web-based tool for supporting argumentative collaboration and the underlying creation, leveraging and utilization of the relevant knowledge. Generally speaking, our approach allows for distributed (synchronous or asynchronous) collaboration and aims at aiding the involved parties by providing them with a series of argumentation, decision making and knowledge management features. Moreover, it exploits and builds on issues and concepts discussed in the previous section.

3.1 Analysis of requirements

A series of interviews with members of diverse communities (from the engineering, management and education domains) has been performed in order to identify the major issues they face during their argumentative collaboration practices. These issues actually constitute a set of challenges for our approach, in that the proposed collaboration model and infrastructure must provide the necessary means to appropriately address them. These issues are:

- *Management of information overload:* This is primarily due to the extensive and uncontrolled exchange of comments, documents and, in general, any type of information/knowledge resource, that occurs in the settings under consideration. For instance, such a situation may appear during the exchange of ideas, positions and arguments; individuals usually have to spend much effort to keep track and conceptualize the current state of the collaboration. Information overload situations may ultimately harm a community's objectives, requiring users to spend much time on information filtering and comprehension of the overall collaboration status.

- *Diversity of collaboration modes* as far the protocols followed and the tools used are concerned: Interviews indicated that the evolution of the collaboration proceeds incrementally; ideas, comments, or any other type of collaboration object are exchanged and elaborated, and new knowledge emerges slowly. When a community's members collaboratively organize information, enforced formality may require specifying their knowledge before it is fully formed. Such emergence cannot be attained when the collaborative environment enforces a formal model (i.e. predefined information units and relationships) from the beginning. On the other hand, formalization is required in order to ensure the environment's capability to support and aid the collaboration efforts. In particular, the abilities to support decision making, estimation of present state or summary reports benefit greatly from formal representations of the information units and relationships.

- *Expression of tacit knowledge:* A community of people is actually an environment where tacit knowledge (i.e. knowledge that the members do not know they posses or knowledge that members cannot express with the means provided) predominantly exists. Such knowledge must be able to be efficiently and effectively represented.

- *Integration and sharing of diverse information and knowledge:* Many resources required during a collaborative session have either been used in previous sessions or reside outside the members' working environment. Moreover, outcomes of past collaboration activities should be able to be reused as a resource in subsequent collaborative sessions.

- *Decision making support:* Many communities require support to reach a decision. This means that their environment (i.e. the tool used) needs to interpret the information types and relationships in order to proactively suggest trends or even calculate the outcome of a collaborative session (e.g. as is the case in voting systems).

3.2 Conceptual Approach

To address the above issues, our approach builds on a conceptual framework where *formality* and the *level of knowledge structure* during argumentative collaboration is not considered as a predefined and rigid property of the tool, but rather as an adaptable aspect that can be modified to meet the needs of the tasks at hand. By the term formality, we refer to all the rules enforced by the system and to which all discourse actions of users must comply. Allowing formality to vary within the collaboration space, incremental formalization, i.e. a stepwise and controlled evolution from a mere collection of individual ideas and resources to contextualized and interrelated knowledge artifacts, can be achieved.

In the proposed collaboration model, *projections* constitute the "vehicle" that permits incremental formalization of argumentative collaboration (see Figure 1). A projection can be defined as a particular representation of the collaboration space, in which a consistent set of abstractions able to solve a particular organizational problem during argumentative collaboration exists. With the term abstraction, we refer to the particular discourse types, relationships and actions that are available at a particular projection, and with which a particular problem can be represented, expressed and - ultimately - be solved.

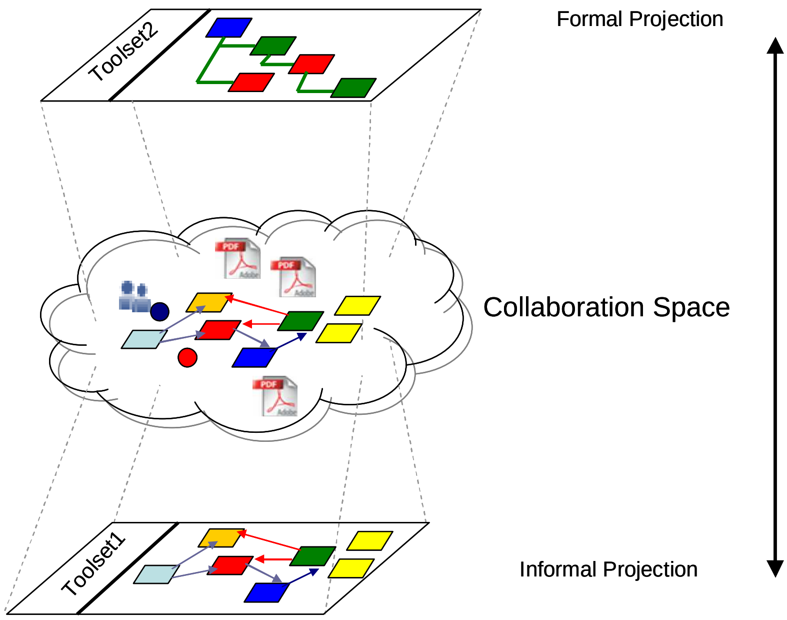

Figure 1: *Alternative projections of a collaboration space.*

Each projection of the collaboration space provides the necessary mechanisms to support a particular *level of formality*. More specifically, the more informal is a projection, the more ease-of-use is implied; at the same time, the actions that users may perform are intuitive and not time consuming (e.g. drag-and-drop a document to a shared collaboration space). Informality is associated with generic types of actions and resources, as well as implicit relationships between them. However, the overall context is human (and not system) interpretable. On the other hand, the more formal is a projection, ease-of-use is reduced (users may have to go through training or reading of long manuals in order to comprehend and get familiar with sophisticated system features); actions permitted are less and less intuitive and more time consuming. Formality is associated with fixed types of actions, as well as explicit relationships between them. The overall context in this case is both human and system interpretable.

An informal projection also aims at supporting information triage. It is the informal nature of this projection that permits such an ordinary and unconditioned evolution of knowledge structures. While such a way of dealing with knowledge resources is conceptually close to practices that humans use in their everyday environment (e.g. their desk), it is inconvenient in situations where support for advanced decision making processes must be provided. Such capabilities require knowledge resources and structuring facilities with fixed semantics, which should be understandable and interpretable not only by the users but also by the tool. Hence, decision making processes can be better supported in environments that exhibit a high level of formality. The formal projections of the collaboration space come to serve such needs.

3.3 Examples

To better illustrate our approach, this subsection presents two alternative (already implemented) projections of a particular collaborative session (the session is about which is the most appropriate treatment for a patient with breast cancer). The first one is fully informal and complies with the abovementioned information triage principles, while the second one builds on an IBIS-like formalism (Conklin and Begeman, 1989) and supports group decision making.

3.3.1 Informal projection

As mentioned above, the aim of an informal projection of the collaboration space is to provide users the means to structure and organize information units easily, and in a way that conveys semantics to users. Generally speaking, informal projections may support an unbound number of discourse element types (e.g. comment, idea, note, resource). Moreover, users may create any relationship among discourse elements (there are no fixed relationship types); hence, relationship types may express agreement, disagreement, support, request for refinement, contradiction etc. Informal projections may also provide abstraction mechanisms that allow the creation of new abstractions out of existing ones. Abstraction mechanisms include:

- *Annotation and metadata:* the ability to annotate instances of various discourse elements and add (or modify) metadata.
- *Aggregation:* The ability to group a set of instances of discourse elements so as to be handled as a single conceptual entity. This may lead to the creation of additional informal sub-projections, where a set of discourse elements can be considered separately, but still in relation to the context of a particular collaboration.
- *Generalization/Specialization:* The ability to create semantically coarse or more detailed discourse types. Generalization/specialization may not lead to additional informal projections but may help users to manage information pollution of the collaboration space leading to ISA hierarchies.
- *Patterns:* The ability to specify instances of interconnections between discourse elements (of the same or a different type) as templates acting as placeholders that can be reused within the discussion.

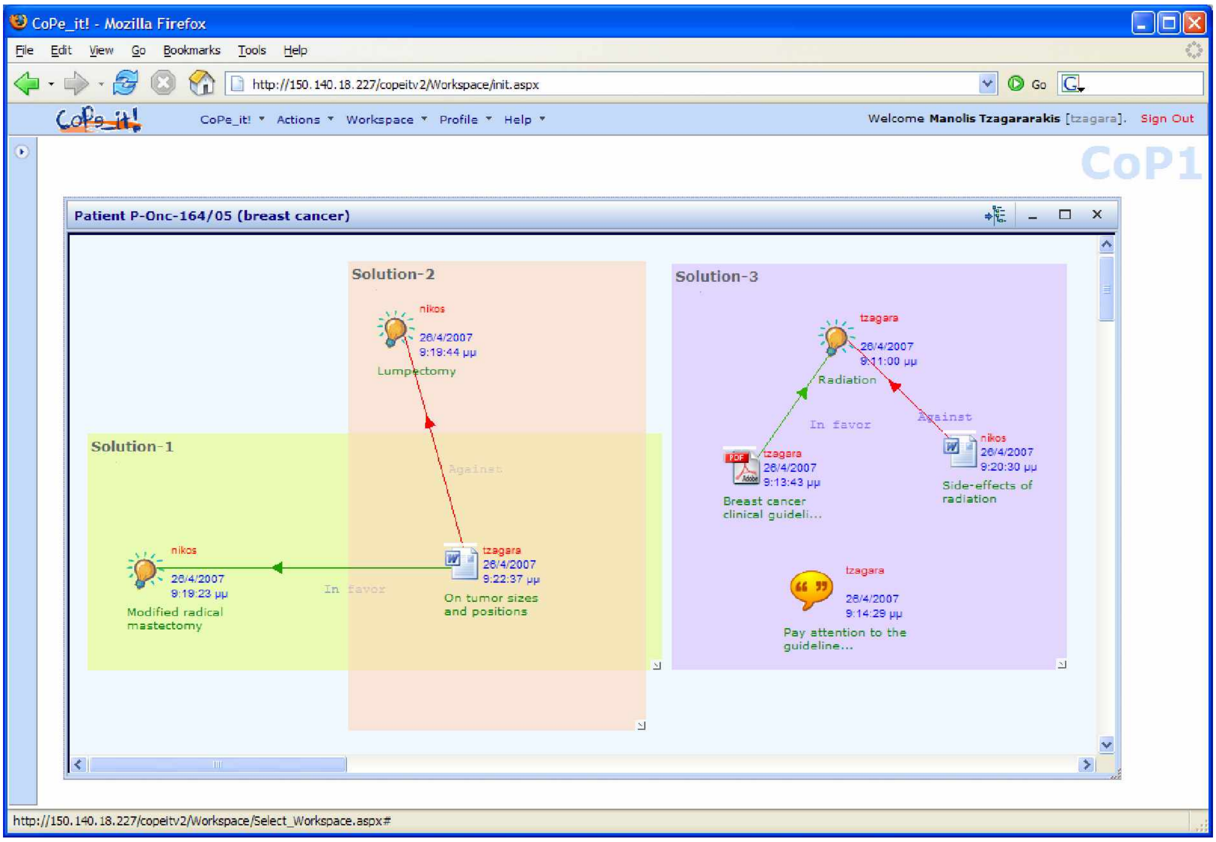

Figure 2: *Instance of an informal projection.*

Figure 2 presents an example of an informal projection of the collaboration session considered. Medical doctors discuss the case of a particular patient aiming at achieving a decision on the most appropriate treatment. Since initially the process of gathering and discussing the available treatment options is unstructured, highly dynamic and thus evolving rapidly, the informal space provides the most appropriate environment to support collaboration at this stage. The aim is to bring the session to a point where main trends crystallize, thus enabling the switch to a formal projection (upon the participants' wish).

In the example of Figure 2, three approaches to the patience's treatment – proposed by three different users – have been (so far) elaborated, namely "*modified radical mastectomy*", "*lumpectomy*" and "*radiation*". Each proposed treatment is visible on the collaboration space as an "idea". Participants may use relationships to relate resources (documents, links etc.), comments and ideas to the proposed treatment. The semantics of these relationships are user-defined. Visual cues may be used to make the semantics of the relationship more explicit, if desired. For instance, a red arrow indicates comments and resources that express objection to a treatment, while green arrows express approval of a treatment. Note that the resource entitled "*On tumor sizes positions*" seems to argue against the solution of "*lumpectomy*" while, at the same time, it argues in favor of "*modified radical mastectomy*". This is due to the information contained in it (in that some "chunks" advocate or avert from a particular solution; this is to be further exploited in a formal projection). Other visual cues supported in this projection may bear additional semantics (e.g. the thickness of an edge may express how strong a resource/idea may object or approve a treatment). Informal projections also provide mechanisms that help aggregating aspects of collaboration activities. For example the colored rectangles labeled as "solution-

1", "solution-2" and "solution-3" help participants visualize what the current alternatives are. Although - at this projection instance – these rectangles are simply visual conveniences, they play an important role during the switch to formal projections, enabling the implementation of abstraction mechanisms.

3.3.2 Formal projection

While an informal projection of the collaboration space aids the exploitation of information by users, a formal projection aims mainly at the exploitation of information by the machine. As noted above, formal projections provide a fixed set of discourse element and relationship types, with predetermined, system-interpretable semantics. More specifically, the formal projection presented in Figure 3 is based on the approach followed in the development of *Hermes* (Karacapilidis and Papadias, 2001). Beyond providing a workspace that triggers group reflection and captures organizational memory, this projection provides a structured language for argumentative discourse and a mechanism for the evaluation of alternatives. Taking into account the input provided by users, this projection constructs an illustrative discourse-based knowledge graph that is composed of the ideas expressed so far, as well as their supporting documents. Moreover, through the integrated decision support mechanisms, participants are continuously informed about the status of each discourse item asserted so far and reflect further on them according to their beliefs and interests on the outcome of the discussion. In addition, the particular projection aids group sense-making and mutual understanding through the collaborative identification and evaluation of diverse opinions.

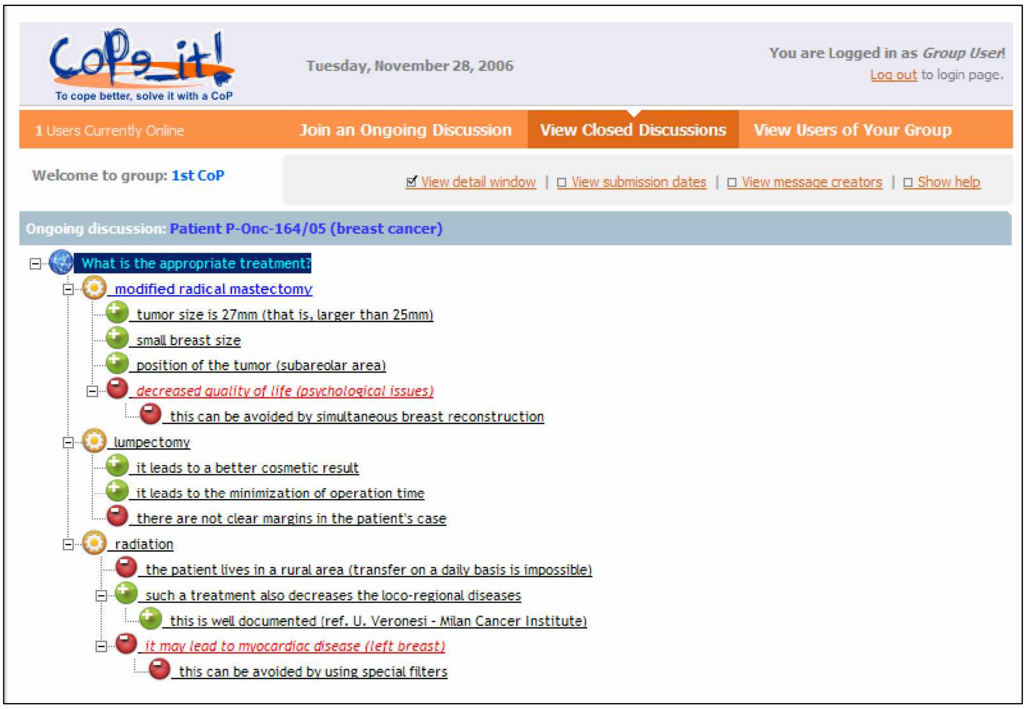

Figure 3: *Instance of a formal projection.*

The discourse elements allowed in this projection are "issues", "alternatives", "positions", and "preferences". Issues correspond to problems to be solved, decisions to be made, or goals to be achieved. They are brought up by users and are open to dispute (the root entity of a discourse-based knowledge graph has to be an issue). For each issue, users may propose alternatives (i.e. solutions to the problem under consideration) that correspond to potential choices. Nested issues, in cases where some alternatives need to be grouped together, are also allowed. Positions are asserted in order to support the selection of a specific course of action (alternative), or avert the users' interest from it by expressing some objection. A position may also refer to another (previously asserted) position, thus arguing in favor or against it. Finally, preferences provide individuals with a qualitative way to weigh reasons for and against the selection of a certain course of action. A preference is a "tuple" of the form [position, relation, position], where the relation can be "more important than" or "of equal importance to" or "less important than". The use of preferences results in the assignment of various levels of importance to the alternatives in hand. Like the other discourse elements, they are subject to further argumentative discourse.

The above four types of elements enable users to contribute their knowledge on the particular problem or need (by entering issues, alternatives and positions) and also to express their relevant values, interests and expectations (by entering positions and preferences). Moreover, the system continuously processes the elements entered by the users (by triggering its reasoning mechanisms each time a new element is entered in the graph), thus facilitating users to become aware of the elements for which there is (or there is not) sufficient (positive or negative) evidence, and accordingly conduct the discussion in order to reach consensus.

Further to the argumentation-based structuring of a collaborative session, this projection integrates a reasoning mechanism that determines the status of each discourse entry, the ultimate aim being to keep users aware of the discourse outcome. More specifically, alternatives, positions and preferences of a graph have an activation label (it can be "active" or "inactive") indicating their current status (inactive entries appear in red italics font). This label is calculated according to the argumentation underneath and the type of evidence specified for them ("burden of proof"). Activation in our system is a recursive procedure; a change of the activation label of an element is propagated upwards in the discussion graph. Depending on the status of positions and preferences, the mechanism goes through a scoring procedure for the alternatives of the issue (for a detailed description of the system's reasoning mechanisms, see (Karacapilidis and Papadias, 2001)). At each discussion instance, the system informs users about what is the most prominent (according to the underlying argumentation) alternative solution. In the instance shown in Figure 3, *"modified radical mastectomy"* is the better justified solution so far. However, this may change upon the type of the future argumentation. In other words, each time an alternative is affected during the discussion, the issue it belongs to is updated, since another alternative solution may be indicated by the system.

3.4 Switching projections

The projections discussed above could individually serve the needs of a particular community (for a specific context). However, they should be also considered (and exploited) jointly, in that a switch from one to the other can better facilitate the argumentative collaboration process. Adopting an incremental formalization approach, a formal projection can be considered as a filtered and machine-interpretable view of an informal one. Our approach is able to support cases where argumentative collaboration starts through the informal projection (see Section 3.3.1), where instances of any discourse element and relationship type can be created (by any participant). Such collaboration may start from an empty collaboration space or may continue elaborating an informal view of a past collaboration session (existing resources and relationships between them can thus be reused).

At some point of the collaboration, an increase of the formality level can be decided (e.g. by an individual user or the session's facilitator), thus switching to the formal projection (see Section 3.3.2), where discourse and relationship type instances will be transformed, filtered out, or kept "as-is". The above are determined by the associated (visualization and reasoning) model of the formal projection (consequently, this process can be partially automated and partially semi-automated). For instance, referring to the projections discussed above, the colored rectangles shown in Figure 2 will be transformed to the alternatives of Figure 3 (each alternative is expressed by the related idea existed in Figure 2). Moreover, provided that a particular resource appearing in the informal view has been appropriately annotated, the formal projection is able to exploit extracts ("chunks") of it and structure them accordingly. Such extracts appear as atomic objects at the formal projection. For instance, consider the multiple arguments in favor and against the alternatives of Figure 3; these have been resulted out of the appropriate annotation of the resources appearing in Figure 2.

One may also consider a particular argumentative collaboration case, where decrease of formality is desirable. For instance, while collaboration proceeds through a formal projection, some discourse elements need to be further justified, refined and elucidated. It is at this point that the collaboration session could switch to a more informal view in order to provide participants with the appropriate environment to better shape their minds (before possibly switching back to the formal projection). Note that there may exist more than one informal projections that are related to a particular formal view (depending on the type of the discourse element to be elaborated). Switching from a formal to an informal projection is also supported by our approach.

3.5 Other issues

In addition to the above, our approach permits users to create one or more private spaces, where they can organize and elaborate the resources of a collaboration space according to their understanding (and their pace). Although private in nature, users are able to share such spaces with their peers. Moreover, each projection is associated with a set of tools that better suit to its purposes. These tools enable the population, manipulation and evolution of the discourse element types allowed in that particular projection. There can be tools allowing the reuse of information residing in legacy systems, tools permitting authoring of multimedia content, annotation tools, as well as communication and management tools.

A web-based prototype version of CoPe_it!, supporting various levels of formality using projections as the ones described above, has been implemented. The prototype makes use of Web 2.0 technologies, such as AJAX (Asynchronous JavaScript and XML), to deliver the functionalities of the different projections to end users. Based on these technologies, concurrent and synchronous collaboration in every projection is provided. Individual collaboration sessions are stored in XML format. There is at least one XML schema for each formality level (i.e. projection) that encodes and implements the constraints and rules that are active in it. More formal levels are manifested as more strict XML schemas, where types and relationships are fewer and more explicit than in cases of less formal levels.

4. Discussion and Conclusion

Referring to (Shipman and Marshall, 1994), we first draw remarks concerning the advantages and limitations of the proposed approach against issues such as cognitive overhead, tacit knowledge, premature structure, and situational differences. Speaking about the first issue, we argue that our approach mirrors working practices with which users are well acquainted (they are part of their ordinary tasks), thus exhibiting low “barriers to entry”. Moreover, it reduces the overhead of entering information by allowing a user-friendly reuse of existing documents (mechanisms for reusing existing knowledge sources, such as e-mail messages and entries or topics of web-based forums, as well as multimedia documents, such as images, video and audio, have been also integrated). In addition, our approach is able to defer the formalization of information until later in the task. This may be achieved by the use of the appropriate annotation and ontology management tools. In any case, however, users may be averted from the use of such (usually sophisticated) tools, thus losing the benefits of a more formal representation of the asserted knowledge resources. A remedy to that could be that such processing is performed by experienced users. One should also argue here that, due to the collaborative approach supported, the total overhead associated with formalizing information can be divided among users.

Speaking about management of tacit knowledge, we argue that the alternative projections offered, as well as the mechanisms for switching among them, may enhance its acquisition, capturing and representation. Limitations are certainly there; nevertheless, our approach promotes active participation in knowledge sharing activities which, in turn, enhances knowledge flow. Reuse of past collaboration spaces also contributes to bringing previously tacit knowledge to consciousness.

Our approach does not impose (or even advocate) premature structure; upon their wish, participants may select the projection they want to work with, as well as the tasks they want to perform when working at this projection (e.g. a document can be tagged or labelled whenever a participant wants; moreover, this process has not to be done in one attempt). Finally, considering situational differences, we argue that our approach is generic enough to address diverse collaboration paradigms. This is achieved through the proposed projection-oriented approach (each projection having its own structure and rationale), as well as the mechanisms for switching projections (such mechanisms incorporate the rationale of structures’ evolution).

As mentioned above, the proposed approach is the result of action research studies for improving argumentative collaboration. It has been already introduced in diverse educational and organizational settings for a series of pilot applications. Preliminary results show that it fully covers the user requirements analyzed in Section 3.1. Also, it stimulates interaction, makes users more accountable for their contributions, while it aids them to conceive, document and analyze the overall argumentative collaboration context in a holistic manner. In addition, these results show that the learning effort for the proposed tool is not prohibitive, even for users that are not highly adept in the use of IT tools; in most cases, an introduction of less than an hour was sufficient to get users acquainted with the tool’s features and functionalities.

Concluding, we argue that the proposed approach provides the means for addressing the issues related to the formality needed in argumentative collaboration support systems. It aims at contributing to the field of social software, by supporting argumentative interaction between people and groups, enabling social feedback, and facilitating the building and maintenance of social networks. Future work directions include the extensive evaluation of the corresponding system in diverse contexts and collaboration paradigms, which is expected to shape our mind towards the development of additional projections, as well as the experimentation with and integration of additional visualization cues, aiming at further facilitating and augmenting the information triage process.

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