A Process to Support and to Report Collaborative Decision

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Abstract

This paper introduces a process to support a collaborative decision made by experts, like collaborative modelling, design choice or collaborative validation, and a formal framework to understand and analyze the final decision. We propose a methodology in two steps: a graphical modeling of the debate to support experts and a more formal framework to record the rationale of the decision. The intended benefits of this methodology are to support the collaborative decision process and to record the motivations of the decision, we illustrate it with an industrial study case.

1. Introduction

In [PC11], we presented a formal framework to automatically analyse a decision taken by a group of experts. Based on graph theory, this framework allows to check if a decision is sufficiently supported by arguments or if the arguments are evidence-based, and to define numerical validity degrees of a final decision.

If this framework is sufficient to report a collaborative decision, it appeared, in practice, that it was not easy to use. Indeed, such framework needs to be integrated in the collaborative decision process, meaning from the meeting of experts until the recording of the final decision, and it also must not increase the complexity of the decision-making process. So, we decided to use a more user-friendly representation of the discussion amongst experts at the beginning of the decision process and to project it into our formal framework afterwards.

Regarding the beginning of the decision-making process, for example a meeting where experts discuss a choice, having a representation of the debate can be a valuable help for taking decisions and those for several reasons. Firstly, as [Twa04] shows, with a visual representation, people better understand the links amongst arguments and reason more easily. Secondly, because short-term memory is limited, it is difficult to constantly remember all the ins and outs of a complex conversation. Having a representation of the conversation sharing by participants avoids to debate the same arguments again and again and, *in fine*, allow to verify that there are no open points anymore at the end of the debate i.e. that no issue was forgotten.

Obviously, keeping a record of meetings that captures both the arguments and their relationships can help in the understanding of design rationales, design choices and trade-offs [Bat08]. In fact, having a structured form to record arguments supports communication [SH94]. Keeping track of meetings is very interesting for the constitution of a corporate memory. Over a product's lifecycle, there is a danger that explanations of design decisions are forgotten. Very often, when a project is over, no one remembers why certain choices have been made, mainly because people have left the company or have forgotten, and the reasons for decisions have not been recorded. Recording arguments would avoid having the same discussion all over again, with the same arguments. In addition, recording the rationale of a collaborative decision would allow the discussions to be resumed and experts could introduce new arguments if they felt the need to.

In this paper, we focus on specific collaborative decisions: decisions with consensus. In

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other words, we focus on collaborative decisions where experts take only a single decision. This does not necessarily mean that all experts agree, but only that a decision is eventually taken. Take for instance a committee for the validation of a product. Suppose that, if all experts do not agree then the product is not validated. Therefore, in case of disagreement, we still have a final decision: the product is not validated. One might think that our hypothesis is very restrictive and in most collaborative decisions we do not have a single final decision but rather decisions, a set of options. But, in the European project TOICA[1], we have many cases where it is mandatory for an expert group to make a decision and a single decision. Indeed, we are in cases where not to make a decision, or to hesitate between several alternatives, can be a blocking element in the development process.

TOICA is a European project with 32 partners from eight countries. The purpose of TOICA is to improve aircraft design processes by modelling and simulating it in a collaborative environment. In this context, we have a specific decision maker, the aircraft architect, who is a specialist in conceiving, defining, planning and validating an overall aircraft design. For that, he is assisted by experts from different disciplines and, sometimes, from different companies. In TOICA, an aircraft architect and a group of expert often make collaborative decisions such as: the validation, or not, of a simulation, the pass, or not, for a product to the next Technology Readiness Level or tradeoffs between design alternatives in preliminary phases. Note that, in all these examples, decisions are not making only with "rational scientific" arguments but also with pragmatic arguments (like managerial arguments).

So, our aim is to support and to justify collaborative decision-making. For that, we propose a two-step process to support collaborative decision-making and to report and understand it. In this article, we will explain each step of our process and we will illustrate it with an example. More precisely, in Section 2, we will explain how graphical argumentation can be used to capture the arguments of the experts during a debate as well as the relationships between these arguments. In Section 3, we will present how to record the decision, after it is taken, in our formal framework and Section 4 is devoted to the conclusion.

2. Support and capture a collaborative decision

In this section we introduce how to capture a debate in a graphical way, with the support of argumentation visualisation tools.

2.1. Graphical representation of argumentation

A lot of works used graph visualisation to represent all kinds of activities such as rhetorical reasoning, inference, debates, and trials. In all these works, whether in computer science, legal, logic or linguistic fields, graphical representations of argumentations are "boxes and arrows" diagrams with boxes corresponding to arguments and arrows corresponding to relationships amongst arguments. Of course, it could be possible to use natural language, but the natural language is poorly structured, it is very difficult to track information with it and relations amongst arguments are not clear. The use of graphical notations in engineering sciences, like the Unified Modeling Language (UML), is now common. Recently, graphical notations appeared in a lot of engineering fields like system safety or requirements. Graphical notations, like the Goal Structuring Notation (GSN) [CPK04], are used in the system safety domain to improve the comprehension of safety arguments amongst stakeholders. In the domain of requirements engineering, graphical notations are also used. We can cite, for example, the Requirement Diagram in Systems Modeling Language (SysML) or the KAOS approach[DvLF93].

In the field of collaborative work, the first framework dedicated to the argumentation is

[1] Thermal Overall Integrated Conception of Aircraft `http://www.toica-fp7.eu/`

Issue-Based Information Systems (IBIS) [KR70]. IBIS is an Information System and it was designed to support and to document an information process. IBIS [KBSC03] define three elements: *Questions*, *Ideas* and *Arguments*. Questions are elements representing all questions relative to the topic of the debate. For instance, if a team of experts had to decide which model to use for a simulation, you could have a first question: *"what model to use?"*, but you could link to this root Question to a lot of Question elements such as *Şis a plate model fit-for-purpose?"*, is *"is a beam model fit-for-purpose?"* or *"what is the cost of a plate model?"*. Ideas are simply answers or solution of a Question and Arguments are opinions, facts, data, etc. An Argument could be specified in Pros, or Cons, if it supports, or attacks, an Idea. All these elements are linked by arrows forming a graph called an *argument map*. [KBSC03] present a set of case studies and feedback on how IBIS is used in practice.

During the last decade, an increasing number of visual software has been developed to organise, structure and visualize ideas, tasks and concepts (like mind maps, concept maps, fishbone diagrams, etc.). Using graphics to support reasoning is not new, but the progress of human-computer interaction played a critical role in this evolution. Today, there is a lot of software for visual representation of the structure of an argument (for more information, the reader may refer to [RWM07] for an overview of argumentation representation). For instance, we could name tools like Araucaria[2][RRK03][RR08], Argumentative[3], ArguNet[4][SVB07] or the IBIS software Compendium[5]. In Compendium, new IBIS elements are added, like *List*, *Note* or *Decision*, and there are many relations to connect two elements, for instance: *support*, *specializes* or *expand*. Even if these new elements are needed to finely capture the rational of a debate, they increase the complexity of IBIS and therefore the cognitive cost of using it.

2.2. Our methodology

Our aim is to support experts to come to a decision during a meeting. For that, we propose to capture all arguments given by experts in a document shared by all experts. The notation in this document should be as simple and intuitive as possible. The notation should be also very efficiently in the elicitation of the rational of the debate. A key point is that reading this notation should be natural for the experts, it should not cause cognitive overhead. At this step, it is important to understand that the *argumentation graph* is not a *decision tree*, it does not explain what to do and why a decision has been taken: the argumentation graph is just a report of the debate. We will see in section 3 how we convert the argumentation graph to a decision tree.

Many works studied finely relations amongst arguments. For example, [Wal09] studies the difference between two types of corroborative evidence, firstly, when two arguments support a claim and, secondly, when an argument supports a claim and the second argument is ancillary, it just supports the first argument. In fact, there are a large number of possible relations amongst arguments, but it is not possible to make all these kinds of distinctions on the fly during a meeting. Even if you just focus on relations like attack and support, sometimes, it is difficult to know if an argument given by an expert is pro or con, it could be just a piece of information. Moreover, marking explicitly an argument given by an expert con, in other words saying that an expert attacks an argument given by another expert, could create a feeling of aggression and disturb the collaborative process.

So, after testing a lot of possible notations, we choose to use a graph representation notation and to keep only the IBIS distinction between Argument and Question elements. In-

[2] `http://araucaria.computing.dundee.ac.uk/doku.php`
[3] `http://argumentative.sourceforge.net/`
[4] `http://www.argunet.org/`
[5] `http://compendium.open.ac.uk/`

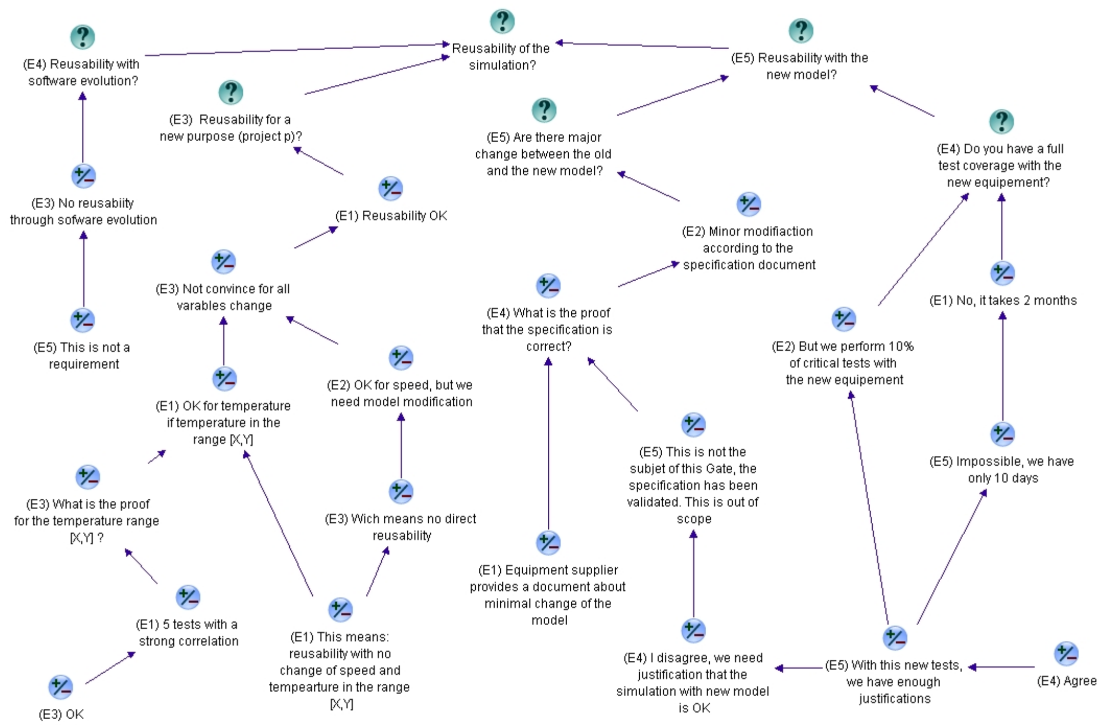

Figure 1: *Argumentation graph example: reusability of the simulation (with Compendium)*

deed, the initial question of a meeting is often too generic and it is refined, clarified, in new questions throughout the meeting. Therefore, it is important to express these new questions and to make the difference between them and the rest of assertions given by experts.

In addition, we add to Question and Argument elements the name of the expert who gives the assertion. We are in a technical context and it is very important to know which expert said something to check if the expert is regarded as authoritative in the domain. For example, if a thermal expert asserts something about a thermal topic it could be considered more important than if the same expert says something about a structure topic.

In conclusion, our notation for argumentation graph has three elements:

- Argument, it consists of two parts, the statement given by expert and the name of the expert;
- Question, it is a special Argument, marked with an "?", and the statement given by expert must be a question;
- Arrow, it connects two Arguments together, and we can give the following intuitive semantic: *"this argument says something about the other argument"*.

For us, an argumentation graph is only composed by Argument and Question elements, sometimes connected by Arrows, and with a special Question element, the *root Question*, which contains the issue of the meeting and with the expert part empty.

Note that, it is possible that an Argument is without any connection with any other argument (without Arrow). Such an argument means that an expert said something rationally unrelated to anything that was said during the debate, in other words we have an irrelevant argument in the rationale point of view. But, it does not mean that the argument is necessarily without value, so it is relevant that this piece of information is captured in the first step of our process.

2.3. Experimentation

In [DVP+13], we defined the notion of quality gates in a simulation process, where a simulation, or a model, must be assessed and qualified, on the basis of verification and validation evidence, by a group of experts. This is a crucial point. Indeed, following the decision of the group of experts, the simulation process may stop. So we propose to use our decision support and capture methodology to support and to document the experts assessment, but also to help the decision maker to analyse and to understand the decisions taken at the gate.

The running example of this paper is an experimentation in the context of a quality gate, where an expert committee is convened to perform the validation of the reuse of a simulation in a new project, namely p, with a minor modification in the model of a component. The reuse is a common problem in design, indeed, as noted by [FG05], 90% of design activities are based on existing design. We chose to perform one meeting, face-to-face, and the quality gate committee is composed of five experts from different companies:

- expert 1 ($E1$) and expert 2 ($E2$). They are in charge of the simulation. They have simulation evidence such as tests results or information about modifications of the component's model;
- expert 3 ($E3$), a thermal design expert;
- expert 4 ($E4$), represents the users of the simulation;
- expert 5 ($E5$), the business expert (person in charge of the planning of the project, cost, delay, ...).

Capturing arguments and rationale during an expert meeting requires attention and argumentation knowledge. To avoid bias, one of these experts in the meeting cannot perform this task. Therefore, we chose to use an argumentation specialist, independent from the experts (he does not work in the same company), and is able to report the arguments impartially.

To capture debates during our experimentations we tried three methods. Firstly, the specialist is like a secretary of the meeting, she captures the debate, but does not interact with the experts. Secondly, the specialist is like in the first case except that at the end of the meeting, she interacts with the experts and shows them issues remained open for a new round of discussion. Thirdly, the specialist acts both as facilitator and secretary, she interacts with experts throughout the meeting.

Finally, in all our experimentations, all experts preferred the third method. With a facilitator, the debate between experts is richer, the argumentation loops, where the same arguments come back again and again, are avoided and no issue is forgotten in the passion of the meeting.

In Figure 1 we give the argumentation graph of our example using the method three, the specialist acts both as facilitator and secretary of the meeting. For this experimentation, we chose to use the software Compendium for argumentation mapping. Compendium is released by the not-for-profit Compendium Institute and the source code was released under LGPL licence.

3. Report and analyze a collaborative decision

At this step, the group of experts has taken a decision. The experts have given arguments and there were arguments for both sides, pro and con of the final choice. In [PC11] we propose a formal representation framework, a decision tree, mapping the deliberation of the experts in order to help the decision maker to understand the final choice and to perform automatic analyses. In this section, after a brief presentation of our framework, we will illustrate how to use decision tree in our example.

3.1. An argumentation framework

After the experts have reached a consensus, it is useful to structure it in a formal framework to record it. If there are many works in argumentation representation[6], a lot of them, unfortunately, are interested in dialectic and defeasible evidence representation. Still, it is possible to use this legacy to define some properties and measures to help the managers understand the debate.

In our framework, the principal element is the *Argument Node*. Argument Node is defined as a triple. The first item is an expert assertion represented by a proposition in natural language. The second item is the name of the expert (the one who came up with the argument). Finally, the third item is a list of evidence given by the agent to support the assertion (evidence can consist of mathematical models, academic articles, simulation results, demonstrations, past projects references, business reasons, etc.).

In fact, because our framework is included in an information system, the second item, the name of the expert, can be a link to information about the expert like name, company, credentials, etc. and the third item, the list of evidence, can be links to evidence documents.

So, an Argument Node is a triplet $\langle \Psi, e, s \rangle$ where:

- Ψ is a proposition in natural language;
- $e \in E$, with E the set of experts;
- s is a set of proposition, possibly empty (denoted $\emptyset$).

We have a particular Argument Node, the *Conclusion*, defined as follows: Conclusion is an Argument Node $\langle \Psi, E, \emptyset \rangle$.

Argumentation theory studies many relations amongst arguments, and the various associated subcategories. Here, we are in the context of a technical meeting and it seems reasonable to consider that at each stage of the meeting, an expert utters an assertion that simply *corroborates* (or supports) or *attacks* (or challenges) a previous assertion.

Finally, in our framework, a decision tree, $DT = (V, A)$, is a connected directed acyclic graph[7] with:

- vertex in V are Argument Nodes;
- there is one and only one sink[8] which is a conclusion;
- each edge in A between v_1 and v_2 is labelled with $+$ if v_1 corroborates v_2;
- each edge in E between v_1 and v_2 is labelled with $-$ if v_1 attacks v_2;
- two vertices are connected by at most one edge.

3.2. Our methodology

We have on side an argumentation graph, which keeps track of the meeting and records all ideas raised, and, on the other side, a formal framework to store the rational of a decision. Of course, we need to store both in the corporate memory. The point is how to extract the decision tree from the argumentation graph? For that, we use a simple methodology. Today, this extraction is not automated, it is done by a human, in practice the facilitator.

For that, we use a simple three-step method. Firstly, the debate ends because the group of experts takes a decision. In the decision tree, we no longer have a Question as it has turned into a Conclusion. The conclusion of the debate is one of the alternatives that has been chosen by the group of experts. It represents a complex idea that has been decomposed into several questions. However, in a debate, many hypotheses could be criticised. Experts promote ideas, but at the end there is only one conclusion to the debate. In this step, we do not want to track all experts' options, but only

[6] Today, the study of the validity of an argument and its underlying mechanisms is studied by a variety of disciplines such as computer science (through artificial intelligence), linguistics, epistemology and the legal sciences, see [PC11].

[7] A *DAG* (directed acyclic graph) is a graph $G = (V, A)$ where V is a set of vertices, or nodes, and A set of directed edges (arrows), each edge connecting one vertex to another, such that there is no cycle.

[8] A *sink* is a particular node with only incoming edges.

the final choice of the group. Consequently, we cut all branches of the argumentation graph linked to the root Question and those that are not part of the debate conclusion.

In some cases, this choice could be drastic. Take for example the argumentation graph for *"which model to use for a simulation"* given in Figure 2. If the answer of experts is *use a beam model*, we take *use a beam model* as Conclusion of the decision tree and cut all nodes related to *plate models*.

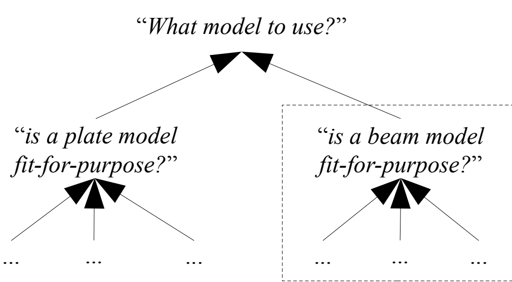

Figure 2: *Example of "*cut*" from argumentation graph to decision tree*

Secondly, we need to identify for every relation amongst Arguments in argumentation graph whether it is a corroborate or an attack relation. In the decision tree, it should be noted that all arguments are relevant to the discussion since they corroborate or attack a previous one. Thirdly and last, we add links from Argument Nodes to evidence documents.

3.3. Experimentation

We create a tool for decision tree visualisation. Our tool colors automatically in red the arguments that are against the Conclusion and in green those who are pro and it labels the arguments with evidence. It also performs the two following automatic analyzes: detection of assertions from the same experts both pro and con the conclusion; calculating a validity degrees for the Conclusion. The visualisation of the decision tree for the running example in our tool is given in Figure 3.

Surprisingly, the automatic analyses do not add a lot of information in this example. Indeed, no expert gave arguments both pro and con the decision and all of our validity degrees[9] are at 100%. We do not have a clear explanation, but, in the light of our experiments, it would seem that trade-off decisions are more controversial than validation decisions (like in a quality gate).

However, in this example, automatic analyses enlighten the fact that the argument given by expert 5 *"with this new tests, we have enough justifications"* is not supported by evidence. It could be a problem because the argument is in a key position in the decision rationale, but here, the decision maker agrees with this argument.

In our experimentation, from the decision maker point of view, the benefit of having our decision tree is to have mechanisms to collect, analyse and store the decisions taken at the quality gate and to document the experts assessment attached to the decision.

4. Conclusion

We introduced a methodology in two steps: the first step is to capture the debate; the second one is to report and analyse the conclusion of the debate. For capturing the debate, we use a graphical notation of arguments and relations amongst arguments. In the second step, we analyse the captured debate and simplify it. The report of the debate is thus the part of the diagram that summarizes arguments defining, supporting or challenging the conclusion. At the end, the decision maker has a clear representation of the debate; for each decision, the manager has a graphical representation of the argument with its associated analysis and all this structured information can be stored in a corporate memory.

We considered in this work that decisions are taken during a face-to-face meeting, in fact,

[9] In fact, we have defined different degree of validity (see [PC11]) like, for instance, the number of sources in the DAG against the conclusion over the number of sources.

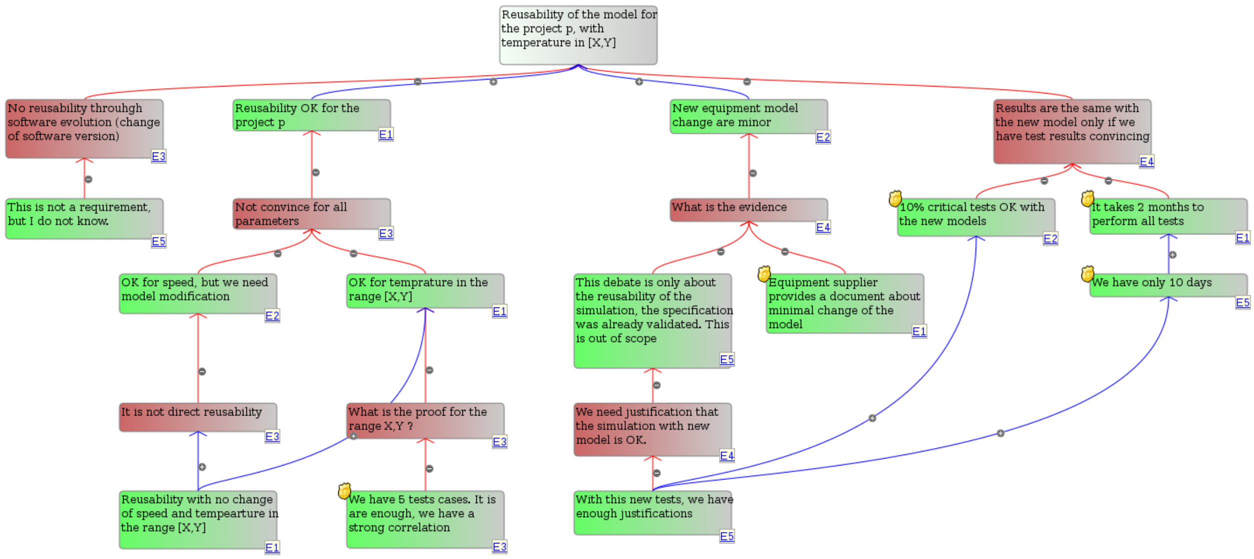

Figure 3: *Decision tree example: report the decision of experts*

in a context of international projects, this is less and less the case. In future work, we will need to adapt our methodology to virtual meetings with collaborative tools, where a decision is taken over a long period of time.

To conclude, the transformation from an argumentation graph to a decision tree is manual, and is relies on the person recording the debate. There is a risk that some arguments get lost in the course of the process. Today, only the review by the experts can prevent any loss (during argumentation pruning, links addition, etc.). This emphasizes the importance of the specialist who will perform the support and capture step. This role shall be played by a person that is properly trained to exercise this role and is as much as possible independent from the stakes, stepping back and being able to impartially report the arguments. Ideally this role shall be played by a third-party, especially if the argumentation is performed in the context of a customer-supplier relationship.

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