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ON A WORLD WIDE WEB-BASED PLANNING SUPPORT SYSTEM

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Abstract. Work presented in this paper focuses on the design of a computer-mediated system for supporting group planning on the World-Wide Web platform. It is shown that, by developing a set of appropriate intelligent tools and providing a public-domain application, any Web browser, such as Mosaic or Netscape, may be sufficient for an agent to take part in a planning procedure. The specific role of the system is that of an assistant and advisor, recommending solutions and leaving the final decisions and actions to the agents. In other words, it emphasizes on a human-human coordination, communication and problem solving, rather than on a human-machine one. The proposed framework decomposes the problem of group planning into decision-making, uncertainty handling, constraint satisfaction and propagation, and integrates them appropriately.

Keywords: Group decision support systems, world-wide web, planning, argumentation, computer-supported cooperative work.

1. INTRODUCTION

The basic objective in planning is the identification of and selection among alternative courses of action. In real world planning instances one has to take into account the following:

- usually, planning has to be performed through a lot of debates, negotiations and arguments; conflicts of opinions are inevitably revealed;
- reasoning is defeasible; that is, further information may cause an alternative to be preferable to what seems best at the moment;
- there may be arguments supporting or against the choice of a certain alternative, but this should not yield to the consideration of the whole system as irrational or inconsistent;
- factual knowledge is not always sufficient to make a decision; value judgements are also required;
- both not enough and too much information may coexist, combined with limited resources for finding a solution; in addition, however much information is available, opinions may differ about its truth, relevance or value in deciding an issue;
- in most cases, uncertainty and incomplete knowledge of the world are inherent, and
- the assignment of quantitative values to various arguments may be difficult; planning agents usually need a framework to express preferences qualitatively.

The role of planners in the classical AI planning model is to construct plans revealing *knowledge states* that satisfy particular goals. In spite of the success of hierarchical non-linear planning in search reduction, such systems lack sufficient basis for choice of action [22], and adequate representation for consistency and replanning [14]. The rough distinction of the above states into those satisfying and those not satisfying some goals poses problems in real instances. In these cases, planning agents may assert objectives that can be partially satisfied. Decision making formalisms could provide the desired platform, yet lack some of the computational advantages of planners [11].

The rest of the paper is organized as follows: an argumentation-oriented framework for planning is presented in Section 2; data types and concepts are defined, and the decision making procedure is outlined. Section 3 discusses advancements coming from the area of Computer Supported Cooperative Work, and illustrates a World-Wide Web gateway for the system. Finally, motivations for such an approach, as well as related and future work are discussed in Section 4.

2. AN ARGUMENTATION FRAMEWORK FOR PLANNING

In this section we propose a framework for planning, which can efficiently handle the above-mentioned conditions that planning agents usually face. We also outline a method for approaching the corresponding issues of priority relationships, decision making and dependency propagation.

Propositions are at the lowest level of our framework. Any kind of data an agent wants to assert during the planning process can be used to represent a proposition. A proposition may be represented by a text, spreadsheet, graphic, part of a database, etc. The proposition used can be true or false, important or irrelevant for the corresponding problem, and may become acceptable or non-acceptable. Each proposition has a *label* denoting its acceptance status, taken either automatically (that is, recommended by the system) or chosen by the system users. We allow for the following labels:

- SRA: "system recommended accept",
- SRR: "system recommended reject", and
- NSR: "no system recommendation".

Issues consist of two parts: a set of alternative propositions and a set of related *constraints*. The propositions represent the positions asserted so far. The issue is which alternative position to prefer, if any. In addition, each issue includes a dummy position, namely *nil*, denoting the selection of none of the current positions. *Nil* provides a means of indicating that none of the alternative propositions in an issue is recommended. Constraints provide a qualitative way to argue about preferences and value judgements in order to weigh reasons for and against a certain option. In other words, they give the users the ability to rank the quality of alternative positions. Constraints are interpreted as *meta-issues*, including a *nil* position as well as possible constraints on them. This provides a means of expressing the agent's belief for the constraint, that is, either acceptance or rejection of it, or no decision about its validity. Finally, *arguments* are assertions about the positions regarding their properties or attributes, which speak for or against them. We allow two kinds of arguments: *supporting arguments* (pro) and *counterarguments* (con). An argument links together two propositions of different issues.

In order to make the above concepts more clear, we give the following example: the goal of a part of a planning problem is to find a constructor for a specific tool. There are some alternative choices already asserted, that is to order it from two candidate subcontractor companies, Constructor-1 and Constructor-2. Decision makers argue about the quality, delivery time and costs that the above alternatives provide. In this instance, the issue is "*finda constructor for the tool*" and the existing propositions are "*select Constructor*-1" and "*select Constructor*-2". A supporting argument for the first proposition may be: "*Constructor*-1 *offers high quality work*" ; a counterargument for the second proposition may be: "*Constructor*-2 *is expensive*" ; constraints asserted may be: "*quality is considered to be more important than price*" , and/or "*theco-existence of low quality and low price is considered more important than delayed delivery*" .

Following [2], we consider that there are no unrefutable arguments. In addition, two conflicting arguments can be simultaneously applied. An instance of the systems structure is presented in Fig. 1. Positions are denoted with ellipses (the *nil* positions are shaded), issues with rectangles, supporting arguments with plain arrows, and counterarguments with arrows crossed by a simple line. Constraints appear in the second part of each issue. Due to space limitations, they are simply shown with shaded rectangles, although they retain the full structure of an issue.

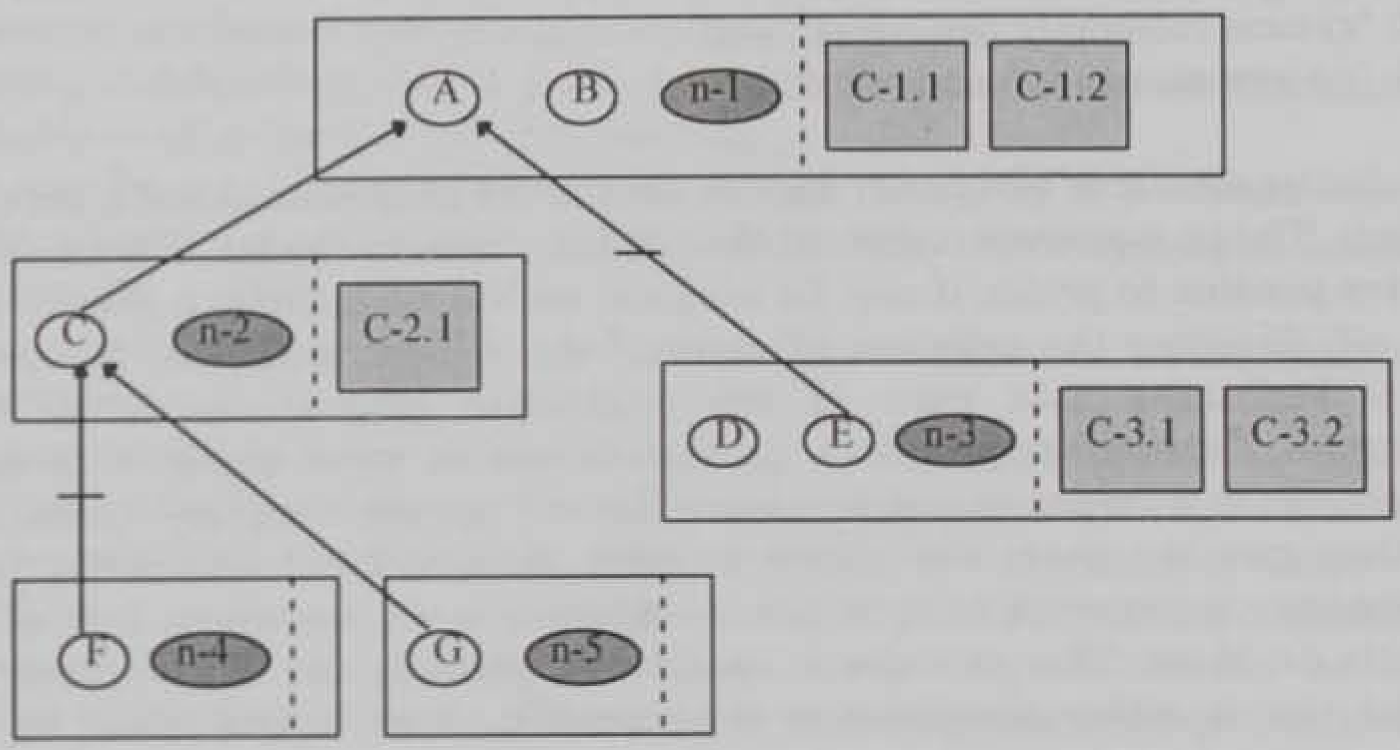

Figure 1: An instance of the system's structure.

Our framework draws on concepts first introduced in [3] about a Qualitative Value Logic (QVL), a logic for defeasible qualitative decision making. As illustrated in [10], supporting and counterarguments can be weighed against each other. The constraints of an issue allow for a combination of weak arguments to defeat a strong argument.

The subject of priority relationships and preference orders has been mostly handled through quantitative approaches (see for example [15] and [19]), using the concepts of *the cost of not taking a premise into account* and *confidence factors*, respectively. Well-defined utility and probability functions regarding properties or attributes of alternative positions, used for example in traditional OR approaches, as well as complete ordering of these properties are usually absent. On the contrary, a complete preference ordering among arguments is not always attainable; there may be some formal properties such as transitivity and non-circularity, but still a partial ordering is often all that we are able to achieve. In addition, there is not always complete information for each alternative proposition of an issue regarding the attributes asserted by the arguments. For instance, in order to conclude an issue with two alternative propositions A and B, it is possible that we only know that "*A has the attributes a, b and c*", while "*B has the attributes a and d*" (consider also the case where no information regarding the ordering of a, b, c, d has been given).

Trying to solve an issue, our framework considers the related supporting and counter arguments as well as the asserted constraints. Depending on the information provided, the system can:

- recommend the acceptance of a *single* proposition (SRA), and, consequently, the rejection of the rest of them (SRR);
- recommend the rejection of some positions (for example, in cases resulting in only partial preferences among the positions, the SRR label may appear $m \leq n$-2 times, where n is the number of the alternatives), or
- make no recommendation at all.

Let I be the set of issues in a debate, $I = \{I_1, I_2, ..., I_n\}$, C_i the set of constraints of an issue i, $C_i = \{C_{i,1}, C_{i,2}, ..., C_{i,k}\}$, P_i the set of propositions of an issue i, $P_i = \{P_{i,1}, P_{i,2}, ..., P_{i,p}\} \cup nil_i$, $n, k, p \in N$, and $P_i' = \{P_{i,1}, P_{i,2}, ..., P_{i,p}\} = P_i - nil_i$. Let also the functions *label* (x), $x \in P_i$, and *con* (y), $y \in I$, stand for the labelling of propositions and the conclusion of issues, respectively. As stated above, arguments link together propositions of different issues. In the proposed system, we do not allow cycles. Consequently, the structure of the system is tree-like. The decision-making procedure follows a *bottom-up* approach, starting from the leave issues and heading for more "coarse" ones. A first outline of the decision making procedure taking place in each issue is given below (lines starting with # represent comments):

```
in an issue i:
    conclude the constraints C_{i,1}, C_{i,2}, ..., C_{i,k}
    # find the accepted, rejected and undecided ones
    if the accepted constraints are inconsistent
            then    con (i) = undecided
            else    {
                    label (x)=NSR, ∀ x ∈ P'_i
                    # initially we assume that every position is not recommended
                    solve the issue       # find total or partial preferences
                    labelling and conclusion of the issue
                    propagation of decision
                    }
    endif
```

The *labelling* procedure for the propositions of an issue i is:

```
if      (optimal solution := P_{i,x})
        then    {
                label (P_{i,x})=SRA;
                label (P_{i,y})=SRR, ∀ P_{i,y} ∈ P'_i , y≠x;
                label (nil_i)=SRR;
                }
elseif  (P_{i,k} better than P_{i,m})
        then    {
                label (P_{i,m})=SRR;
                label (nil_i)=SRA;
                }
else            {
                label (P_{i,v})=SRR, ∀ P_{i,v} ∈ P'_i ;
                label (nil_i)=SRA;
                }
```

Finally, the *conclusion* procedure is:

```
if      (∃ P_{i,j} ∈ P'_i ∋ label (P_{i,j})=SRA)
                then    con (i) = decided
                else    con (i) = undecided
```

Initially, any issue of the problem is considered undecided. After the labelling and conclusion procedures, *propagation* of the eventual decision has to take place. Obviously, this has to be done only when a solution has been found (for more, see [10]).

3. CSCW AND THE WORLD WIDE WEB PLATFORM

The argumentation framework presented above may exploit advancements in electronic communication and computing. *Computer Supported Cooperative Work* (CSCW) has been defined as computer-assisted coordinated activity for communication and problem solving, carried out by a group of collaborating individuals [7], [8]. Key issues of CSCW are group awareness, multi-user interfaces, concurrency control, communication and coordination within the group, shared information space, and the support of a heterogeneous, open environment, which integrates existing single-user applications.

The most successful CSCW technology to date is undoubtedly the *electronic mail*. Other well-developed technologies so far include *computer conferencing* (based on a structured form of electronic mail, in which messages are organized by topic and dialogues are often mediated by a convenor), *teleconferencing or desktop videoconferencing* (the act of conferencing at a distance with the aid of audio and video links), *group authoring* (enabling cooperative writing with additions, revisions, comments and annotations), and *group decision support systems* (where problem solving is directed at issue organization and decision support). The last category consists of mediating systems that support discussion, argumentation, negotiation and decision making in groups.

Most taxonomies of CSCW technologies distinguish them in terms of their abilities to bridge time and space. However, this is a rough distinction, initiated from their initial or most common use. Citing [1], CSCW technologies of the future should focus on an *any time - any place* environment. CSCW is currently strongly supported and explored from both industry and academic research [24].

A principal aim for the designer of a planning system for groups should be to apply state-of-the-art CSCW technology to provide advanced support for the users over wide area networks, in particular the Internet. The leading commercial groupware products, such as *Lotus Notes* and *DEC's LinkWorks*, are generic tools for developing groupware applications within a single organization, primarily over local area networks. Usually, a planning environment requires support for communication and cooperation across organizational, or even national, boundaries. The primary advantages of commercial systems over the Web and other Internet services, at the moment, are well-integrated tools for creating documents and messages. Unfortunately, these systems typically use proprietary formats and communications protocols. Conversely, the primary weakness of the Web as a basis for groupware (that is, the multi-user software supporting CSCW [5]) is the present difficulty for ordinary users to create, link, index and store new documents. Two developments make it easier for them to develop content, which can be disseminated over the Web: (i) the increasing availability of HTML and SGML editors, often as extensions to popular word processors and (ii) the use of Portable Document Format, which may be generated automatically from almost any document using a special printer driver.

In addition, most persons will not want or be able to maintain a Web server. A way must be found to provide users with the opportunity to add information and assert their positions, which does not exacerbate the already difficult problem of later finding and retrieving information. Computer conferencing and group decision support systems alleviate this problem by using the discourse structure of a set of related messages to automatically index and organize the data base of documents. For example, messages may be organized by topic or "thread" in a hierarchy according to the "reply" relation. The Web does not yet support this kind of interaction well. What is needed is a better integration of conferencing systems, such as the *Usenet news groups*, group decision support technology, such as Issue-based Information Systems, and the Web. There have been some experiments along these lines, such as Web Interactive Talk and the Open Meeting project in the USA. Following the above, CSCW technology is better applied to construct *mediation systems*, for supporting a "round table" discussion between equal partners, rather than control systems for managing the interests of a single actor. A mediation system assists the "trusted third parties", i.e., persons having no personal stake in the outcome of the project, whose job is to facilitate negotiations, moderate discussions, and perhaps arbitrate the resolution of disputes.

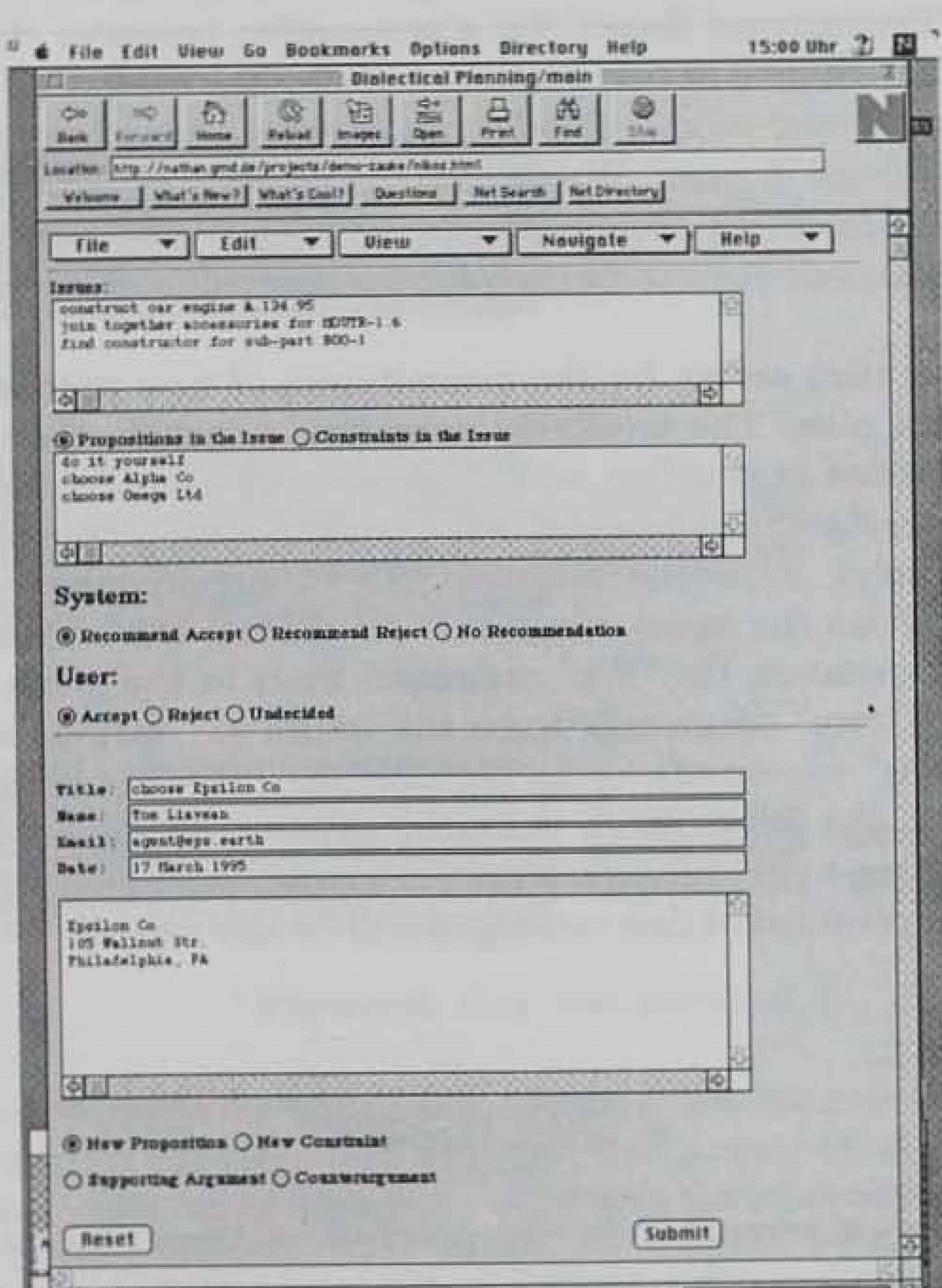

Figure 2: The World Wide Web gateway.

Fig. 2 illustrates a mock-up of a Web gateway through which each planning agent might assert his own positions and constraints in a planning paradigm (see also [11]). The File menu includes the usual commands such as New, Open, Close, Send, Save, Print or Quit a plan. Each paradigm contains all corresponding positions, arguments and constraints asserted so far via our mediating system. The specification of rights and duties among agents would affect their potential access to the list of available commands. Several agents can open and modify the same plan simultaneously. An agent can modify the discussion by asserting new positions, and consider alternative decisions in spite of the system's recommendations. "What-if " scenarios might be tested before an agent decides about what he finally wishes to assert. The Edit menu includes the usual Undo, Cut, Copy, Paste, Clear, Select, Find and Replace commands. Similarly, the View, Navigate, Options and Help menus include well-tried commands from Web browsers adapted in our formalism.

As shown in Fig. 2, the file corresponding to the problem has been retrieved and its related issues are listed in the first scrollable pane under the main menu bar. The agent can select any of them and click either on the "Propositions in the Issue", or on the "Constraints in the Issue" button to see what has been asserted (second scrollable pane). Automatically, he would find out the system's conclusion for the issue by observing for which proposition the "Recommend Accept" button is on. Possible weaknesses for solving the issue will be represented by the "No Recommendation" button being on. "Recommend Reject" for a proposition indicates that the system has identified a better alternative in this issue. Preserving the mediating role we intend for the system, an agent would be able to select an alternative, and assert his own opinion by clicking on the Users "Accept", "Reject" or "Undecided" buttons. Working this way, agents would be able to observe the consequences of their decisions at higher levels of the planning tree and evaluate alternative plans.

The bottom part serves for the commitment of new propositions, arguments and constraints in a plan. The scrollable pane would include their description. The linking a newly asserted proposition with an existing one can be made by clicking on one of the "Pro" and "Con" buttons (declaring intention for a supporting or a counter argument, respectively), after the selection of the corresponding proposition. The Navigate menu provides the usual commands for tracing the corresponding graph of the discussion. For instance, the "Top" command leads to the prime goal of the plan, and the "Up" and "Down" commands trace the issues at various abstraction levels. "Next" and "Previous" commands cycle through the other arguments of a selected proposition. Finally, the View menu provides suitable decision-making graphs and options for overall representations of a plan. For instance, other views of the dialectical graph, such as a temporal list of past messages, will be also useful.

4. DISCUSSION

The framework presented in the previous sections embraces *hypertext* and groupware technologies, smoothly applied on the amalgamation of a *discussion model* and classical planning algorithms. Hypertext systems feature machine-supported links, both within and between documents, that have opened exciting new possibilities for using the computer as a communication tool. The discussion model can enhance the quality of the dialogue process within a conceptual organization by providing the structure for the discussion of complex problems. The motivations behind the integration of an argumentation framework for planning are:

- to support and reason about commonly prevailing conditions in dynamic planning environments, such as argumentation, negotiation, and conflict resolution;
- to facilitate and rationalize the communication among multiple agents in the planning process;
- to extend and cumulate the existing knowledge across the planning agents, and
- to adapt supporting planning algorithms on qualitative decision making environments.

Our framework stimulates a decomposition of planning and scheduling activities into constraint propagation, decision-making, and intelligent control of both (see also [13]). Future work should focus on an open planning support system, which would make information more accessible and affordable, and help to open and democratize decision making procedures. This would also improve the quality and acceptability of decisions and reduce the considerable expense of unnecessary delays and conflicts. Services that should be integrated towards such a system are (Fig. 3):

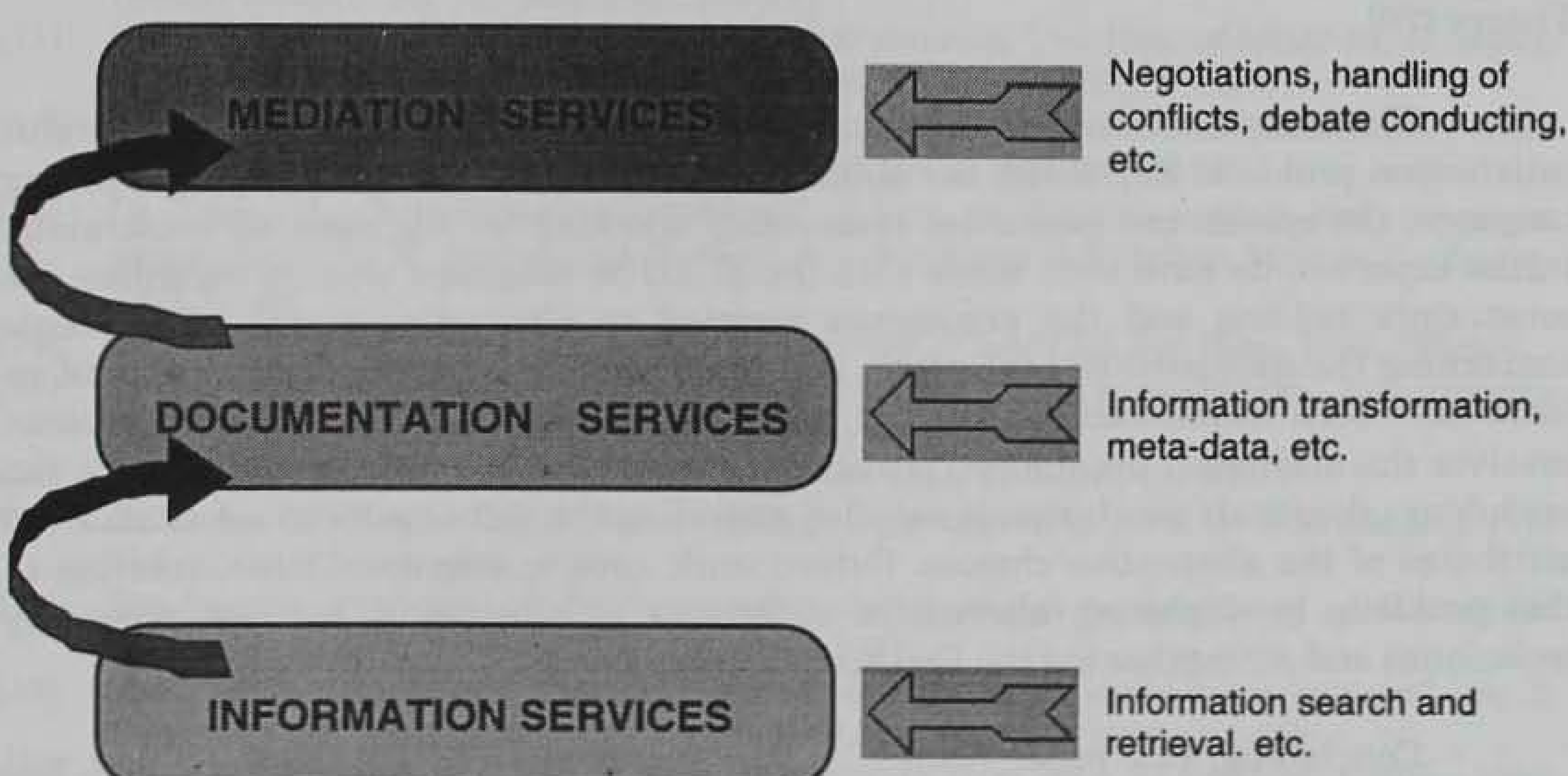

Figure 3: Required services.

- The *information services*, which will improve the interoperability of proprietary systems, providing efficient and cost-effective access to the multimedia data in heterogeneous, distributed databases, over wide-area networks. This would include services for finding relevant data, converting proprietary data to standard formats for data interchange, as well as ways of controlling remote servers from within compound documents and general purpose electronic mail, conferencing systems, and hypermedia systems, such as the Web.

- The *documentation services,* which will provide a shared workspace for storing and retrieving the documents and messages of the participants, using standard document formats, such as SGML, OpenDoc, etc. Users will be able to add o.k. and retrieve information from the hyperspace of documents available on the network. Security and privacy issues should also be addressed here. Project document databases may become part of the *collective memory* of a community, facilitating the reuse of plans, designs and their rationales.
- The *mediation services*, which will provide assistance for regulated group activity. Commercial workflow systems will be used to support well-defined, formal administrative procedures within organizations. For group planning and decision-making procedures, services will be provided to support the human mediators of electronic "round table" discussions.

The implementation of a fair, efficient and rational rhetorical model plays a key role in such a system. Among the most prominent related work, we mention here the early work of Toulmin on argumentation theory [21], Pollock's OSCAR model of defeasible reasoning [16], Rescher's work on formal disputation theory [18], and the Issue-Based Information System (IBIS) rhetorical method developed at MCC [4]. The legitimate aspect of logic behind such a rhetorical model, in order to implement a set of norms for regulating this kind of discourse, has been highlighted in Toulmin's work, and is extensively discussed in [6] and [17]. We also mention here related work coming from the AI area, such as the BURIDAN planning algorithm [12], the PYRRHUS planning system [23], utility models for planners [9], and the Qualitative Decision Theory [20].

The conclusion of an issue usually implies the solution of a constraint satisfaction problem. Exploiting the abilities of a constraint satisfaction programming language, the system can guarantee consistency checking for the asserted constraints. Initial experiments have been made with the *ECLiPSe* language. Jointly regarding the constraints holding and the arguments asserted to alternative positions, concepts concerning the *optimistic or pessimistic*, and the *credulous or skeptical* conclusion of an issue have been introduced in [10]. The optimistic (pessimistic) conclusion of an issue involves the maximum (minimum) possible values of the alternative choices, while the credulous (skeptical) conclusion is entailed regarding the full (common) set of asserted attributes of the alternative choices. Future work aims at a more efficient solution to this problem, by exploring alternative constraint satisfaction is entailed regarding techniques and strengthening the Qualitative Value Logic.

Concluding, this paper focused on the specification of a framework that will host the appropriate tools for supporting and reasoning about fair, rational and effective group planning. A Web gateway for such systems has been suggested, aiming at providing the broadest access among agents, and assuring portability and platform-independence. Key issues taken into account are the awareness of the planning agents, multi-user interfaces, communication and coordination within the group of planning agents, shared information space and the support of a heterogeneous and "open environment". The approach proposed emphasizes the *human-human* coordination, communication and problem solving, rather than the *human-machine* one.

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