Chapter 1

ARGUMENTATION THEORY AND DECISION AIDING

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Abstract The purpose of this chapter is to examine the existent and potential contribution of argumentation theory to decision-aiding, more specifically to multi-criteria decision-aiding. On the one hand, Decision aiding provides a general framework that can be adapted to different contexts of decision-making and a formal theory about preferences. On the other hand Argumentation theory is growing field of Artificial Intelligence, which is interested in non monotonic logics. It is the process of collecting arguments in order to justify and explain conclusions. The chapter is decomposed in three successive frames, starting from general considerations regarding decision theory and Artificial Intelligence, moving on to the specific contribution of argumentation to decision-support systems, to finally focus on multi-criteria decision-aiding.

Keywords: Argumentation Theory, Multiple Criteria, Decision Analysis, Decision Support Systems.

1. Introduction

Decision-support systems aim at helping the user to shape a problem situation, formulate a problem and possibly try to establish a viable solution to it. Under such a perspective decision aiding can be seen as the construction of the reasons for which an action is considered a "solution to a problem" rather than the solution itself [133]. Indeed the problem of decisions *accountability* is almost as important as the decision itself. Decision support can therefore be seen as an activity aiming to construct arguments through which a decision maker will convince first herself and then other actors involved in a problem situation that

"that action" is the best one (we are not going to discuss the rationality hypotheses about "best" here). Decision Theory and Multiple Criteria Decision Analysis have focussed on such issues for a long time, but more on how this "best solution" should be established and less on how a decision maker should be convinced about that (for exceptions on that see [16, 25]).

On the other hand, in the field of Artificial Intelligence, argumentation has been put forward as a very general approach allowing to support different kinds of decision-making [96, 102]. Typically, one will construct for each possible decision (alternative) a set of positive arguments, and a set of negative arguments. Adopting an argumentation-based approach in a decision problem would have some obvious benefits. On the one hand, the user will be provided with a "good" choice and with the reasons underlying this recommendation, in a format that is easy to grasp. On the other hand, argumentation based decision making is more akin with the way humans deliberate and finally make a choice. Moreover, the arguments allows us to take into account the non monotonic aspect of a decision process and the problem of incomplete information. Aspects that are, sometimes, poorly controlled in decision theory.

The aim through this chapter is to introduce the reader to some contribution of argumentation theory to decision aiding. The chapter is organized as follows: in the next section, we introduce and discuss two main concepts that follow more or less directly from Simon's criticisms to classical models of rationality. In particular, we shall see what requirements this puts on decision support approaches. Firstly, decisions result from a complex process which is hardly captured by classical mathematical languages. Secondly, these languages are not necessarily appropriate to handle preferential information as it is stated by the client (because it may, for instance, involve generic, ambiguous, or incomplete statements). The section which follows (Section 3) advances that argumentation theory is a good candidate to handle some of the challenging requirements that came out from the previous discussion. To justify this claim, we first offer a brief introduction to argumentation theory (in an AI oriented perspective). We then review a number of approaches that indeed use argumentative techniques to support decision-making. This section is intended to offer a broad (even though not exhaustive) overview of the range of applicability of argumentation. In fact, the use of argumentation in decision support system has been greatly encouraged. Such systems have the aim to assist people in decision making. The need to introduce arguments in such systems has emerged from the demand to justify and to explain the choices and the recommendations provided by them. Section 4 focuses more specifically on approaches adopting (more or less explicitly) a multiple criteria decision analysis perspective. The final section presents some advances on the use of argumentation in a decision aiding process.

2. Decision Theory and AI

The story we are going to tell in this chapter results from a long history that we can trace back to Simon's criticisms to traditional "economic" models of rationality (and thus of rational behaviour and decision making, see [128]). Focussing on how real decision makers behave within real organisations Simon argued that several postulates of "classic rationality": well defined problems, full availability of information, full availability of computing resources, were utopian and unrealistic. Instead decisions (following Simon) are based upon a "bounded rationality" principle which is subjective, local and procedural. A decision is thus "rational" now, under that available information, with that given computing capability, within that precise context because subjectively satisfies the decision maker.

These ideas can be found at the origin of research conducted both in new directions of Decision Analysis and in Artificial Intelligence (see more in [134]). We are not going to explore the whole contribution of Simon, we are going to emphasise two specific innovations Simon directly or indirectly introduced:

- the concept of decision process;

- the subjective handling of preferences.

2.1 Decision Process and Decision aiding

Decisions are not just an "act of choice", they are the result of a "decision process", a set of cognitive activities enabling to go from a "problem" (a state of the world perceived as a unsatisfactory) to its "solution" (a state of the world perceived as satisfactory, if any exists). Even if we consider at the place of a human decision maker an automatic device (such as a robot or other device with some sort of autonomous behaviour) we can observe, describe and analyse the process through which a "decision" is reached. However, it is clear that is not a process only about solving a problem: a decision process implies also understanding and shaping a decision problem.

In fact, research conducted in what is known as "Problem Structuring Methodologies" ([48, 113, 124]) emphasised that decision aiding is not just to offer a solution to well established mathematically formulated problem, but to be able to support the whole decision process, representing the problem situation, formulating a problem and possibly constructing a reasonable recommendation. Thus, to the concept of decision process we can associate the concept of "decision aiding process" where the cognitive artifacts representing the modeling of different element of the decision process are described and analysed. A decision aiding context implies the existence of at least two distincts actors (the decision maker and the analyst) both playing different roles; at least two objects, the client's concern and the analyst's methodological knowledge, money, time, etc [115, 117, 134].

A formal model of decision aiding process, that meets these needs, is the one described by Tsoukiàs in [133]. The ultimate objective of this process is to come up with a consensus between the decision maker and the analyst. Four cognitive artifacts summarise the overall process:

- a representation of a problem situation: the first deliverable consists in offering a representation of the problem situation for which the decision maker has asked the analyst to intervene.

- a problem formulation: given a representation of the problem situation, the analyst may provide the decision maker with one or more problem formulation. The idea is that a problem formulation translates the client's concern, using the decision suppport language, into a "formal problem".

- an evaluation model: For a given problem formulation, the analyst may construct an evaluation model, that is to organise the available information in such a way that it will be possible to obtain a formal answer to a problem statement.

- a final recommendation: The evaluation model will provide an output which is still expressed in terms of the decision support language. The final recommendation is the final deliverable which translate the output into the decision maker's language.

The above process is a dialogue between the analyst and the decision maker where the preference statements of the former are elaborated using some methodology by the latter, the result expected to be a contextual and subjective model of the decision maker's values as perceived, modelled and manipulated by the analyst. Such a process is expected to be understood and validated by the client. In a "human-to-human" interaction the above dialogue is handled through typical human interaction, possibly supported by standard protocols (as in the case of constructing a value or an utility function or assessing importance parameters in majority based procedures). In any case we can fix some explicit formal rules on how such a process can be conducted. Consider now the case where the analyst part is played by a device collecting information about some user's preferences (a typical case being recommender systems). We need to be able to structure the dialogue on a formal basis in order to be able to control and assess what the device concludes as far as the user preference models are concerned and what type of recommendations (if any) is going to reach.

In both the above cases (human-to-human and human-to-machine) we need on the one hand some formal theory about preferences (and this is basically provided by decision analysis), and on the other hand some formal language enabling to represent the dialogue, to explain it, to communicate its results, to convince the user/decision maker that what is happening is both theoretically sound and operationally reasonable. Under such a perspective we consider that *Argumentation theory* provides a useful framework within which develop such a dialogue.

2.2 Preferences and Decision Aiding

Decision support is based on the elaboration of preferential information. The basic idea in decision aiding methodology is that, given a decision problem, we collect preferential information from the decision maker such that his/her system of values is either faithfully represented or critically constructed and thus we are able to build a model which, when applied, should turn a recommendation for action to the decision maker. Then the fundamental step in decision aiding is the modeling and the representation of the decision maker's preferences on the set of actions [26]. Furthermore, handling the preferences of a decision maker in a decision aiding process implies going through the following steps:

1 *Preference learning.* Acquire from the Decision Maker preferential information under form of preference statements on a set of "alternatives" A. Such statements can be on single attribute comparisons or assessments (I prefer red shoes to brown shoes; red shoes are nice) or multi-attribute ones (I prefer shoe x to shoe y; x is a nice shoe, x and y being vectors of information on a set of attributes). Possibly such statements can carry some further quantitative information or take more complex form: my preference of x over y is stronger than the one of z over w or twice stronger etc.. Problems arising here include what to ask, how to ask, what rationality hypotheses to do about the decision maker, what degrees of freedom allow to the decision maker's replies, how much the interaction protocol influence the decision maker (see more in [15, 22, 37, 59, 61, 62, 64, 121, 122, 149]).

2 *Preference Modeling.* Transform the preference statements in models. These can take the form of binary relations on the set of actions A, on the set $A \times A$, on the set $A \times P \cup P \times A$, ($P$ being a set of reference points) or of functions [72, 90, 112, 114]. In this latter case we can talk about "measuring the preferences" on some appropriate scale. Once again the models may concern single or multiple attributes. An attribute to which we are able to associate a preference model is denoted as a

criterion. There is a very standard theory on how single attribute (or uni-dimensional) preference models can be defined and these concern the well known concepts of total order, weak order, semi order, interval order, partial order etc.. It is less studied (mainly in conjoint measurement theory) the case of multi-attribute preference models. We call representation theorems the results providing necessary and sufficient conditions for numerical representations of particular types of preference models. The typical problem is to fit the preference statements in one such representation theorem (if any)

3 *Preference Aggregation.* In case we have several attributes on which we constructed preference models we may consider the problem of aggregating such preferences in one single model [119, 118, 140]. It is the typical problem of both social choice and multi-attribute utility theory. There exist several procedures and methods proposed for this purpose. In case we have global preference statements and/or a multi-attribute preference model we may consider the inverse problem: obtain preferences on single attributes compatible with such global statements and/or model.

4 *Exploiting Preferences.* Constructing a preference model (either directly or through preference aggregation) does not necessarily imply that we can get an "operational result". That is we do not necessarily have an "order" such that we can identify a subset of maximal elements or at least a partial ranking etc.. It might be that it is necessary to make some further manipulation in order to get such a result. A simple case is to have an acyclic binary relation, but not transitive, and to complete it through transitive closure. There are many procedures suggested for these type of problems [27, 139].

However, handling the preferential information provided by the decision maker may seem a simple task but in reality presents two majors problems.

1 From a formal point of view preferences are binary relations applied on a set of objects (alternatives, lotteries, combinations of values in a multi-attribute space etc.). However, not always the decision maker is able to provide the information under such a form. She may be able to state that she likes red shoes, but not that these are necessary better than brown shoes, or that she dislikes black shoes, but not more than that. She may have a target of shoes in mind but not necessarily these are the maximal elements of a ranking of available shoes in the market. In other terms the preference statements a decision maker may make do not necessarily fit the formal language traditionally used for representing preferences.

2 The way through which preferences are expressed depend on the process though which they are acquired and on the model expected to be used in order to elaborate them. However, we do not know a priori what type of method we should use. We also do not know what information is lost or neglected when we make a certain type of question. If we ask somebody what music he likes to hear we do not consider the option of silence. If we ask somebody how much is ready to pay more in order to increase safety of a certain device we implicitly assume that costs and safety can compensate one the other (but perhaps we never asked if this makes sense: worse, had we make the question is not sure this would be understood).

Thus, we can observe that in practice conventional mathematical languages used in decision theory do not necessarily fit with such requirements, therefore, it is necessary to look for languages explicitly allowing to take them into account (see for instance [132]; an alternative idea, the so called "Decision Rule approach" has been developed by Greco et al., see [57, 58]). Such idea was emphasized by Doyle and Thomason in [40] who suggest that it is essential to formalise the decision-making process more generally than classical decision theory does (where actions and outcomes are assumed to be fixed to start with, for example). Indeed, if you are to send a robot to complete a mission on a remote area, it is of course crucial to cater for the possibility that some *information may be missing*, that *preferences may change*, that *goals can be revised*, and so on. But also to provide *explanations and reasons* as to why this particular action has been eventually chosen. In short, many elements of the practice of decision analysis need to be incorporated in a model. But this means that the formal language used in classical decision-theory is maybe not enough expressive, not enough flexible. One distinctive feature of AI approaches is precisely that they usually base their representation of agents' preferences on cognitive attitudes, like goals or beliefs (see [36]), which are expressive and intelligible to the human user. Moving to this type of representations allows to represent and reason about the underlying reasons motivating a particular preference statement: for instance, it becomes possible to identify conflicting goals or unforseen consequences of certain actions to be chosen.

Regarding the issues of expressiveness and ability to deal with contradiction that we emphasised here, *argumentation* seems a good candidate. Indeed, the AI literature offers a corresponding argument-based approach to decision making [2, 7, 23, 31, 45, 55, 69, 92]. It appears that such approaches have much to offer to decision models, because they allow a great expressivity in the specification of agents' preferences, because they naturally cater for partial specification of preferences, and because they make explicit many aspects that are usually somewhat hidden in decision models.

3. Argumentation for Decision Support

In this section our first aim is to provide an overview of argumentation theory. As briefly mentioned before, it may offer several advantages to multi-criteria decision analysis, such as the justification and the explanation of the result, the expressive nature of the language used, or the possibility to handle incomplete or even contradictory informations... Thus, after a brief introduction to argumentation theory, we present some decision support systems that use diverse elements of this theory. The purpose is to show the different areas involving both decision and argumentation.

After that, we propose to discuss, in more details, some approaches that have focused to what may be an argument for an action (a decision), and this discussion will be from a MCDA point of view.

3.1 Argumentation Theory

Under the classical logical reasoning (propositional, predicate,...), we can infer that a conclusion is true despite the additions in the set of proposition which allowed us to reach this conclusion. That is what we call *monotonicity*. In other words, no additional information can cause conclusions to be modified or withdrawn. There are no rules which allow to draw conclusions which may be faulty, but are nonetheless better than indecision. This is obvious if our reasoning concerns a mathematical demonstration (indeed classic formal logic has been developed mainly for such a purpose [150]). It is far less obvious if we are concerned by more general reasoning languages where conclusions are not necessarily definite truths.

For instance, if we look at our daily life reasoning, we can observe that this reasoning is not necessarily monotonic. Indeed, we can change our minds and move from one to another conclusion on the simple fact that new information is available or not. Besides, we are often faced with decision situations where we are far from knowing with certainty all data and information necessary to make this decision. We build our conclusion on the basis of available information at that moment and we reserve the right to change it at any time. Indeed, we do not have the time or mental capacity to collect, evaluate, and process all the potentially relevant information before deciding what to do or think. In such cases monotonicity in reasoning is not very useful. In the sense that it does not offer ways to face this type of reasoning. Another example is where we take into account beliefs. Indeed, a human reasoning is not based solely on facts or action but also on its own beliefs. In this case, classical logic offers no theory about how to deal with beliefs. For instance, which beliefs to prefer given that certain things are known in a particular case.

These limitations of classical logic caused a number of Artificial Intelligence researchers to explore the area of *non-monotonic logics*. The emergence of these logics were initially developed by McCarthy [81], McDermott and Doyle [82], and Reiter [107]. Part of the original motivation was to provide a formal framework within which to model phenomena such as defeasible inference and defeasible knowledge representation, i.e., to provide a formal account of the fact that reasoners can reach conclusions tentatively, reserving the right to retract them in the light of further information. A familiar example in the literature of this kind of reasoning is the one of Reiter [108]:

EXAMPLE 1 *(Reiter,1987)*

- *Birds fly;*
- *Tweety is a bird;*
- *Therefore, Tweety flies.*

The problem with this example concerns the interpretation of the first premise "Birds fly". To infer a valid conclusion, a possible interpretation can be: "for all x, if x is a bird, then x flies". But what is if Tweety is a penguin, a type of bird that does not fly?. If we add this new information, the conclusion becomes false, but the second premise is true, therefore to maintain the deduction valid, the first premise should be false. However, this interpretation is problematic, because the first premise, in reality, still seems be true. As Reiter said:

> "a more natural reading of this premise is one that allows for possible exceptions and allows for the possibility that Tweety could be an exceptional type of bird with respect to the property of flying, that is, 'Normally, birds fly' or 'typically the birds fly' or 'if x is a typical bird, then we can assume by *default* that x flies'."

The *default* refers to the fact that we should consider that Tweety flies until we can say or prove that it is atypical.

Much interest has been brought to non-monotonic reasoning from researchers in Artificial Intelligence, in particular, from those interested in model human intelligence in computational terms. The challenge has been to formalize non-monotonic inference, to describe it in terms of a precisely-defined logical system which could then be used to develop computer programs that replicate everyday reasoning. Different non-monotonic reasoning formalism emerged, within AI, such as: default logic [107], autoepistemic logic [83], etc. In this chapter we are interested by one kind of these reasoning which is *argumentation theory*.

Indeed, argumentation provides an alternative way to mechanise such kind of reasoning. Specifically, argument-based frameworks view this problem as a process in which arguments for and against conclusions are constructed and compared. Non-monotonicity arises from the fact that new premises may enable the construction of new arguments to support new conclusion, or stronger counter-arguments against existing conclusions. Thus, argumentation is a reasoning model based on the construction and the evaluation of interacting arguments. Those arguments are intended to support, explain, or attack statements that can be decision, opinions, preferences, values, etc.

The important motivations that brought argumentation into use in AI drove from the issues of reasoning and explanation in the presence of incomplete and uncertain information. In the 1960s and 1970s Perelman and Toulmin were the most influential writers on argumentation. Perelman tried to find a description of techniques of argumentation used by people to obtain the approval of others for their opinions. Perelman and Olbrechts-Tyteca called this “new rhetoric” [95]. Toulmin, on the other hand, developed his theory (starting in 1950’s) in order to explain how argumentation occurs in the natural process of an everyday argumentation. He called his theory “The uses of argument” [131]. Early studies using argumentation inspired methods in AI contexts can be found in the work of Birnbaum, Flowers, and McGuire [21] in which a structural model of argument embracing notions of support and attack within a graph-theoretic base. Moreover, the need of some model of argument for common sense reasoning can be traced to Jon Doyle’s work on truth maintenance systems [39]. Doyle offered a method for representing beliefs together with the justifications for such belief, as well as procedures for dealing with the incorporation of new information.

In most AI oriented approaches argumentation is viewed as taking place against the background of an inconsistant knowledge base, where the knowledge base is a set of propositions represented in some formal logic (classical or non-monotonic). Argumentation in this conception is a method for deducing justified conclusion from an inconsistent knowledge base. Which conclusion are justified depends on attack and defeat relations among the arguments which can be constructed from the knowledge base. Instantiation of Dung’s [41] abstract argumentation framework are typically models of this kind. In such a framework, an argumentation system is a pair of a set of argument and a relation among the arguments, called an attack relation.

However, in the decision making context, it is not always possible to assume the existence of a fixed knowledge base to start the process. This point has been emphasised by Gordon and Walton [56], who state:

> “in decision-making processes, we cannot assume the existence of a knowledge base as input into the process. Problems for which all the relevant information and knowledge have been previously represented in formal logic are rare.”

Indeed, we are often faced with decision situations where we are far from knowing with certainty all data and information necessary to make this decision. We build our conclusion on the basis of available information at that moment and we reserve the right to change it at any time. As a consequence, argumentation can be seen as:

> a kind of process for making justified, practical decisions [...] The goal of the process is to clarify and decide the issues, and produce a justification of the decision which can withstand a critical evaluation by a particular audience.[56]

On the other hand, argumentation systems formalise non-monotonic reasoning in terms of the dialectical interaction between arguments and counterarguments. They tell us how arguments can be constructed, when arguments are in conflict, how conflicting arguments can be compared, and which arguments survive the competition between all conflicting arguments. Thus, an argumentation process can be described as a succession of different steps. Prakken and Sartor [101] suggest to distinguish the following layers in an argumentation process:

- **Logical layer.** It is concerned with the language in which information can be expressed, and with the rules for constructing arguments in that language. In other terms, it defines what argument are, i.e. how pieces of information can be combined to provide basic support for a claim. There are many ways to address the form of an argument: as trees of inferences [68], as a sequences of inferences (deductions) [136], or as simple premisses-conclusion pairs. The different forms of arguments depend on the language and on the rules for constructing them [4, 19, 32, 103, 143]. The choice between the different options depends on the context and the objective sought through the use of argumentation. A general form is the one of *Argument Schemes* [144]. These are forms of arguments that capture stereotypical patterns of humans reasoning, especially defeasible ones [88, 145]. The first attempt to give an account of scheme, was in the work of Aristotle. Indeed, he has introduced schemes in a common forms of argumentation called *topics* (places) in *Topics* [10], *On Sophistical Refutations* and *Rhetoric* [9]. After that, argument schemes have been employed, by Perelman and Olbrecht [95] in *The New Rhetoric*, as tools for analyzing and evaluating argument used in everyday and legal discourse. More recently there has been considerable interest in schemes in computer science, especially in AI, where they are increasingly being recognized, in fields like multi agent system, for their usefulness to refine the reasoning capabilities of artificial agents [104, 138]. For special use in Artificial Intelligence systems, Pollock's OSCAR identified some ten schemes [97]. In addition, Reed and Walton [105] present some examples of application of argument schemes.
- **Dialectical layer.** It focuses on conflicting arguments and introduces notions such as counter-argument, attack, rebuttal, etc. Pollock [97] drew an important distinction between two kinds of arguments that can attack and defeat another argument, calling them *rebutting defeaters* and *undercutting defeaters*. A rebutting attack concerns arguments that have con-

tradictory conclusions. An undercutting defeater has a different claim. It attacks the inferential link between the conclusion and the premise rather than attacking the conclusion. Moreover, recent studies have proposed to represent another kind of relation between argument, namely a positive relation, called *support relation* [4, 68, 137]. Indeed, an argument can defeat another argument, but it can also support another one. This new relation is completely independent of the attack one (i.e., the support relation is not defined in terms of the defeat relation, and vice-versa). This suggests a notion of bipolarity, i.e. the existence of two independent kinds of information which have a diametrically opposed nature and which represent contrasting forces [30]. Another way to challenge an argument is to use the concept of *Critical Questions* [63]. The critical questions are associated to an argument schemes. They represent attacks, challenges or criticisms which, if not answered adequately, falsify the argument fitting the scheme. In other terms, asking such question throws doubt on the structural link between the premises and the conclusion. They can be applied when a user is confronted with the problem of replying to that argument or evaluating that argument and whether to accept it [138, 147, 146].

- **Procedural layer.** It regulates how an actual dispute can be conducted, i.e., how parties can introduce or challenge new information and state new argument. In other words, this level defines the possible speech acts, and the discourse rules governing them. In fact, arguments are embedded in a procedural context, in that they can be seen as having been put forward on one side or the other of an issue during a dialogue between human and/or artificial agents. In other terms, one way to define argumentation logics is in the dialectical form of *dialogue games* (or dialogue systems). Such games model interaction between two or more players, where arguments in favor and against a proposition are exchanged according to certain rules and conditions [29]. The information provided by a dialogue for constructing and evaluating argument is richer that just a set of sentences. Indeed, the context can tell us whether some party has questioned or conceded a statement, or whether a decision has been taken accepting or rejecting a claim [5, 80, 99]. An influential classification of dialogue type is that of Walton and Krabb [148]. Indeed, the authors have identified a number of distinct dialogue types used in human communication: Persuasion, Negotiation, Inquiry, Information-Seeking, Deliberation, and Eristic Dialogues.

Finally, recent research has shown that argumentation can be integrated in growing number of applications. As examples we quote: *legal reasoning* [101], *handling inconsistency in knowledge bases* [3, 20], *knowledge engi-*

neering [28], *clustering* [53], *Multi-agent systems* [6, 94, 91], *decision-making* [8, 23, 93].

In this chapter, we are interested by presenting the use of argumentation for multiple criteria decision aiding. Thus, the rest of this document is devoted to such a purpose.

3.2 Argumentation-based Decision Support Systems

Computer based systems are being increasingly used to assist people in decision making. Such system are knows as decision support systems. The need to introduce arguments in such systems has emerged from the demand to justify and to explain the choices and the recommendations provided by them. Other needs have motivated the use of argumentation, such as dealing with incomplete information, qualitative information and uncertainty [8, 23, 45, 92]. In what follows we present a range of decision systems involving the use of argumentation. This section does not pretend to list all the existing systems but simply to give an overview of the different domains where argumentation has proven to be useful for supporting decision making. As we shall see, these different applications domains may involve very different type of decision-makers, from experts (medical domains) to potential buyers (recommender systems) or simple citizens (public debate); and even largely autonomous pieces of software that should act on behalf of a user (multi-agent). Of course the contexts of these applications varies a lot, from mediated human interactions to human-computer interaction. Our ambition is not to discuss the technical specificities of each of these, but merely to illustrate the wide range of application of argumentation techniques.

Supporting an expert decision. Medical applications using argumentation have been numerous. We just cite three examples here. Atkinson *et al.* in [14] describe how to use argumentation in a system for reasoning about the medical treatment of a patient. The focus of the paper is the *Drama* (Deliberative Reasoning with ArguMents about Actions) agent which deals with a number of information sources (e.g. medical knowledge) in argumentation terms, and comes to a decision based on an evaluation of the competing arguments. Glasspool *et al.* in [50] present a software application (REACT, for Risks, Events, Action and their Consequences over Time), based on argumentation logic, which provides support for clinicians and patients engaged in a medical planning. The approach may provide a general aid for clinicians and patients in visualizing, customizing, evaluating and communicating about care plans. Shankar *et al.* present the system WOZ [123] as an explanation framework of a clinical decision-support system based on Toulmin's argument structure to define pieces of explanatory information. Initially, WOZ was developed as a part of the EON architecture [87]—a set of software components with which developers can build robust guideline-based decision-support systems. After that, an extension of WOZ was realised in order to build the explanation function of ATHENA DSS, a decision support system for managing primary hypertension [52].

Mediating public debate. Atkinson [12] presents one particular system– the PARMENIDES (PersuasivE ArguMENt In DEmocracieS) developed by Atkinson *et al.* [13]. It is designed to encourage public participation and debate regarding the Government's justifications for proposed actions. The idea is to enable members of the public to submit their opinions about the Government's justification of a particular action. Morge [85] presents a computer-supported collaborative argumentation for the public debate. The framework is based on the Analytic Hierarchy Process (AHP, [120]). The aim is to provide a tool to help the users to build an argumentation schema and to express preferences about it. The "Risk Agora" has been proposed as a system to support deliberations over the potential health and environmental risks of new chemicals and substances, and the appropriate regulation of these substances [78, 79, 106]. The framework is grounded in a philosophy of scientific inquiry and discourse, and uses a model of dialectical argumentation. The system is intended to formally model and represent debates in the risk domain.

Acting as a collaborative assistant. George Ferguson *et al.* [42] implemented a mixed-initiative planning system for solving routing problems in transportation domains. By mixed-initiative, they refer to the fact that the computer acts as a collaborating assistant to the human, anticipating need, performing the tasks it is well suited for, and leaving the remaining task to the human. The unifying model of interaction was implemented as a form of dialogue. Both the system and human are participants in a dialogue. The ZENO system was developed to support decision-making in urban planning [54, 55, 71, 106]. The system was designed to be used in a mediation system, an advanced kind of electronic discussion forum with special support for arguments, negotiation and other structured forms of group decision-making. The argumentation model used by ZENO is a formal version of IBIS system (Informal Issue-Based Information) [111] modified for the urban-planning model. The modification allows the expression of preferences. Karacapilidis *et al.* describe an advanced Group Decision Support System [75] for cooperative and non-cooperative argumentative discourse, named HERMES System [69, 68, 70]. The system can be used for distributed, asynchronous or synchronous collaboration, allowing agents to communicate without constraints of time and space. Moreover, it supports defeasible and qualitative reasoning in the presence of ill-structured information. HERMES system is a variant of the informal IBIS model of argumentation [76, 111].

Recommending novice web users. Recommender systems are aimed at helping users with the problem of information overload by facilitating access to relevant items [77]. They are programs that create a model of the user's preferences or the users task with the purpose of facilitating access to items that the user may find useful. While in many situations the user explicitly posts a request for recommendations in the form of a query, many recommender systems attempt to anticipate the user's need and are capable of proactively providing assistance. These systems adopt two different approaches to help predict information needs. The fist one, called user modeling, is based on the use of the user model or user profile which is constructed by observing the behaviour of the user. The second approach is based on task modeling, and the recommendation are based on the context in which the user is immersed. Consequently, two principles paradigms for computing recommendations have emerged, content-based and collaborative filtering [51]. Advanced recommender systems tend to combine collaborative and content-based filtering, trying to mitigate the drawbacks of either approach and exploiting synergetic effect. ArgueNet system is an approach towards the integration of user support systems such as critics and recommender systems with a defeasible argumentation framework [31, 34, 35]. Critiquing and recommendation systems have evolved in the last years as specialised tools to assist users in a set of computer-mediated tasks by providing guidelines or hints [51, 77, 74, 110]. ArgueNet provides solutions to problems encountered with existing recommander systems. Indeed, they are unable to perform qualitative inference on the recommendations they offer and are incapable of dealing with defeasible nature of user's preferences (see [34]). In this context, defeasible argumentation frameworks [98, 141, 142] have evolved to become a sound setting to formalise qualitative reasoning. The basic idea in this system is to model the preference associated with the active user and a pool of users by means of facts, strict rules and defeasible rules, named a DeLP program [49]. These preferences are combined with additional background information and used by an argumentation framework to prioritise potential recommendations, thus enhancing the final results provided to the active user. An application where such argumentation framework is used is the one proposed by Chesnevar [33], where the authors present an argumentative approach to providing proactive assistance for language usage assessment on the basis of usage indices, which are good indicators of the suitability of an expression on the basis of the Web Corpus [73].

Autonomous decision-making. In recent years, argumentation has been promoted as a primary technique to support autonomous decision making for agents acting in multiagent environment. Kakas *et al.* [66] present an argumentation based framework to support the decision making of an agent within a modular architecture for agents. The proposed framework is dynamic as it allows the agent to adapt his decisions in a changing environment. In addition, abduction was integrated within this framework in order to enable the agent to operate within an environment where the available information may be incomplete. Parsons and Jennings [93] summarise their work on mixed-initiative decision making which extends both classical decision theory and a symbolic theory of decision making based on argumentation to a multi-agent domain. One focus of this work is the development of multi-agent systems which deal with real world problems, an example being the diagnosis of faults in electricity distribution networks. Sillince [126] has investigated conflict resolution within a computational framework for argumentation. The author analysed how agents attempt to make claims using tactical rules (such as fairness and commitment). The system does not require truth propagation or consistency maintenance. Indeed, agents may support inconsistent beliefs until another agent is able to attack their beliefs with a strong argument. Parsons *et al.* in [94] try to link agents and argumentation using multi-context systems [60]. In this approach agents are able to deal with conflicting information, making it possible for two or more agents to engage into dialogue to resolve conflicts between them. Sycara [129, 130] developed PERSUADER, a framework for intelligent computer-supported conflict resolution through negotiation and mediation. She advocates persuasive argumentation as a mechanism for group problem solving of agents who are not fully cooperative. Construction of arguments is performed by integrating case-based reasoning, graph search and approximate estimation of agent's utilities. The paper of Sierra *et al.* [125] describes a general framework for negotiation in which agents exchange proposals backed by arguments which summarise the reasons why the proposals should be accepted. The framework is inspired by the work of the authors in the domain of business process management and is explained using examples from that domain.

4. Arguing over actions: A multiple criteria point of view

The ultimate aim of a multi-criteria decision analysis study is to build a possible recommendations that will be considered useful by the users in the decision process where they are involved. Such recommendations are based on formal preference models [90]. Different steps (which can be implicit in a decision process) are required in order to obtain a recommendation [119]: formulate and structure the problem, build an evaluation model which allow us to obtain a formal answer to a given problem and construct a recommendation which translate the output of the process into the client's language. To reach a recommendation, multi-criteria decision analysis uses different tools for learning and aggregating preferences [25, 43, 140].

In an argumentation context, in general, the whole decision process will be made explicit in terms of different steps: construct arguments in favour and against each alternative; evaluate the strength of each argument [3, 20, 100, 127]; and compare pairs of choices on the basis of the quality of their arguments. The comparison can be based on different aggregation procedures of arguments (e.g. [24]).

Very broadly speaking, on the one hand, we have an evaluation process and on the other hand an argumentation process. The first is devoted to construct the necessary mechanisms to achieve "the best solution" on the basis of different points of view and preferences. The second one also leads to the "best solution" but in such a manner that will provide the explanation and the justification for this choice. Both processes appear to borrow two different ways to reach a solution, but in substance are very complementary.

In this section, we present a set of approaches that attempted to combine both evaluation and argumentation (or explanation). Before to do that, we start by discussing in general the notions of arguments and criteria. We then provide some examples of argument schemes proposed in the literature to account for decision making, and more generally to decision aiding processes.

4.1 Arguments, criteria and actions

When facing a decision problem, the first step may be to identify the different objects submitted to the decision aiding process. These objects can be potential decisions, projects, feasible solutions, items, units, alternatives, candidates, etc. and will be called the *actions*. In decision analysis, the concept of *criterion* is a tool constructed for evaluating and comparing the actions according to a point of view which must be (as far as possible) well defined. Thus, a criterion plays an important role in the process of actions evaluation. Indeed, the construction of the set of criteria is a central activity in the decision aiding process. It can be either the result of a direct process (creating from dimensions through direct questioning of the client) or of an indirect process (establishing criteria "explaining" global preferences expressed by the client on examples or already known cases [26, 59, 64]). A criterion can be regarded as a point of view against which it is possible to compare different alternatives. For such a comparison we need the user's preferences either explicitly stated (through a binary ordering relation) or implicitly associated to "values" (how much it is?) "utilities" (measures or preferences). Therefore, a criterion models the decision maker's preferences [26, 134]. On the other hand, the evaluation of an action can be the result of the construction of positive and negative reasons for that action. In argumentation theory, such reasons are formally represented by the mean of arguments. Thus, we can have both arguments in favour and against an action. Those arguments are intended to support, explain, or attack the action.

Consequently, we have two evaluation tools, but two different practices. An argument is designed more to justify the consequences of an action. The criterion, in turn, is built for purposes of preferences representation. Indeed, the structure (or more precisely the premises) of an argument provides explicit evidence that will be used to support (or not) a precise action. The criterion however, does not seem to have this feature. It certainly helps to model the decision maker's preferences, which then can be used to justify why we can be in favour of an action. The problem is that this information is not explicit and visible for the decision maker. It is not easy to guess what is the model (or reasoning) that helped to promote an action rather than other.

A further difference between an argument and a criterion, concerns the way by which the actions are compared. Decision analysis allows to identify models of preferences which can be used to compare and choose actions, either on the basis of an *intrinsic evaluation* (the evaluation of an action is based on its comparison to some pre-established norms) or a *pairwise comparison* (the choice is defined with respect to the comparison of the actions among themselves). In argumentation, however, the evaluation is rather intrinsic and the pairwise comparison of actions only comes as a by-product of the construction of arguments pro/ con each alternative. One may argue that, in decision analysis, it is always possible to retrieve pairwise comparison on the basis of intrinsic valuations. But this is more than a simple technicality. The hypothesis done in almost all Multiple Criteria Decision Analysis methods (see [72, 118]) is that criteria represent complete preferences (all alternatives being comparable to all the other ones). This is empirically falsifiable as well as other hypotheses (for instance transitivity of preferences).

Finally, a basic requirement on the criteria set is separability: each criterion alone should be able to discriminate the actions, regardless of how these behave the other criteria (further conditions can apply, that we shall not discuss here; for more details the reader is referred to [72, 119, 140]). With arguments, it not possible to provide such result on the set of action on the basis of a single argument. Each argument constructed concerns a particular action.

To summarise, the concept of criterion is devoted to model the decision maker's preferences, and an argument is designed, in general, to explain and justify conclusions. From our point of view, argumentation can be seen as a way to make explicit the reasons justifying each preference ranking among actions. That is, if the decision-making were to ask the question "why did you say that you preferred a over b?", we may give those reasons.

Under such a perspective, what can be the structure of such reasons? In other terms, what is the structure of an argument for an action? In fact, argumentation is usually conceived as a process for handling (potentially conflicting) *beliefs*. In AI, many systems have been proposed that allow to capture the defeasible nature of this kind of reasoning. Thus, the basic building block (the argument) can typically be defined as a premise/conclusion pair, whereby you state that this conclusion should be reached under these premises. What is discussed here is the truth-value of the conclusion, so an argument supporting a conclusion basically asserts some evidence to believe that this conclusion holds. When it comes to decision-making though, this rather crude argument scheme needs to be refined. Indeed, as it has been recognised for a long-time now, a significant difference exists between argumentation for beliefs and argumentation for actions [46, 47]. This is better explained by means of a simple example, borrowed to Amgoud [1].

EXAMPLE 2 *This example is about having a surgery or not, knowing the patient has colonic polyps. The knowledge base contains the following information: "having a surgery has side effects", "not having a surgery avoids having side-effects", "when having a cancer, having a surgery avoids loss of life", "if a patient has cancer and has no surgery, the patient would lose his life", "the patient has colonic polyps, having colonic polyps may lead to cancer".*

- *The first argument: "the patient has a colonic polyps" and "having colonic polyps may lead to cancer", is considered as an epistemic argument believing that the patient may have cancer. While,*
- *The second argument: "the patient may have cancer", "when having a cancer, having a surgery avoids loss of life" is a practical argument for having a surgery. This argument is in favor (or supports) the option "having a surgery".*

In what follows, we address some of the approaches that have contributed to improve our understanding on what makes the argumentation about actions crucially different from mere epistemic argumentation. The idea is to understand how to judge or evaluate an action in order to conclude that we have an argument in its favour. Moreover, we propose to review these works, taking a decision theory perspective, more precisely a multi-criteria decision analysis perspective. Thus, the intuitive reading for an argument for an action, is that action a will have "good consequences". Then, we must first somehow *valuate* the outcome of the action. In decision models, this would typically be done by using an ordered scale defining the different values that can be used to assess the action (for instance, marks from 0 to 20 for students). After that, what counts as a positive or negative outcome is specific to each decision maker, and depends of its (subjective) preferences. That is, we have to classify the outcome of the actions. In decision models, one approach is that the decision maker uses an evaluation scale and specify a frontier, that is, a *neutral point* (or zone), thus inducing a *bipolar scale*. This will in turn allow us to determine what counts as an argument pro, or against, the action.

The concept of "bipolarity" in scales measuring value is not really new in the literature. Rescher [109] has been the first to introduce this concept. Roy [116] has introduced the concept of concordance/discordance in Multiple Criteria Decision Analysis (through the outranking procedures) and Tsoukiàs and Vincke [135] used a specific logic formalisms in order to extend preference models under the presence of positive and negative reasons, among others. In this work, the concept of bipolarity refers to the existence of two independent types of information, positive and negative. The first provides support to the action and the second allows to express a disagreement against this action. Furthermore, in argumentation theory, several studies have emphasised the possibility of having this bipolarity (positive vs negative) between arguments [4, 137]. Thus, we can construct arguments in favour of a conclusion and arguments against that conclusion.

Consequently, considering such aspects of multi-criteria evaluation, what are the benefits provided by these approaches and what are their limits in this type of context? To guide our discussion, for each approach we will try to provide answers to the following questions:

- how is the notion of criterion (point of view) captured in this model?
- how are pro/con arguments constructed?
  - how are the user's preferences represented?
  - what is the scale used to evaluate outcomes?
  - is there an explicit reference to a preference model?

In our view, these issues include the major necessary basic elements to build an argument in favour of an action, by taking into account the different aspects of a multi-criteria evaluation.

4.2 Argument schemes for action

Our aim in what follows is to present and discuss different approaches that have attempted to define an argument for an action. we will use the following example to illustrate the different approaches.

EXAMPLE 3 *We want to select a candidate for a given position, and we have a number of candidates applying for it. We need to evaluate the outcome of* *each possible action, that is, how good is the situation induced by accepting each given candidate. For instance, a desired consequence is to have a strong enough candidate as far as academic level is concerned. Let us suppose that this is assessed by using a bipolar scale referring to marks, where 12 stands for our neutral point. Then, we could say that according to "marks", we have an argument in favour of accepting this candidate if its mark is more than 12.*

Fox and Parsons [46] is one of the first work that tried to advocate an argumentative approach to decision-making, building on Fox's earlier work [44]. They recognise and clearly state what makes argumentation for actions different from argumentation for beliefs, and put forward the following argument scheme:

Table 1.1. Fox and Parsons' argument scheme.

We should perform A (A has positive expected value)
Whose effects will lead to the condition C
Which has a positive value

This argument can be represented as follows:

$$\begin{array}{llllll} A \rightarrow C & : & G & : & + & e_1 \\ C & : & G' & : & + & v_1 \\ A & : & (e_1, v1) & : & + & ev_1 \end{array}$$

where in the general formulae $< St : G : Sg >$: St (Sentence) represents the claim, G (Grounds) are the formulae used to justify the argument, and Sg (a signe) is a number or a symbol which indicates the confidence warranted in the conclusion. As explained by Fox and Parsons, the advantage of this representation is that it makes explicit three inference steps:

- e_1: that C will indeed result from action A;
- v_1: that C has some positive value, and eventually;
- ev_1: that A has a positive expected value.

Clearly, steps (v_1) and (ev_1) requires additional information in order to be able to assign values to situations, and to decide whether the action has indeed a positive expected value. The valuation of the condition is subjective (dependent of the agent's preference), and represented here by "labelling the proposition describing C with a sign drawn from a dictionary", which can be qualitative or not and plays the role of *a scale*. Interestingly, different values can be assigned to C from different *points of view*. However, it is not clear how we can handle these different points of view in order to reach a conclusion. For instance, one can ask if these points of view are predefined.

We can apply this approach to our example 3, then we can say, for instance, opting for a given candidate (say a) could lead to an outcome where the chosen candidate has a mark of 14. This would be captured by the first epistemic step e_1 of the scheme, where ga stands for the justification of this step. Together with the two following steps, this could be represented with this scheme as follows:

$$\begin{array}{llllll} chose_a \rightarrow mark = 14 & : & ga & : & + & e_1 \\ mark = 14 & : & va & : & + & v_1 \\ chose_a & : & (e_1, v_1) & : & + & ev_1 \end{array} \qquad (\textit{case 1})$$

The second step (v_1) means that the condition $mark = 14$ is positively evaluated by our agent (noted by symbol +) (it then counts as a positive argument), where va is the justification for this value assignment. Although this aspect is not deeply explored in the paper, a very interesting feature of this approach is that it makes explicit the grounds allowing to assign this value to this condition: what may count as obvious candidates to justify this value assignment, if we take the view of the multicriteria-decision approach, would be *the user's preferences* ("I consider that the mark is good from 12"), as well as *the preference model* used ("a mark is good (or positive) as long as it is beyond the limit previously stated").

We could also directly encode within this scheme that opting for a given candidate would lead to an outcome where the condition that the chosen candidate has a mark over 12 is satisfied, a fact that we consider positive. This could be represented as follows:

$$\begin{array}{llllll} chose_a \rightarrow mark \geq 12 & : & ga & : & + & e_1 \\ mark \geq 12 & : & va & : & + & v_1 \end{array} \qquad (\textit{case 2})$$

meaning that the condition $mark \geq 12$ is positively evaluated by our agent (noted by symbol +) (it then counts as a positive argument), where va is the justification for this value assignment. In this case, the nature of this justification is less clear, for it leads to support the agent's preferences.

These two alternative ways of representing argument schemes about actions seem somewhat unsatisfactory. On the one hand, chosing to directly represent the neutral action (here 12) drawn from the agent's preferences (case 2) drops the relation linking an action and its consequences. On the other hand, not representing it (case 1) assumes it is somehow encoded within a "value assignment" mechanism. Finally, this approach does not really acknowledge that actions themselves can be evaluated against a number of meaningful, predefined, dimensions: in fact, each condition induces a new dimension against which the action can be evaluated.

One of the most convincing proposal recently put forward to account for argument-based decision-making is the one by Atkinson et al. [14, 12]. They propose an extension of the "sufficient condition" argument scheme proposed by [144], called, argument scheme for practical reasoning.

The need for practical reasoning has emerged from the recent growth of interest in software agent technologies (see [151]), that puts action at the centre of the stage. Indeed, for software agents to have the capability of interacting with their environment they also need to be equipped with an ability to reason about what actions are the best to execute in given situations.

To define the scheme of Table 1.2, the authors have taken Walton's notion of a goal and separated it into three distinct elements: *states* (a set of propositions about the world to which they can assign a truth value), *goals* (propositional formulae on this set of propositions) and *values* (functions on goals). Therefore, unlike the previous approach, the notion of value is used here in a different sense. Atkinson explains [11] that values should not be confused with goals as "they provide the actual reasons for which an agent wishes to achieve a goal".

Table 1.2. Atkinson's argument scheme.

In the circumstances R
We should perform A
Whose effects will result in state of affairs S
Which will realise a goal G
Which will promote some value V

A given action can induce different state of affairs that may satisfy many goals, hence affecting different values. Indeed, a function *value* maps goals to pairs $\langle v, sign\rangle$ where $v \in V$, and $sign$ belongs to the scale $\{+, -, =\}$. Thus, The valuation of the consequences of an action is based on a scale, related to v, which express the fact the value is promoted or demoted. So, unlike the previous one, this approach addresses explicitly action's consequences, and states actually desired by the agent (preferences). We believe this distinction remains important even if there is no discrepancy between observed and inferred states [17]. For instance, using our running example, we could have

$$value(mark \geq 12) = \langle academic\_level, +\rangle$$

meaning that the value (criterion) academic level is promoted when the mark is over 12.

In this approach, *values* seem to play the role of *criteria*, in the sense that we can assess the action's consequences according to a point of view (here v). The particularity of a criterion is its ability to model the agent's desires. In this approach such desires are specified through the goals. However, the declarative nature of goals allows for more flexible classifications than what we typically have in decision models. For instance, it is possible to easily express that

$$value(age \geq 18 \wedge age \leq 32) = \langle youth, + \rangle$$

the value "youth" is only promoted when the *age* falls between 18 and 32. It is also important to note that this approach does not cater for an explicit representation of all the justifications of the value assignment (this only rely on the logical satisfaction: a goal reached or not, which justifies the value assignment). In this case, it is not possible to represent or indeed challenge the preference structured used. We also refer to Bench-Capon and Prakken [17] for a detailed discussion related to this scheme.

In Amgoud et al. [2], the authors proposed an approach explicitly linking argumentation to multi-criteria decision-making. They see an argument as a 4-tuple $\langle S, x, c, g \rangle$ where

- $S \subseteq \mathcal{K}$: the support of the argument.
- $x \in \mathcal{X}$: the conclusion of the argument.
- $c \in \mathcal{C}$: is the *criterion* which is evaluated for x.
- $g \in \mathcal{G}$: represents the way in which c is satisfied by x (goals).

Where: $\mathcal{K}$ represents a knowledge base gathering the available information about the world; $\mathcal{X}$ is the set of all possible decision; $\mathcal{C}$ is a base containing the different criteria and $\mathcal{G}$ is the set of all goals.

It is required that S is consistent when we add the fact that the action x has taken place. Here, in a way that is reminiscent of the previous approach, each goal g is explicitly associated to a criterion by means of a propositional formula $g \rightarrow c$, although the possibility of having goals referring to different criteria is also mentioned. More precisely, the goal g refers to the satisfaction of criterion c. Indeed, each criterion can be translated into a set of consequences. In turn, the consequences are associated with the satisfactory level of the corresponding criterion. This satisfaction is measured on the basis of a bipolar scale which has a neutral point that separate the positive and the negative values. Therefore, in this approach, unlike in [11], the use of (bipolar) scale is explicitly mentioned: the goals will fall either on the negative or on the positive side, which represent two subset of consequences. In addition, this approach also allows for a quantitative measure of how good are the attained goals.

To apply this approach to the example 3, we may specify that the knowledge base has several layers

$$G_2^+ = \{mark \geq 14\};\ G_1^+ = \{14 > mark \geq 12\};\ G_1^- = \{mark < 12\}$$

which means that the marks are considered as "good" from 12, and even "very good" from 14, while it is insufficient when it is below 12. This comes together with formulae of the form

$$mark \geq 14 \rightarrow academic\_level$$

which explicitly states that the goal G_2^+ affects the criterion "academic level". Now each decision will have some consequences, that will in turn fulfill some goals or not. An argument is in favour this decision if this later satisfies positively a criterion. In other terms it satisfies positive goals. However, an argument is against a decision if the decision satisfies insufficiently a given criterion. So, it satisfies negative goals. Thus, it is possible to identify arguments pro and cons a given decision x, by simply scanning the knowledge base and checking which positive (resp. negative) goals are satisfied by the occurrence of a given decision x. For instance, in our example of chosing a candidate a having a mark = 14, we have an argument in favour of $chose_a$ because it satisfies the positive goal G_2^+.

In conclusion we can notice that this approach seems to be the first tentative work that investigates the interest and the question raised by the introduction of argumentation capabilities in multiple criteria decision making.

To conclude, what we have seen along this section, is that each approach is rather marginally different from the other ones, but they share the fact that a decision process can be represented by explicit and distinct steps. Therefore, these approaches allow to focus on the different aspect of this process. Specifically, Fox and Parsons [46] are the only ones to explicitly represent the justification of a value assignment, however, they do not fully explore this avenue; and hardwire the possibility of having different criteria. Atkinson [11] makes this latter distinction clear, but on the other hand, do not cater for an explicit representation of all the justifications of the value assignment (this only rely on the logical satisfaction: a goal is reached or not, which justifies the value assignment). In this case, it is not possible to represent or indeed challenge the preference structures used. Amgoud et al [2] also rely on the logical satisfaction of goals to justify the value assignment, but the goals are ordered in a way that indeed allows to refine the preference structure, to express various degrees of satisfaction of a goal. Still, this is directly encoded in the knowledge base and cannot be discussed in the process. Also, by using a bipolar scale, they constrain the syntax of goals and prevent themselves from using the full expressivity provided by the logic.

There are, on the other hand, many similarities between these approaches. First, the evaluation is made possible by an explicit representation of the consequences of the action. By relying on logic to represent such states of affairs, it is more expressive than the ordered scale that is usually used in decision models. One further possibility that is offered by this representation is that some action evaluation may be implicit or partial, whereas in decision models you would require each action to be evaluated on each criterion. The third, perhaps most striking similarity, is that they all rely on a method of *intrinsic evaluation*, and use more or less explicitly a neutral (or fictive) action.

However, if we consider the context of decision aiding process, such approaches do not necessarily meet the expectations of such a field. Indeed, most approaches do not refer explicitly to the criterion which is the main tool to assess and compare alternatives according to a well defined point of view. This concept does not only evaluate actions but reflects the decision maker's preferences. Moreover, unlike in decision analysis, where several different problem statements are allowed (such as choosing, rejecting, ranking, classifying, etc.), the different argumentation-based approaches [68, 86] assume only one kind of decision problem, namely "choosing", where the aim is to select the best solution. Other approaches [12, 46] rely on the intrinsic evaluation of the consequences of an action, while many decision problems involve the relative evaluation of actions. Furthermore, they focus much more on the construction of arguments for and against an action and do not care about the construction of the final recommendation. Finally, several approaches [2, 24] used aggregation procedures based only on the number or the strength of arguments, while in decision analysis there existe a range of aggregation procedures. Regarding the latter, one can ask the question of how to justify the use of a procedure rather than another. Indeed, argument schemes can also be designed to make explicit aggregation techniques that can be used on the basis of preferential information.

4.3 Argument schemes for the decision aiding process

Decision aiding has to be understood as a process, where several different versions of the cognitive artifacts may be established. Such different versions are due, essentially, to the fact that the client does not know how to express clearly, at the beginning of the process, what is his problem and what are his preferences. Thus, as the model is constructed, the decision maker revise and update his preferences and/or objectives. Thus, it is necessary to have a language that enables to:

- capture the feedback loops present in such process;
- account for the inconsistencies which may appear during the process;
- account for irreducible uncertainties, possibly of qualitative nature;
- consider the necessary revisions and updates that may occur along such processes.

Under such a perspective, argumentation as we have seen throughout this chapter, seems to be a good alternative in order to reply to such needs. A first work that tried to introduce argumentation within a decision aiding process is the one of Moraitis et al. [38, 84]. The aim of the authors was, on the one hand to design autonomous agents able to undertake decision aiding tasks and on the other hand to show why such a theory could be helpful for automatic decision purposes in autonomous agents. Moreover, they claimed to be able to provide a way allowing the revision and the update of the cognitive artifacts of decision aiding process. To do that, they use different elements from Kakas et al. [67, 66]. They establish:

- a number of object level rules showing the relations between problem formulation and evaluations models,
- the default context priority rules which help in applying the object level ones, and
- the specific context rules which will give priority to the exceptional conditions rules.

The idea is to show how argumentation theory can be used in order to model the decision aiding process, besides being a formalism enabling to take in account the defeasible character of the outcomes of such a process. It is clear that this approach represents a first step toward using argumentation in decision aiding process. However, some features remains not clear or unsatisfactory. For instance, a decision aiding process is an interaction between an analyst and a decision maker, and in this framework it is not very clear how we can model this interaction, even through an automatic system.

In a recent paper, Ouerdane et al. [89] advocated the use of argument schemes to handle the various stages of decision aiding processes. Following this approach, a hierarchy of schemes can be designed, allowing to make explicit many of the assumptions that remain otherwise hidden in the process, for instance: justification and revision. The idea is to specify in argumentative terms the steps involved in a multi criteria evaluation process. To do that, they make use of the notion of argument schemes already introduced before. Thus, a hierarchical structure of argument schemes allows to decompose the process into several distinct steps—and for each of them the underlying premises are made explicit, which allows in turn to identify how these steps can be dialectically defeated.

5. Conclusion

This chapter explores the links between decision aiding and argumentation theory. We did a brief introduction to argumentation (in a AI perspective), and discussed how and why it result to be useful in different contexts of decision aiding. We have also discussed several existing approaches to argument-based decision-making involving (or at least referring to) more specifically MCDA techniques. In particular, we have seen that argument schemes:

- can be employed to explicitly state what justifies a chosen course of action. They can be based on various notions: underlying motivations, goals, or direct comparison of alternatives based on user's preference statement. Note that by relying on underlying goals, we must then chose a specific criterion to be able to compare two possible states of the world (do I prefer a situation where many secondary goals are satisfied vs. one in which only, but prominent, is?). There are of course many possible options here (see [24]), that we shall not discuss further. From our brief review, it came out that different approaches make explicit different steps of the process.
- are of primary importance: by expliciting the inference steps of an argument, we also define what counts as valid "critical question", that is how arguments will interact with each others (how they can be attacked and so on).
- more prospectively, argument schemes can also be designed to make explicit aggregation techniques that can be used on the basis of preferential information. For instance, a user may want to challenge the use of a weighted majority principle. Even more than that, we have seen that in a real decision aiding process it is possible to modify problems formulations, or other statements.

So far, research has largely focused on the benefits of adopting an argument-based approach in that it allows to ground preferential information on underlying motivational attitudes. We want to stress here that we believe it also has much to contribute when it comes to capture the decision-aiding process. We conclude adding one more research perspective concerning interleaving argument structures and preferential information. This highly interesting avenue of research is taken by a growing number of researchers [18, 65], which only provides a further and final example of the vivid activity blossoming at the interface of MCDA and argumentation.

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