Chapter 6
Exploiting Alternative Knowledge Visualizations and Reasoning Mechanisms to Enhance Collaborative Decision Making

Spyros Christodoulou, Nikos Karacapilidis and Manolis Tzagarakis

Abstract Collaborative decision making in today's knowledge intensive and multi-disciplinary environments is a challenging task. The diversity of these environments and the associated plurality of decision makers' perceptions of the issue under consideration require the exploitation of a variety of meaningful knowledge visualizations and reasoning mechanisms to effectively support the overall stakeholders' collaboration towards making a decision. This chapter reports on an innovative approach that offers a number of interrelated visualizations of the knowledge exchanged and shared during a collaborative decision making process. These visualizations incorporate suitable reasoning mechanisms that exploit human and machine understandable knowledge to facilitate the underlying what-if analysis and aid stakeholders towards reaching consensus and, ultimately, making a collective decision.

Keywords Collaboration · Multi-criteria decision making · Group decision making · Computer-supported cooperative work

6.1 Introduction

Knowledge intensive work is becoming increasingly collaborative in nature. In many settings, multi-disciplinary teams are formed to manage big amounts of data associated with their decision making tasks. Within such teams, decisions are usually collective; the decision making process involves a group of stakeholders, each one having his own perception for the context under consideration [1]. For instance, in the clinico-genomic domain, teams comprising statisticians, biologists and genomic

S. Christodoulou · N. Karacapilidis (✉) · M. Tzagarakis
Computer Technology Institute & Press "Diophantus" and University of Patras, 26504 Rio Patras, Greece
e-mail: nikos@mech.upatras.gr

S. Christodoulou
e-mail: shristod@cti.gr

M. Tzagarakis
e-mail: tzagara@upatras.gr

J.W. Tweedale et al. (eds.), *Intelligent Decision Technology Support in Practice*, Smart Innovation, Systems and Technologies 42,
DOI 10.1007/978-3-319-21209-8_6

researchers have to collaborate and decide how to structure an experiment, which of the available data to take into account and how to interpret the experimental results; in the medical domain, teams consisting of biologists, medical doctors and technicians engaged in clinical drug trials need to elaborate a number of medical treatment issues; in the marketing domain, professionals involved in web-based opinion mining tasks have to consider issues related to which sites to monitor and how to interpret the associated results.

In the aforementioned settings, the decision making process should take into consideration a variety of criteria. Reaching consensus [2] requires, apart from adequate decision making algorithms, diverse collaboration mechanisms for the expression of concerns, conflicting ideas (interpersonal conflicts) [3] and tacitknowledge (knowledge that the members do not know they possess or knowledge that members cannot express with the means provided). Such issues become even more important when decision making is conducted in data-intensive contexts, characterized by great volume, velocity and variety of data [4].

A number of Group Decision Support Systems (GDSS) have been proposed in the literature [5], each of them implementing an aggregation preference method to enhance reaching of consensus among a group of individuals. Among the various aggregation preference methods, Multiple Criteria Decision Making (MCDM) methods [6] were found to be particularly suitable for GDSS since they are interactive, permit multiple viewpoints of a problem and focus on the decision process rather than on its outcomes alone [7]. However, GDSS usually focus on the needs of specific communities and implement reasoning mechanisms suited to a specific type of problem. As a consequence, decision makers facing diverse problems are forced to use separate systems to meet their needs. In addition, GDSS lack media richness as most of the information has to be in textual form. Moreover, limited support is provided for 'what-if' analysis and expression of tacit knowledge. Current systems only inform decision makers about the optimal decision but this is rarely enough; stakeholders require additional information concerning how each decision was made, the parameters taken into account and the processes/data that led to these decisions (decision provenance).

This chapter presents an approach aiming to remedy the above problems by providing an integrated environment that facilitates and augments collaboration and decision making in diverse data-intensive and cognitively-complex settings. The proposed approach builds on the formalization of the collaboration space to provide alternative visualizations that enable both human and machine understandable argumentative discourses. A number of diverse reasoning mechanisms have been integrated to support multi-disciplinary decision makers reach a decision; stakeholders are able to focus on the multiple 'components' of the decision making process (including the mechanism parameters and related data) to realize why an alternative is preferred over another one. The proposed approach has been developed in the context of an FP7 EU research project, namely Dicode (http://dicode-project.eu/).

The remainder of this chapter is structured as follows: Sect. 6.2 presents requirements and challenges related to collaboration and decision making support in knowledge intensive environments; Sect. 6.3 discusses related work in the area of multi-criteria decision making; Sect. 6.4 describes the overall approach followed in the Dicode project, while Sect. 6.5 focuses on the mechanisms supporting collaborative decision making; Sect. 6.6 uses an example scenario to demonstrate how Dicode may be used to augment the quality of collective decision making; finally, Sect. 6.7 concludes the chapter.

6.2 Requirements and Challenges

To meet the challenges associated with supporting collaboration and decision making in diverse data-intensive and cognitively-complex settings, a series of interviews to identify the major issues that stakeholders face during their collaboration practices was performed. These were:

- **Information overload**. This is primarily due to the extensive and uncontrolled exchange of diverse types of data and knowledge resources. For instance, such a situation may appear during the exchange of numerous ideas about the solution of a public issue, which is accompanied by the exchange of big volumes of positions and arguments in favor or against each solution.
- **Difficulty in monitoring social behavior**. The representation and visualization of social structures, relationships and interactions taking place in a collaborative environment with multiple stakeholders are also of major importance. This is associated to the perception and modeling of actors, groups and organizations and their behaviors in the diversity of collaborative contexts. A problem to be addressed is to provide the means to appropriately represent and manage user and group profiles, as well as social relationships given that they are not static but changing over time.
- **Diversity of collaboration modes**. Interviews indicated that the evolution of a collaboration session proceeds incrementally; ideas, comments, or any other type of collaboration objects are exchanged and elaborated, and new knowledge emerges slowly. When members of a community participate in a collaborative session, enforced formality may require them to specify their knowledge before it is fully formed. Such emergence cannot be attained when the collaborative environment enforces a formal model from the beginning. On the other hand, formalization is required in order to ensure the environment's capability to support decision making or estimate the present state of the collaboration
- **Expression of tacit knowledge**. A group of people is actually an environment where tacit knowledge predominantly exists and dynamically evolves.
- **Difficulty in exploiting and integrating legacy resources**. Many resources required during a collaborative session have either been used in previous sessions or reside outside the members' working environment such as e-mails and results from the execution of various data processing algorithms. Moreover, outcomes of past collaboration activities should be able to be reused as input in subsequent collaborative sessions. Such functionality must be provided in ways that do not disrupt or impede an ongoing collaboration.

- **Data processing and decision making support**. In the settings under consideration, timely processing of data related to both the social context and social behavior is required. Such processing will significantly aid the members of a community to conclude the issue at hand (by extracting meaningful knowledge and reaching a decision). This means that their environment needs to interpret the knowledge item types and their interrelationships in order to proactively suggest trends or even aggregate data and calculate the outcome of a collaborative session.

The above issues delineated some categories of crucial requirements to be met during the development of Dicode's collaborative decision making support services.

6.3 Multi-criteria Decision Making

MCDM concerns the evaluation of a number of *alternatives* on the basis of a number of *criteria* (attributes) [6]. Alternatives refer to the different (usually finite) choices available to the decision maker for the problem under consideration, while criteria correspond to the different dimensions from which the alternatives may be viewed. A number of different MCDM methodologies have been proposed, each one suited to address a different type of problem. Major MCDM categories include *elementary methods*, methods based on *Multi-Attribute Utility Theory* (MAUT) and *outranking* approaches [8].

The elementary methods are rather simple; they require small computational effort for the analysis and are more suited to problems with a relatively small number of alternatives and criteria. Methods of this category include: (i) the *maximin* method (the best alternative is considered to be the one with the highest score concerning the weakest criterion) and *maximax* method (the best alternative is the one with the best score concerning the criterion with the highest performance), (ii) the *conjunctive* method (calculates a set of acceptable alternatives, where an acceptable alternative is defined as one which performs above a predefined threshold for all the criteria) and *disjunctive* method (an acceptable alternative should perform above a predefined threshold for at least one criterion), and (iii) the *Lexicographic Decision Making* (LDM) rule (the best alternative is the one with the best performance relatively to the most important criterion).

Approaches based on MAUT are compensatory as they permit trade-offs among the attributes of an alternative (a good performance concerning one attribute may compensate for a bad performance concerning another attribute). Each criterion is associated with a weight to balance the performance of the alternative on the basis of the specific criterion (computing the corresponding alternative's subscore). The total score of an alternative is calculated by aggregating its partial subscores. The simplest method of this category is the Weighted Sum Model (WSM) method, where the alternative's score is calculated as the weighted sum of its subscores. The Analytic Hierarchy Process (AHP) [9] uses a linear additive model to calculate the alternatives' scores, based on pairwise comparisons among the criteria (the relative importance of criterion A to criterion B) and the alternatives (the relative importance of alternative A to alternative B with respect to each criterion).

Finally, the outranking methods are based on the concept of *outranking* to eliminate alternatives that are "dominated". An alternative $A$is considered to outrank an alternative B if there are enough criteria of sufficient importance such that A outperforms B (with respect to these criteria) and there are not any criteria such that A has significantly inferior performance with respect to B. Outranking methods allow two alternatives to be noted as "incomparable". Among the most popular outranking methods are those of the ELECTRE family [10]. ELECTRE I is based on the calculation of the concordance and discordance indices to calculate a partial ranking and choose a set of promising alternatives. ELECTRE I evolved in ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE IS and ELECTRE TRI. The family of PROMETHEE methods [11] has been designed to help a decision-maker rank partially (PROMETHEE I) or completely (PROMETHEE II) a set of alternatives evaluated on k criteria. The steps of the basic PROMETHEE method include the definition of a preference function for each criterion, a multi-criteria preference index and the preference flows (normed flows), as well as the computation of a complete or partial ranking of alternatives based on the defined preference structure.

6.4 The Dicode Approach

The overall goal of the Dicode project is to facilitate and augment collaboration and decision making in diverse data-intensive and cognitively-complex settings [12]. To do so, it builds on prominent high-performance computing paradigms and large scale data processing technologies to meaningfully search, analyze and aggregate data existing in diverse, extremely large, and rapidly evolving sources. At the same time, particular emphasis is given to collaboration and sense making support issues. The Dicode approach brings together the reasoning capabilities of the machine and the humans and enables the meaningful incorporation and orchestration of a set of interoperable web services to reduce the data-intensiveness and complexity overload in collaborative decision making settings.

Services developed and integrated in the context of the Dicode project are released under an open source license. Services already provided for the context under consideration include (this chapter focuses on the last category of services):

- **Data acquisition services**: They enable the purposeful capturing of tractable information that exists in diverse data sources and formats. Much attention is given to issues such as exploitation of new data sources, augmentation of the data volume, and data cleansing.
- **Data mining services**: These services provide functionality such as looking for subgroups in any user provided data (by searching the rules that cover many target value examples and few non-target values) and recommending similar users or documents from log file data (based on similarity models examples).

- **Collaborative decision making support services**: They facilitate the synchronous and asynchronous collaboration of stakeholders through adaptive workspaces, efficiently handle the representation and visualization of the outcomes of the data mining services (through alternative and dedicated data visualization schemas) and enable the orchestration of a series of actions for the appropriate handling of data. These services provide an interactive search and analysis mechanism for indexing and searching of standard documents. In addition, they aim to enhance (both individual and group) sense- and decision-making by supporting stakeholders in locating, retrieving and arguing about relevant information and knowledge, as well as by providing them with appropriate notifications and recommendations (taking into account parameters such as preferences, competences, and expertise). Services of this category build on an appropriate formalization of the collaboration and exploit a series of reasoning mechanisms to support stakeholders in their daily decision making processes.

Central to the proposed approach is the concept of the Dicode Workbench [13], a web-based application that follows a widget-based approach [14] to enable the seamless integration of heterogeneous services and ensure their interoperability from both a technical and a conceptual point of view. In this regard, semantics techniques have been exploited to define an ontological framework for capturing and representing the diverse stakeholder and services perspectives.

Technically speaking, the Dicode Workbench uses *iframe* elements to display the services (one iframe element per service is used). The service displayed in the iframe may use any of the state-of-the-art web technologies such as HTML5, CSS3, JavaScript, AJAX or jQuery. To integrate a service in the Dicode Workbench, service providers have to follow a number of necessary steps: develop the service (including the implementation of the service logic and the necessary public interface for invoking the service—usually, the exchange of structured information is based on RESTful calls or WS-* (SOAP) [15]), develop the web interface of the service (to allow user interaction with the service), deploy the service and the web interface (both accessible through an URL/URI to the web server hosting the service), and finally register/publish the service in Dicode (service registration includes providing metadata for the service, annotations contained in the Dicode ONtology (DON) [16] and the URI of the service). The Dicode Workbench enables integration of services in two distinct types (it is up to each service's developer to select the most appropriate integration type): at the user interface level (called *light integration*), and at a deeper, semantic level (called *full integration*).

6.5 Collaborative Decision Making in Dicode

Support for collaboration and decision making in Dicode brings together two paradigms: the Web 2.0 paradigm, which builds on flexible rules favoring ease-of-use and human interpretable semantics, and the traditional decision support paradigm, which requires rigid rules that reduce ease-of-use but render machine interpretable semantics. To achieve this, the approach adopted builds on a conceptual framework, where formality and the level of knowledge structuring during collaboration is not considered as a predefined and rigid property, but rather as an adaptable aspect that can be modified to meet the needs of the tasks at hand. The term formality refers to the rules enforced by the system, with which all user actions must comply. Allowing formality to vary within the collaboration space, *incremental formalization*, a stepwise and controlled evolution from a mere collection of individual ideas and resources to the production of highly contextualized and interrelated knowledge artifacts and finally decisions, can be achieved [6].

Dicode offers alternative visualizations of the collaboration workspace (called Dicode *views*), which comply with the above mentioned incremental formalization concept. Each Dicode view provides the necessary mechanisms to support a particular level of formality. The more informal a view is, the greater easiness-of-use is implied. At the same time, the actions that users may perform are intuitive and not time consuming; however, the overall context is human (and not system) interpretable. On the other hand, the more formal a view is, the smaller easiness-of-use is rendered; the actions permitted are less and less intuitive and more time consuming. The overall context in this case is both human and system interpretable [7]. The views supported in the Dicode approach are:

- **Mind-map view**, where a collaboration workspace is displayed as a mind map that enables an informal representation and interrelation of collaboration items, while bearing a set of useful semantics.
- **Formal argumentation view**, which adheres to the IBIS argumentation model [17] and invokes a set of dedicated scoring and reasoning mechanisms to aid users conceive the outcome of a collaborative session and receive support towards reaching a decision.
- **Multi-criteria decision making view**, where a set of multi-criteria decision making algorithms can be executed to rank the alternative solutions.

During collaboration sessions, each user can individually choose the view with which he/she may want to conduct the collaboration. In the following, the three views are presented in more detail.

6.5.1 Mind-Map View

In this view, the collaboration workspace is displayed as a mind map (Fig. 6.1), where users can upload and interrelate diverse types of items. This view deploys a spatial metaphor permitting the easy movement, arrangement and structuring of items on the collaboration workspace. The aim of this view is to support *information triage* [18], the process of sorting and organizing through numerous relevant materials and organizing them to meet the task at hand.

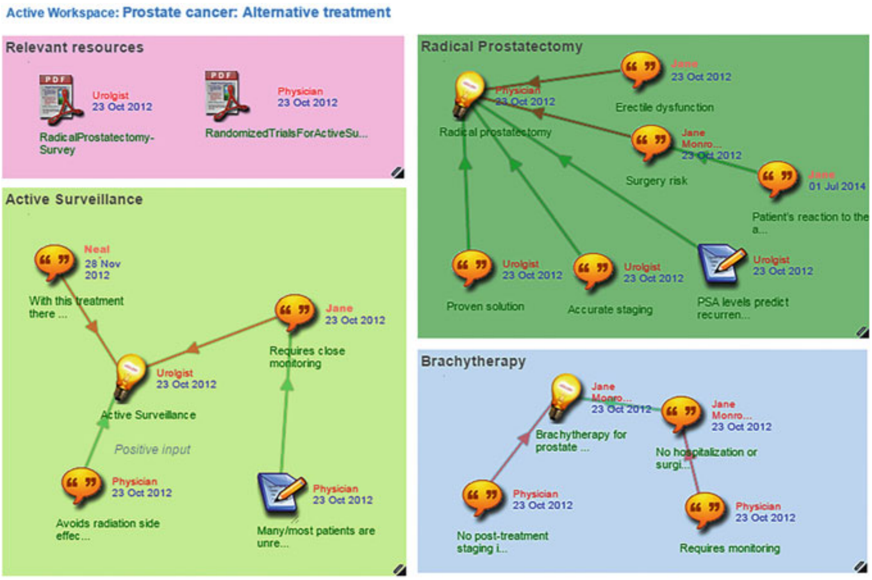

Fig. 6.1 An instance of the mind-map view of a collaboration space with various collaboration items and interrelations among them

While working in the Mind-map view of the collaboration workspace, stakeholders may organize their collaboration through dedicated item types such as ideas, notes, comments and services. Ideas stand for items that deserve further exploitation; they may correspond to an alternative solution to the issue under consideration and they usually trigger the evolution of the collaboration. *Notes* are generally considered as items expressing one's knowledge about the overall issue, an already asserted idea or note. *Comments* are items that usually express less strong statements and are uploaded to express some explanatory text or point to some potentially useful information. Finally, *service* items enable users to upload, configure, trigger and monitor the execution of external services from within the collaboration workspace, and allow the automatic upload of their results into the workspace (as soon as the execution of the service is completed). The service items as well as the results they produce are part of the discourse and can be handled like any other of the available items. Multimedia resources can also be uploaded into the Mind-map view (the content of which can be displayed upon request or can be directly embedded in the workspace). In any case, the set of available item types in the Mind-map view is not fixed; users may expand the existing set by creating new types to be used during their collaboration. This allows them to tailor the discourse to the needs of the problem at hand. Users may rate individual items on a 1–5 scale indicating the importance of each item.

All item types can be explicitly related to express agreement, disagreement, support, request for refinement, and contradiction. Visual cues are used to indicate the semantics of such relationships: for instance, a green-colored relationship indicates agreement, while a red-colored one indicates disagreement. Moreover, the thickness of a relationship may express how strongly an item agrees with or objects to another one. Finally, the Mind-map view provides abstraction mechanisms that enable items to be aggregated and be treated as a single entity within the workspace (see the colored rectangles in Fig. 6.1).

6.5.2 The Formal Argumentation View

The *formal argumentation view* of a collaboration workspace permits a limited set of discourse moves for a limited set of message types whose semantics is fixed and system defined. Following the IBIS argumentation model [17], items of this view include: (i) the *issue* (the problem under consideration), (ii) the *alternatives* (the different choices a decision maker has concerning the problem under consideration), (iii) the *positions* (positions are of two types: "in favor", for supporting, or "against", for refuting another position or alternative), and (iv) the *preferences* (to weigh the importance of two positions).

The formal argumentation view depicts the items created in the mind-map view of the collaboration workspace in a hierarchical way. Collaboration items are laid out in a tree-like structure, where the root (issue) is the title of the problem under consideration and alternatives are nodes appearing as children of the root issue.

Transformation rules allow items appearing on the mind-map view of collaboration workspaces to be transformed into the appropriate abstractions of the formal argumentation view. In particular, specific types in the mind-map view can be configured to be transformed into alternatives, when a transformation is requested. Currently, the default type "idea" is transformed into alternative when the workspace is operated in the formal argumentation view; however, this may vary according to the use case or workspace under consideration and, in general, any type can be specified to be transformed into an alternative. In the mind-map view, all collaboration items linked to items that will be transformed into alternatives, are transformed to form positions (arguments "in favor" or "against") in the tree structure of the formal view, taking into account the corresponding relations in the mind-map view (visual cues are used to specify the semantics of relationships; for instance, a green relation refers to a position "in favor", a red relation refers to a position "against"). Apart from the items earlier created in the mind-map view and depicted in the formal view, the user may use the provided functionality of this view to create new items and interrelations among them (add a new alternative, add a position to support or object to an alternative (or position), add a preference to express the relative importance of a position over another).

Each time an element is added on the formal collaboration workspace, an underlying reasoning mechanism is triggered and, based on the whole tree structure (alternatives, positions and preferences), calculates (and informs users about) the most prominent alternative. The reasoning algorithm of HERMES system [19] has been integrated to evaluate the alternatives. For each alternative, the corresponding alternative score is calculated as the algebraic sum of the weights of the active positions in favour of this alternative minus the weights of the active positions against this alternative as shown in Eq. 6.1.

$$score(e_i) = \sum\nolimits_{\text{in}\_favor_{p_j}} weight - \sum\nolimits_{against_{p_i}} weight \qquad (6.1)$$

The formal argumentation view aims to make the collaboration space machine—understandable and exploit the reasoning capabilities of machine to support the decision making process.

6.5.3 The Multi-criteria Decision Making View

The *multi-criteria decision making view* (Fig. 6.2) of a collaboration workspace is a read-only view; its main purpose is to further support the decision making process by considering the attributes of the collaboration items appearing in the 'mind-map view'

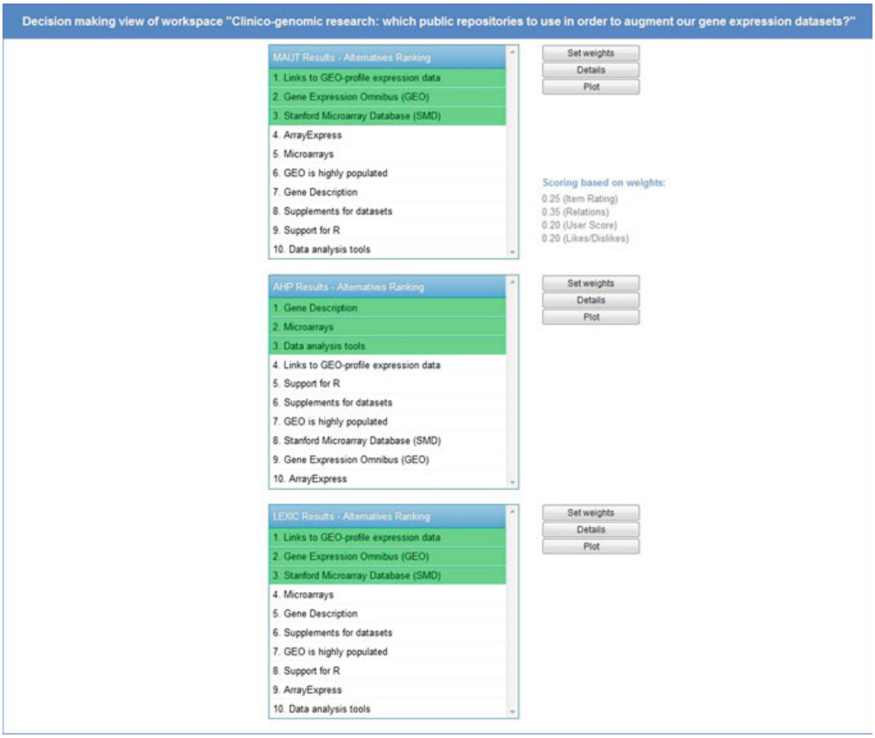

Fig. 6.2 An instance of the Multi-criteria decision making view

and exploiting diverse MCDM algorithms to indicate prevailing solutions. Based on the attributes of each alternative, each MCDM algorithm calculates a corresponding alternative score; the alternative with the highest score is considered to be the best solution to the problem at hand.

In Dicode, four attributes/criteria are used for the evaluation of each alternative:

- *Likes/Dislikes*. The algebraic sum of an item's number of 'Likes' minus its number of 'Dislikes'.
- *Creator Rating*. Calculated as the algebraic sum of all 'Likes' minus all 'Dislikes' corresponding to the items the creator has contributed on a workspace.
- *Relationships in-favor/against*. The algebraic sum of an item's number of 'in favor' relationships minus the item's number of 'against' relations
- *Item rating*. The total rating corresponding to the users' preferences (expressed through an 1–5 rating scale)

The selection of the MCDM algorithms to be implemented in the context of this view was based on a questionnaire filled in by senior decision makers, acting in diverse data-intensive settings. According to the results of this questionnaire, the best suited decision making methodology highly depends on the specific problem under consideration. Depending on the specific problem, decision makers would require support from methodologies that: (i) allow compensation among the attributes/criteria used for the evaluation of the alternatives (a good performance of an alternative concerning one attribute can compensate for a bad performance concerning another attribute), (ii) allow two or more alternatives to be incomparable, and (iii) do not allow compensation among criteria.

Three MCDM algorithms, fulfilling the aforementioned prerequisites, have been implemented in the context of this view: *the Weighted Sum Model (WSM), the Analytical Hierarchy Processing (AHP) and the Lexicographic Decision Making rule (LDM)*. For each algorithm, the user has to set the necessary parameters and, upon the execution of the algorithm, the calculated ranked list of the alternatives is returned. The user may then browse through the detailed results of the algorithm (to realize the reason why an alternative performs better than another one), view the plot with the scores of the alternatives or reset the algorithm's parameters to perform a 'what-if' (sensitivity) analysis [20]. The mechanisms developed in this view build on the reasoning capabilities of the machine to enhance decision making. In the next subsection, the three algorithms implemented in this Dicode view are briefly presented.

6.5.3.1 The Weighted Sum Model

The *Weighted Sum Model (WSM)* is the most popular and probably most used MCDM approach. For a number of M alternatives and N criteria, the best alternative is the one with the top score calculated in Eq. 6.2.

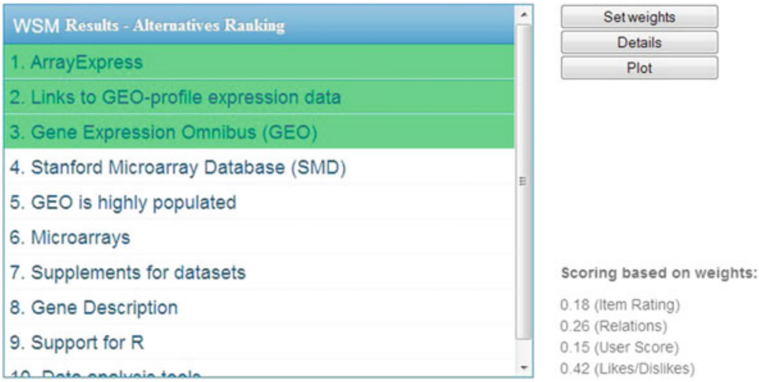

Fig. 6.3 Alternatives ranking based on WSM

$$A^*_{wsm} = max_i \sum_{j=1:N} q_{ij} w_j \quad \text{for } i = 1, 2, 3, \ldots M \tag{6.2}$$

where A^*_{wsm} is the score calculated for the best alternative, N is the number of criteria (for the Dicode case, $N = 4$), q_{ij} is the subscore of the i-th alternative with respect to the j-th factor and w_j is the factor weight (user-defined) reflecting the relative importance of the j-th factor. The output of the algorithm is a list of the alternatives in descending score order (Fig. 6.3).

The user may change the predefined weights of the four factors, browse through each alternative's score and sub-scores (each sub-score corresponds to one of the four factors) or view the plot of the results.

6.5.3.2 Analytical Hierarchy Processing

Analytical Hierarchy processing (AHP) is based on decomposing a problem into a system of hierarchies. Its first step includes constructing a NxN matrix (N is the number of attributes) expressing the relative values of a set of attributes. Setting value x to the a_{ij} element of this matrix states that attribute i is x times more important than attribute j. The next step includes constructing N matrices of dimension MxM (M is the number of alternatives), where setting the value y in the element b_{ij} of the matrix states that alternative i is y times more important than alternative j (with respect to a specific criteria). Values of x and y are taken from a common scale (the Saaty rating scale—see Table 6.1) used to declare the rel ative importance of an attribute (or an alternative) over another.

Based on the previously described matrices, the *Relative Value Vectors* (RVV) and the *Option Performance Matrix* (OPM) are calculated using the eigenvectors of each table. The vector (VFM) including the corresponding alternatives scores is calculated in Eq. 6.3.

$$VFM = OPM * RVV \tag{6.3}$$

Table 6.1 The saaty rating scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experince and judgement slightly favour one over the other
5	Much more important	Experince and judgement strongly favour one over the other
7	Very much more important	Experince and judgement strongly favour one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity
2, 4, 6, 8	Intermediate values	When compromise is needed

In the context of Dicode, an open source library (AHP.NET—http://www.kniaz.net/software/ahp.aspx) has been used to conduct all the matrix calculations needed for the AHP algorithm. Concerning the implementation of the algorithm in Dicode, a wizard (Fig. 6.4) is used to perform all the basic steps of the AHP (that include

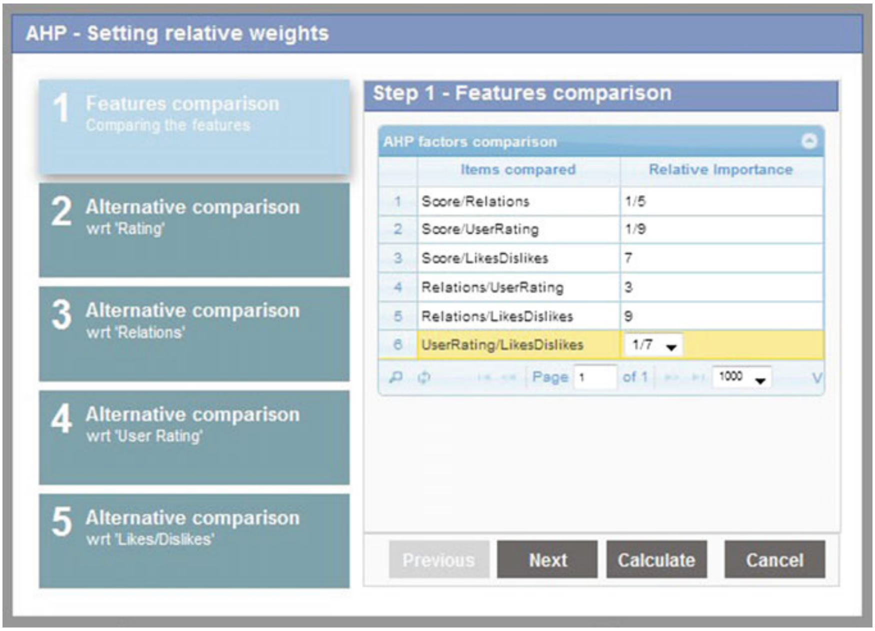

Fig. 6.4 Setting the relative weights in AHP

Fig. 6.5 Sorting attributes with respect to their importance in the Lexicographic DM rule

inputting all the necessary values stating the relative importance among all pairs of criteria and alternatives).

6.5.3.3 The Lexicographic Decision Making Rule

The *Lexicographic Decision Making (LDM) rule* is a decision rule based on ranking the attributes of the decision making process on terms of their importance. No compensation is allowed between the attributes. In the context of Dicode, the user has to rank the four attributes based on their importance. The calculation of the rank of alternatives is based on the partial score (the performance) of each alternative with respect to the most important attribute.

The Dicode user has to rank the four attributes based on their importance (Fig. 6.5). Calculating the rank of alternatives is based on the partial score of the most important attribute. If there are two or more equal sub-scores with respect to the most important attribute, the algorithm moves to the next more important attribute, compares the respective sub-scores and the procedure is repeated until all alternatives are distinguished and ranked (or the attributes are finished, in the case of alternatives with identical sub-scores).

6.6 Scenario of Use

To better illustrate the proposed approach, this section presents an illustrative real-world scenario from the area of prostate cancer research. A physician (George), an urologist (John) and a biomedical researcher (Jane) aim to investigate which is the best alternative treatment for the prostate cancer. Initially, they set up a Dicode collaboration workspace and start using it in the formal argumentation view (Fig. 6.6).

John suggests that one of the best and most popular treatments for the prostate cancer (Fig. 6.6a) is the "active surveillance". He adds an alternative to make his statement (Fig. 6.6b). Jane is not in favor of this option, because it requires close monitoring (regular digital rectal exams, PSA tests, and prostate biopsy) to monitor for signs of progression, so she adds her 'against' position on the collaboration workspace (Fig. 6.6d). Contrary to Jane, George supports the John's opinion ('in favor' position supporting the alternative suggested by John (Fig. 6.6c), in the sense that active surveillance avoids site effects from radiation therapy or prostatectomy. He contradicts to Jane's opinion ('against' position) because, according to his experience, most patients are unreliable as many, or most of them, neglect to visit doctors. On the other hand, he is skeptical as with Active Surveillance there is no post-treatment staging information ('against position'—Fig. 6.6e).

Jane argues that "Brachytherapy" has been also used to treat tumors in many body sites and this could be one option (alternative). One of its major advantages is that this procedure does not need hospitalization ('in favor' position) and, furthermore, there

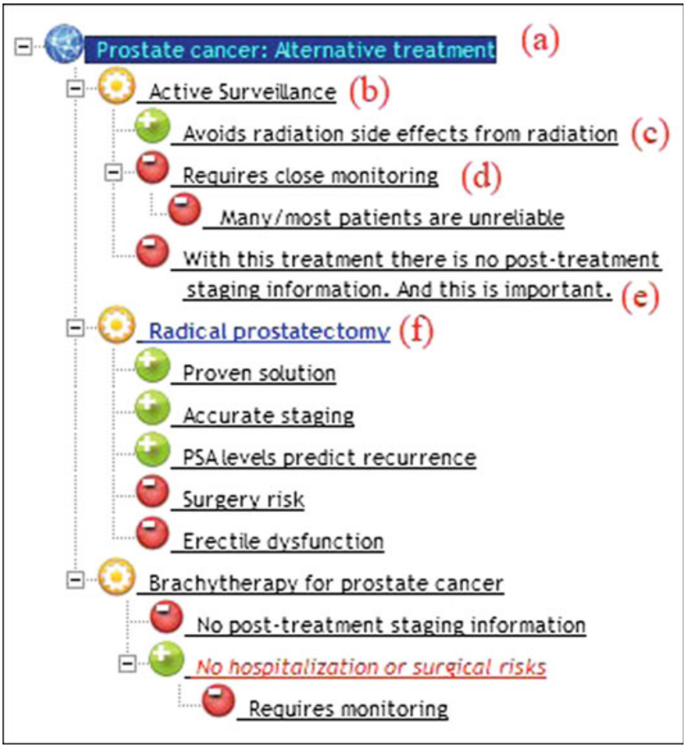

Fig. 6.6 An instance of the formal argumentation view of the collaboration space

are no surgical risks involved. John is not convinced by her arguments as Brachytherapy requires close monitoring ('against' position), which may even include hospital visits. He is so convinced that he adds a preference stating that his position is more important than the one Jane posted before (preference of type 'more important than'). To support his consideration against the Brachytherapy, John denotes that there is no post-treatment staging information which is also an important factor ('against' position).

George argues that the best alternative, in his opinion, is "radical prostatectomy" as it is quite common with very good results. John is in favor of this option ('in favor' position) as this solution is proven to reduce prostate cancer death rates. Moreover, the removed tissue allows accurate stating ('in favor' position), which is very important and the PSA levels may reliably predict the recurrence ('in favor' position). Jane does not share their enthusiasm as, due to surgery, a certain amount of risk is involved ('against' position). Apart from this, an erectile dysfunction is expected at the level of 30–50 % in 5 years. According to the input provided so far by the three collaborators, the underlying reasoning mechanism calculates that the alternative "Radical prostatectomy" is the best argumented/winning one (Fig. 6.6f). It is also noted that the three collaborators, instead of only using the formal argumentation view, could have also used the provided functionality of the mind-map view to express their speculations for the problem at hand (and then move to the formal argumentation view to fire the reasoning mechanism).

Having exploited the functionalities of the formal argumentation view, the above stakeholders have not reached a final conclusion concerning the best treatment for the prostate cancer. Jane suggests using the multi-criteria decision making view of the collaboration workspace, where a number of MCDM algorithms may help them reach a more acceptable decision. They all agree to switch back to the mind-map view of the collaboration workspace to express their likeness/dislikeness and rate preferences on the collaboration items; then, they move to the multi-criteria decision making view.

Jane believes that among the three offered algorithms the one closest to their needs is the WSM, so she sets the respective parameters and browses through the detailed results of the algorithm, the graphical representation of the alternatives scores and the alternatives list. According to WSM results (depicted in Fig. 6.7a), the "Active surveillance" is the optimal alternative to be followed. George believes that the best algorithm to be used is the AHP as it is a very popular algorithm in the area of multi-criteria decision making and allows the pairwise comparison of both criteria and alternatives. He initiates the wizard to set the corresponding AHP weights and calculates the scoring of each alternative revealing that, unlike WSM, "Radical Prostatectomy" is the prevailing alternative (relative AHP scores in Fig. 6.7b). John is in favor of using the LDM rule as, according to his opinion, no compensation should be allowed among the four criteria (in other words, the alternative with the best partial score for the most important criterion should be the winning one). He sets the order of the four criteria and calculates the score for each alternative; the results (Fig. 6.7c) certify that "Brachytherapy" is the best treatment for the prostate cancer. Having used the provided MCDM algorithms, stakeholders compare the respective

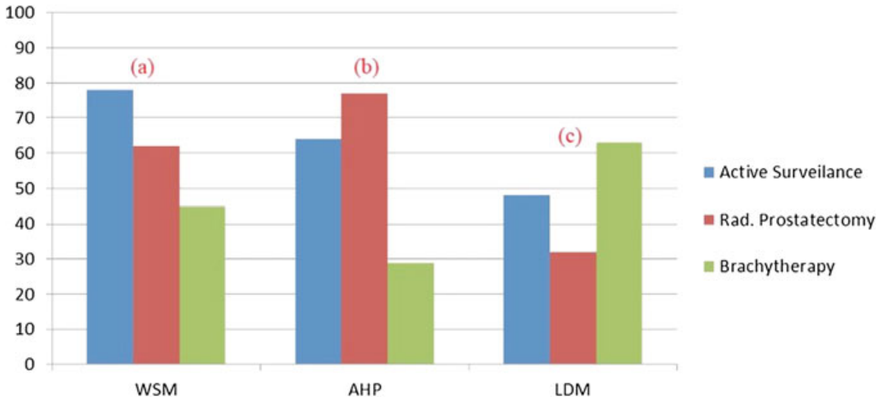

Fig. 6.7 Total scores of the three alternatives calculated after applying the WSM, AHP and LDM methods

results (alternatives' rankings). Through such a sensitivity ('what-if') analysis, they are in a better position to reach a final decision; for instance, they can continue their argumentation towards interpreting the outcomes of the MCDM algorithms provided and reaching consensus on the appropriate treatment to be followed.

6.7 Discussion and Conclusion

Making collaborative decisions in situations involving multi-disciplinary stakeholders with different perceptions remains a challenging task. Traditional decision making systems foster particular reasoning mechanisms aiming at meeting specific needs. On the contrary, the proposed approach integrates a number of reasoning mechanisms into the stakeholders' working context. The integrated collaboration and decision making mechanisms, ranging from simple to compensatory and non-compensatory methods, have been selected to apply to a wide range of decision making contexts. While traditional decision making systems provide limited visualization capabilities, the proposed approach provides a wide range of visualizations, each one offering a varying degree of formality to allow incremental formalization of the overall collaborative decision making context. Work reported in this chapter can be seen as complementary to research focusing on alternative visualizations of argumentation [21].

The major contribution of this work concerns the implementation of a number of mechanisms that are not only capable of displaying the result of the decision making process and enabling a user-friendly 'what-if' analysis, but also of providing additional information concerning how each decision was made and which are the respective processes/data that led to these decisions (decision provenance). Future work directions include the collaborative selection of the appropriate MCDM method to be used as well as the collaborative setting of the parameters that affect the decision making mechanisms; moreover, investigation of additional attributes/criteria to be taken into account in the evaluation of each alternative.

References

1. Jelassi, M.T., Kersten, G., Zionts, S.: An introduction to group decision and negotiation support, In: Bana e Costa, C.A. (ed.) Readings in Multiple Criteria Decision Aid. Springer, Berlin (1990)
2. Ness, J., Hoffman, C.: Putting Sense into Consensus: Solving the Puzzle of Making Team Decisions, Tacoma. VISTA Associates, Wash (1998)
3. Bogetoft, P., Pruzan, P.: Planning with Multiple Criteria: Investigation, Communication, Choice. North Holland, Amsterdam (1991)
4. Challenges and Opportunities with Big Data, White Paper, Computing Community Consortium, Spring (2012)
5. Hwang, C.L., Ling, M.J.: Group Decision Making Under Multiple Criteria. Lecture Notes in Economics and Mathematical Systems, vol. 281. Springer, Berlin (1987)
6. Figueira, J., Greco, S., Ehrogott, M.: Multiple Criteria Decision Analysis: State of the Art Surveys. International Series in Operations Research & Management Science, vol. 78, (2005)
7. Bui, T.X., Jarke, M.: Communications design for Co-oP: a group decision support system. ACM Trans. Off. Inf. Syst. **4**, 2 (1986)
8. Vincke, P.: Multi-criteria Decision-Aid. Wiley, Chichester (1992)
9. Saaty, T.L.: The Analytic Hierarchy Process. McGraw-Hill, New York (1980)
10. Roy, B.: The outranking approach and the foundations of ELECTRE methods. Theory and Decision **31**, 49–73 (1991)
11. Brans, J.P., Mareschal, B., Vincke, Ph.: PROMETHEE: a new family of outranking methods in multicriteria analysis. In: Brans, J.P. (ed.) Operational Research, IFORS 84, pp. 477–490. North Holland, Amsterdam (1984)
12. Karacapilidis, N., Rüping, S., Tzagarakis, M., Poigné, A., Christodoulou, S.: Building on the synergy of machine and human reasoning to tackle data-intensive collaboration and decision making. In: Proceedings of IDT 2011, pp. 113–122. Piraeus, Greece (2011)
13. de la Calle, G., Alonso-Martínez, E., Tzagarakis, M., Karacapilidis, N.: The dicode workbench: a flexible framework for the integration of information and web services. In: Proceedings of the 14th International Conference on Information Integration and Web-based Applications & Services (iiWAS2012), pp. 16–25. Bali, Indonesia, 3–5 Dec 2012
14. Swick, R.R., Ackerman, M.S.: The X toolkit: more bricks for building user interfaces, or widgets for hire. In: Usenix Winter 1988 Conference, pp. 221–228 (1988)
15. Pautasso, C., Zimmermann, O., Leymann, F.: Restful web services vs. "big" web services: making the right architectural decision. In: Proceeding of the 17th International Conference on World Wide Web, pp. 805–814. ACM, New York, NY, USA (2008)
16. Thakker, D., Yang-Turner, F., Lau, L., Dimitrova, V.: Socio-technical ontology development for modelling sensemaking in heterogeneous domains. In: Proceedings of OCAS 2011 Workshop at the 10th International Semantic Web Conference, pp. 60–71. Bonn, Germany, (Oct 2011)
17. Kunz, W., Rittel, H.W.J.: Issues as elements of information systems. Working paper, 1–9. University of California at Berkeley (1970)
18. Marshall, C.C., Shipman, F.M.: III: Spatial hypertext and the practice of information triage, In: Proceedings of the 8th ACM Conference on Hypertext, pp. 124–133. Southampton, United Kingdom, 06–11 (April 1997)
19. Karacapilidis, N., Papadias, D.: Computer supported argumentation and collaborative decision making: the HERMES system. Inf. Syst. **26**(4), 259–277 (2001)
20. Triantaphyllou, E., Sanchez, A.: A sensitivity analysis approach for some deterministic MCDM methods. Decis. Sci. **28**(1), 151–194 (1997)
21. Scheuer, O., Loll, F., Pinkwart, N., McLaren, B.M.: Computer-supported argumentation: a review of the state of the art. Int. J. Comput. Support. Collaborative Learn. **5**(1), 43–102 (2010)