Modeling argumentation in practical reasoning: a conceptual analysis of argument life cycle

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Abstract

Argumentation is the activity of producing explicit justifications for the assertions of a reasoner. It plays a crucial role in a debate, both in revising one's own assertions and in comparing and opposing them to assertions of other reasoners. Several recent works have provided detailed logical characterizations of argument properties, paying however only limited attention to the conceptual structure of an argument, which is indeed a fundamental issue for a correct modeling of the argumentation activity in practical contexts. Starting from the concept of argument life cycle, we propose in this paper a model of argumentation activity encompassing the main phases of argument construction, criticism, and corroboration. Then we introduce a structured representation of an argument, based on the concept of justification graph, and we use it as a basis for the analysis of argument life cycle phases. A simple argumentation example, concerning an athlete doping case, is developed throughout the paper in order to support an intuitive understanding of the proposed ideas.

1. Introduction

An intelligent reasoner, acting in a practical context, should be able to provide justifications for its assertions, either when it has to convince other reasoners about their validity or when it is uncertain about its own assertions and has to decide whether retaining or retracting them.

The activity of producing justifications for one's assertions is called *argumentation*, which more precisely is "the process of constructing arguments about propositions and the assignment of statements of confidence to those propositions based on the nature and relative strength of their supporting arguments"[6]. Studies on argumentation date back to [10] and have recently received a renewed interest [5][9][7][8]. In fact, argumentation plays a crucial role both in the field of uncertain reasoning, where different assertions may be qualified as more or less certain depending on the way they can be justified, and in the area of multi-agent systems, where distinct agents may have different and possibly contrasting beliefs and should be able to conciliate their different points of view on the basis on the justifications supporting them. In particular, in a multi-agent context, argumentation becomes an articulated and dynamic activity: once an agent has built an argument for an assertion, it should expect that his argument may be attacked by another agent and should therefore be ready to reply to such attacks by modifying or extending the argument.

In order to allow a reasoner to discriminate between different levels of argument acceptability, several recent works have focused on providing a characterization of arguments from a logical point of view [7][8]. However, such approaches to argument evaluation feature a limited expressive power and are unable to capture some conceptual aspects whose importance can be easily recognized in practical argumentation. More importantly, such works seem to focus on the construction and qualification of arguments as a static, one-shot activity, while paying scarce attention to the fact that an argument is a dynamic entity, that once constructed, is destined to go through repeated phases of criticism and corroboration in the context of a debate.

The goal of this paper is to propose a new model for argumentation, which, extending the perspective adopted in logical approaches, can encompass some of the most important features of argumentation in practical reasoning contexts. The present work is of conceptual nature and the proposed model is not meant to directly support the implementation of an argumentation system, since there are many aspects which are heavily domain dependent, but rather to provide a structured reference framework for a clear and cognitively plausible representation of argumentation.

The paper is organized as follows. In section 2 we discuss the concept of argument, pointing out some basic limitations of the current logical approaches and proposing a list of requirements for a practical argumentation system. In section 3 we introduce the concept of argument life cycle, and in sections 4, 5 and 6 we describe its main phases with the support of a simple example concerning an athlete doping case. Section 7 presents a comparison with other recent approaches to argumentation and suggests some future research directions.

2. The concept of argument

In very general terms, an *argument* is an information structure a reasoner can adopt for justifying an assertion.

Of course, a reasoner may have different ways for justifying the same assertion and, therefore, he may be able to construct several distinct arguments for it. Justifying an assertion means expliciting an acceptable reasoning line from which the assertion can be derived. A reasoning line normally consists of an inference procedure that, starting from a set of initial assertions, can produce the assertion to be justified. Following [3], reasoning activity involves the use of two kinds of information: *factual evidence*, that is information concerning the specific case at hand and whose validity is limited to the current reasoning situation, and *generic knowledge*, whose validity extends to a whole class of possible situations. Generic knowledge can be further classified as *defeasible*, namely knowledge which is not universally applicable and admits exceptions, or *undefeasible*, namely knowledge which does not admit any exception and is universally accepted.

The above intuitive definition is substantially in accordance with the scheme proposed by Toulmin [10], that, given a *claim*, namely the assertion to be justified, defines an *argument* for the claim as composed by:

- *data*, namely the initial factual assertions describing the current situation, from which the reasoner starts its derivation activity;
- *warrant*, namely the reasoning step which allows one to derive a new assertion from an already existing one; a reasoning step usually involves: verifying the applicability of an item of generic knowledge to the current situation, then applying it through a suitable inference rule, and deriving a new assertion;
- *backing*, which represents the foundation underlying the warrant: if the generic knowledge used in the reasoning process is questioned, it needs in turn to be justified resorting to more fundamental arguments, called backing in Toulmin's terminology.

As it will be better remarked in section 4.1, the identification of the basic elements of Toulmin's scheme has a significant relevance for correctly modeling practical argumentation activity. In particular, they can help in classifying the various ways an argument can be analyzed and attacked, in the context of a debate between contenders holding different opinions. In fact, at least three alternative strategies are possible:

- showing that the initial data the opponent uses are simply wrong, so undermining all the conclusions derived from them;
- pointing out that there is some kind of logical flaw in the reasoning line that relates data to the conclusion, i.e. in the warrant: this might mean questioning the applicability of the knowledge used in the current context or even questioning the inference rules adopted (this case will not be considered, however, in this paper: we assume that inference rules are not questionable);
- questioning opponent's knowledge, calling into question its backing; for instance by counterproposing a different interpretation of the same initial data, based on an alternative model of the portion of the world involved in the argument.

These forms of attack against an argument are clearly distinct in nature; for example, evaluating the reliability of a single datum is quite a different matter than questioning the validity of a general principle. This supports the intuitive idea that a practical argumentation mechanism should be a conceptually articulated entity, able to encompass a rather wide range of distinct methods, strategies and skills. Recent attempts to formalize argumentation [4][5][7][8], however, do not seem to cope with this issue. In fact, they assume a flat representation of the concept of argument, which is merely conceived as a set including all the logical elements (e.g., facts and implication relations) that constitute the basis for a proof of the assertion of interest, without taking into account whether they represent factual or generic knowledge. In the context of such representations, arguments can be qualified according to their logical properties, such as the presence of a contradiction within the argument itself or the possibility of constructing another argument asserting the negation of its claim. However, this kind of qualification can not encompass the important conceptual distinctions mentioned above. For instance, if a contradiction involves facts only, it is contingent to the presence of contrasting evidences concerning the specific situation considered and could be solved by collecting further evidences. Moreover, such a contradiction is confined to the current case and will not affect reasoning in other contexts. On the other hand, if a contradiction is intrinsic to the generic knowledge used by the reasoner, the problem is more substantial and will repeatedly and unavoidably affect any argument produced by the reasoner using this knowledge in any context. Moreover, solving such a contradiction requires a revision of reasoner's generic knowledge base, which is actually a more radical and more complex action than revising contingent beliefs about a single case. As it is evident, these differences can hardly be encompassed by a flat representation of arguments. Moreover, the logics used for argument derivation in most current works are monotonic: this contrasts with the well-known fact that practical reasoning involves the use of defeasible knowledge and is therefore inherently non-monotonic.

From the above considerations a set of *requirements* for an approach to the formal representation of practical argumentation can be drawn:

(i) *Conceptual articulation*: the representation of an argument should account for the different knowledge elements that play a role in practical argumentation, providing an explicit, distinct representation of such elements and of their inter-relations;

(ii) *Reasoning traceability*: in the representation of an argument it should be possible to explicitly trace in detail the reasoning line followed by the reasoner in

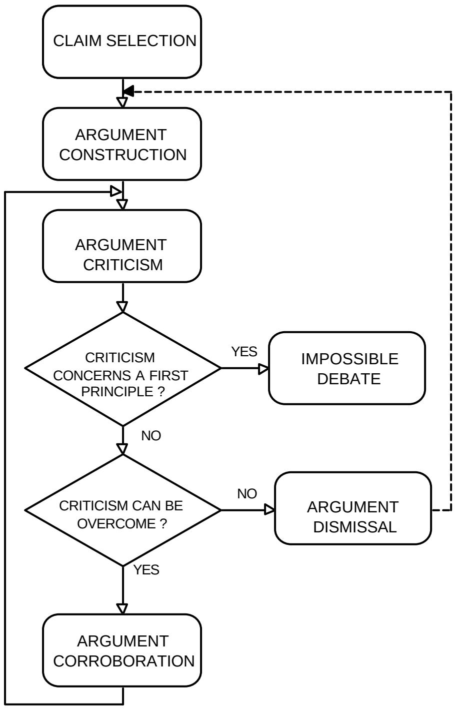

Figure 1: Argument life-cycle

its construction;

(iii) *Use of defeasible knowledge*: the representation of an argument should be allowed to include defeasible knowledge;

(iv) *Heterogeneity*: the representation of an argument should be sufficiently abstract to allow that the contending reasoners employ heterogeneous internal knowledge representation and reasoning formalisms;

(v) *Forms of debate*: the representation of an argument should support the implementation of different strategies of supporting one's own arguments or of attacking the arguments of an opponent reasoner;

(vi) *Recursivity*: the representation of an argument should allow that the components of an argument may become in turn the subject of argumentation, thus allowing a recursive argumentation mechanism, where the components of a justification for an assertion may become in turn assertions to be justified.

The goal of this paper is to propose a novel approach to argumentation which is sufficiently expressive and conceptually articulated to cope with most of the requirements listed above. Our analysis is mainly intended to focus on the dynamic aspects of argumentation and starts therefore from the original concept of argument life cycle, which is then taken as a basis for the development of the overall approach.

3. Argument life cycle

According to the intuitive considerations drawn in section 2, the life cycle of an argument can be defined as shown in figure 1.

In general, an argument life cycle starts with the *selection* of the claim, namely of the assertion whose justification represents the final goal and the "raison d'être" of the argument. The selection of the claim to be supported by the argument actually depends on reasoner's goals and interests. Later, the reasoner has to carry out a *construction* phase, where an argument for the claim is produced, by showing that the claim can be derived from available (or purposely collected) factual evidence, using generic knowledge.

Once the argument has been constructed, it is communicated to other reasoners and a phase of *criticism* starts. Other reasoners may analyze and criticize the argument, by evidencing possible weak points and flaws included in it. If the criticism concerns a first principle, namely an element of the argument which is considered definitely unquestionable by the author of the argument, any further debate is impossible. Otherwise the argument author has to evaluate whether it is possible to satisfactorily reply to the objections proposed against the argument or if the argument can not be supported further. In the latter case, the argument has simply to be dismissed (and possibly a new one is constructed for the same claim), whereas in the former one, a phase of *corroboration* is undertaken, where the argument is modified and reinforced in order to answer the doubts and questions raised in the criticism phase. Once the modified argument has been completed, it is communicated again to the opponent reasoners for a new phase of criticism and the criticism-corroboration loop is restarted.

Argument life cycle terminates in case of definite dismissal. A state of definite acceptance of an argument is not included in the life cycle, since the possibility of criticizing an argument should be considered as always open (even for scientific theories accepted for centuries). In practical reasoning, however, where time plays an important role, it is often the case that decisions are made and the consequent actions executed just after the criticism or the corroboration phases, without waiting for a possible corroboration or for a new criticism. In such cases, the debate is forcedly terminated.

Having briefly sketched the main phases of an argument life cycle, we examine them in more detail in the following sections. In order to support the understanding of the general concepts that will be progressively introduced, we will refer to a simple example, concerning the case of an athlete doping, where the claim is the fact that the athlete should be disqualified.

4. Argument construction

4.1 Internal argument construction

Once an interesting claim has been selected, an argument

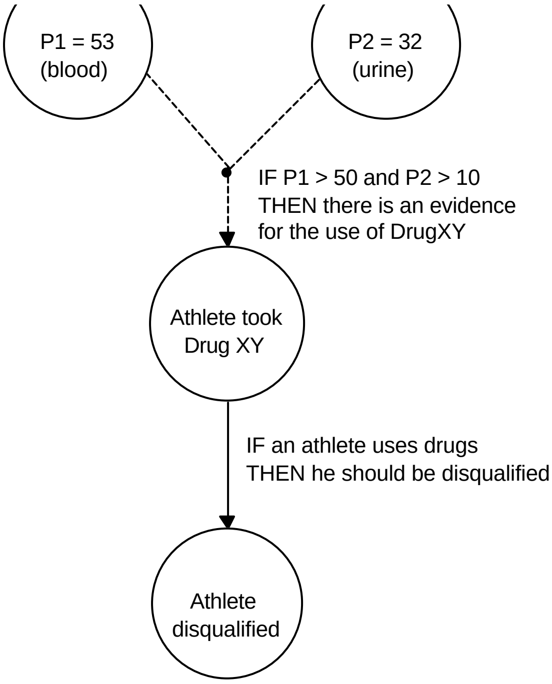

Figure 2: A simple justification graph

for it, namely a reasoning line from which the claim can be derived, has to be built. Argument construction involves deriving the claim from the available data (the possibly necessary activity of data collection from external world is not considered here), through a sequence of reasoning steps, involving the use of generic knowledge and the derivation of intermediate assertions.
Of course, both these activities are internal to the reasoner and strictly depend on the domain considered and on the knowledge and reasoning capabilities the reasoner is endowed with. In the doping example, data to be collected are the results of tests on blood and urine samples of the athlete. If certain chemical parameters of blood and urine are above a given threshold, then it can be derived that the athlete has taken a forbidden drug. Eventually, the use of a forbidden drug implies the disqualification of the athlete.

4.2 External argument representation: inference graphs

Once the argument has been internally constructed by the reasoner, it has to be made available to other reasoners for the criticism phase. This implies that a proper external representation of the argument must be provided that, independently from the actual internal knowledge representation exploited by the author of the argument, allows other reasoners to understand, evaluate and criticize the proposed argument. This representation, which has to be shared between the contenders taking part in the debate, should satisfy the requirements proposed in section 2, so as to give a clear and traceable account of the reasoning line underlying the argument.

According to these requirements, we propose a graph representation for arguments, partially inspired to the concept of *inference graph* [9]. In an inference graph, nodes represent assertions and arcs represent reasoning steps relating assertions among them, so as the graph offers a complete and detailed map of the inferences drawn by the reasoner. In order to better satisfy the requirements of argument representation, we propose a slightly modified version of inference graph, called *justification graph*. A justification graph is an AND-graph where:

- each node represents an atomic assertion, not involving conjunctions or disjunctions;
- each directed arc connects one or more input nodes, representing the premise(s) of the reasoning step, to a single output node, representing the consequent of the reasoning step (see fig. 2); the premises are assumed to be conjunct in AND (disjunctive premises are not considered, since it is assumed that each graph represents exactly one argument).

In order to reflect the conceptual distinctions between factual and generic knowledge, it is explicitly stated that each node of a justification graph correspond to a factual assertion, while each arc corresponds to the application of a piece of generic knowledge to a set of already justified assertions in order to derive (and then justify) a new single conclusion.
This distinction, which is not explicitly encompassed in Pollock's proposal, aims to enforce, within the representation, a clear separation between factual assertions, contingent to the considered reasoning case, and generic knowledge, applicable also to other cases as well. Such separation is in accordance with requirement (i) and is the basis for the satisfaction of requirements (v) and (vi), as it will be shown in the following.
In accordance with requirements (i) and (iii), arcs are explicitly classified as *defeasible* or *undefeasible*, according to the fact that the related piece of knowledge does or does not admit exceptions. Defeasible arcs are graphically represented by dashed thin lines, while undefeasible arcs by solid bold lines.
Note that in our representation we assume that each justification graph J represents an argument for a single assertion A. Therefore, in a justification graph J there is always one and only one leaf node A (a node without leaving arcs) that represents the assertion supported by the argument, namely the claim. On the other hand, in a justification graph J there may be several root nodes (nodes without incoming arcs): these nodes represent factual assertions about the situation at hand which are considered not to require further justifications, namely data. Note also that, assuming Toulmin's schema, the arcs composing the graph, along with their associated items of generic knowledge, represent the steps of the reasoning line leading from *data* to the *claim*, namely the *warrant*.

For a concrete understanding of the concepts introduced above, let us refer to the simple inference graph concerning our doping example (see figure 2):

- Data are represented by the two nodes concerning the results about the parameters P1 and P2 of urine and blood test respectively.
- An arc with two input nodes is used to derive from

such data the assertion that the athlete has used the forbidden drug XY. Such arc is qualified as defeasible since the evidential rule associated to it admits exceptions; in fact, it might happen that, under specific circumstances, the thresholds specified in the rule may be exceeded even if drug XY has not been taken.
- Finally, from the assertion that the athlete has taken the forbidden drug XY, it is possible to derive that he has to be disqualified, by applying a legal rule; the corresponding arc is undefeasible, since such law does not admit exceptions.

5. Argument criticism

The justification graph has the purpose of making the justification of a claim explicit and available for criticism to other reasoners. In order to define how criticism to an argument can be developed, first of all it has to be remarked that an argument may be criticized from a *global* or from a *local* perspective.

The *global* perspective aims at verifying whether some desirable formal properties of the overall argument are satisfied. For instance, it is highly desirable that the argument does not include inconsistencies either involving factual assertions or generic knowledge. The issue of global argument evaluation has received special attention in recent research works based on a logical approaches [4] [7][8][9] (see also section 7.3). Global properties are not, however, the only aspect that can be used to evaluate and criticize an argument. We focus here on a local perspective for argument criticism, which has received, by far, only minor attention in literature, but plays indeed a significant role in practical argumentation.

In order to introduce the *local* perspective, it has to be noted that the construction of a justification involves the use of several unjustified elements, in fact, referring to Toulmin's scheme:

- data represent some initial assertions not further justified;
- warrant encompasses the assumption that a piece of generic knowledge is applicable in the considered context and that given inference rules are adopted;
- backing involves the assumption that the applied piece of generic knowledge is generally valid.

As mentioned also in section 2, it is assumed here that inference rules are unchallengeable; on the other hand, data, and generic knowledge (both for what concerns applicability and validity) may be questioned. The local perspective focuses on these aspects and aims at attacking specific elements of an argument at a time.

We examine now in more detail (without pretending to be exhaustive, however) the different types of local criticism that may involve the three main elements of an argument.

5.1 Criticizing data

Two properties of the data included in an argument are particularly significant for its critical evaluation: *reliability* and *completeness*.

Reliability refers to the actual adherence of data to the real situation they are intended to describe and depends on the way data have been produced or collected. In fact, different experimental procedures may yield differently reliable data and, in some cases, incorrect procedures may give rise to completely wrong data. In several cases, initial assertions used as data in an argument are actually the result of an interpretation, possibly involving articulated reasoning activities: in this case the reliability of data definitely depends on the correctness of the interpretation phase as well. Reliability evaluation is clearly domain dependent and is related to the variety of evidence collection and interpretation procedures that may be available in a specific application context. Unless an initial assertion is considered as a self-evident first principle (see section 6.3), a reasoner should be available to enrich an argument by expliciting the way argument data have been derived and, if possible, by verifying them by repeating their acquisition through the same experimental procedure already utilized or through an alternative one, possibly proposed by the opponent. Referring to the example introduced above, the reliability of analysis results may be questioned by suggesting that they are affected by a significant degree of imprecision. For instance, if it is supposed that the actual value may differ from the measured value of ± 10%, it may then be argued that the actual value might be under the threshold and therefore the derivation is no more valid.

Completeness concerns the consideration of whether all significant evidences have been taken into account in the construction of an argument. Completeness is important to be reasonably sure that further evidences have not been overlooked, that could significantly modify the results of the reasoning process involved in the argument. Of course, the consideration of new data may modify the results of argumentation only in a nonmonotonic reasoning context: therefore the issue of completeness is strictly related to the criticism concerning the application of defeasible knowledge, that will be dealt with in next subsection.

5.2 Criticizing warrant

As mentioned above, the warrant of a single reasoning step involves the assumption that a given piece of generic knowledge is actually applicable to the considered context and that the use of a given inference rule is indeed acceptable. Excluding problems with inference rules, the most significant example of questionable warrant concerns the use of a piece of defeasible knowledge, that is of knowledge which admits exceptions. Therefore, if an argument includes a defeasible arc (as it is unavoidable in practical contexts) the criticism might consist of suggesting that the case at hand is an exceptional case, and that, therefore, the piece of defeasible knowledge considered can not be applied. In particular, the exceptionality of a situation might be evidenced by taking into consideration some additional data. For instance, in the case of the athlete, it might be suggested to consider the data of old medical analyses showing that since his earliest youth the athlete featured anomalous values of the blood and urine parameters considered, thus suggesting that he is an exceptional case and that, therefore, high values may be due to a physiological anomaly rather than to the use of drug XY.

5.3 Criticizing backing

Toulmin's concept of backing calls into question the possibility of criticizing knowledge. In general, knowledge items which are unjustified in the context of an argument, are supported implicitly by some assumptions or by other articulated justifications. If a contender suspects that such implicit assumptions hide some flaw, he may require that they are explicitly presented and in turn subjected to criticism. It should be remarked that both defeasible and undefeasible knowledge can be criticized at the level of backing: in fact, at this level, the general validity of a piece of knowledge is questioned rather than its applicability to the current situation (see [1] for a detailed discussion about the distinction between uncertainty about validity and applicability of a piece of knowledge). In the example (see fig. 2), it might be required to explicit the technical motivations that lead to assert that high values of P1 and P2 demonstrate the use of drug XY, by raising the doubt that the relation between the action of the drug and the parameter values is not sufficiently understood. From a more radical perspective, even the principle that the use of drugs should lead to disqualification could be questioned: one might require to explicit the more basic principles underlying this rule (for instance the need of keeping the competition fair or of preserving athlete's health), with the aim of showing, later on, that the rule does not directly follow from such principles.

6. Argument corroboration

The criticism phase returns to the author a belittled argument, where some of its elements are questioned. The corroboration phase has therefore the aim of repairing, if possible, the original argument by substituting or integrating its weak parts with more solid ones. Corroboration may be realized through a *recursion* on the argument or by a *contraposition* with the opponent.

Recursion is necessary if the criticism concerns data or backing. In this case it is required to make explicit their implicit support and to produce a new justification graph for them. This means that a recursive argumentation has to be undertaken, where an initially unjustified component of the argument, either a datum or a piece of generic knowledge, becomes in turn a claim to be justified. A second level justification graph will need to be produced for each of the new claims. Again, the elements not supported by any explicit justification in the second level graphs might be questioned. This may imply, recursively, the creation of further justification graphs, and so on.

Different considerations apply if the criticism concerns the warrant. Consider the case that the opponent has presented additional data, leading to the conclusion that the situation at hand is exceptional with respect to a piece of defeasible generic knowledge: this means that the opponent counterproposes an argument, where the claim that the piece of knowledge is not applicable is derived from the additional data considered. The author of the initial argument may now follow two alternatives:

- counterattacking the opponent's argument: in this case the roles are exchanged, but the same general considerations developed above about argument criticism apply;
- using some comparison criterion in order to contrast the two arguments and to show which should be preferred: this calls into question the more general issue of argument comparison, which is however beyond the scope of the present paper and will not dealt with here (see for instance [7] for a definition of confidence measures for argument evaluation and comparison).

Both alternatives represent a contraposition, involving the engagement of a debate with the opponent reasoner. Modeling debates between agents is a very important issue related to argumentation activity (see for instance [8]), however it is beyond the scope of the present paper and will not be dealt with here. We will focus therefore on the concept of recursive argumentation introduced above and we will examine the issues of practically constructing an argument for a datum and for a piece of generic knowledge.

6.1 Recursive argumentation on data

Constructing an argument for a datum requires expliciting the way it has been produced or collected. For instance, if the datum was the direct result of a measurement process, justifying the datum means making explicit the adopted measurement procedure and the environmental conditions where it was applied. On the other hand, if the datum was derived from other data (for instance, if it represents the average of a sequence of samples), both original data and the (possibly complex) derivation rules should be explicited. In both cases, in order to represent this type of arguments, it is possible to use a justification graph, where the datum to be justified becomes the claim of the argument. For instance, with reference to the athlete doping case, the criticism about the value of P1 based on the imprecision of the test procedure, may be recovered by showing that such value has been derived by averaging

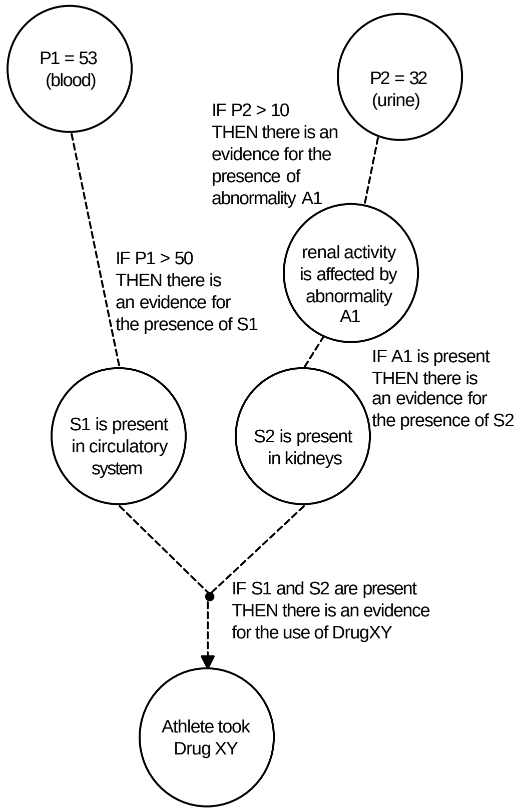

Figure 3: A second level argument obtained by expansion

the values obtained in separate tests carried out independently by different operators. Having been derived this way, the value of P1, say 53, should therefore be considered more accurate than in the case it were derived from a single test. The corresponding second level justification graph, will contain as data all the independent test results and as claim the assertion of the average value 53, derived from the data trough an arc, which represents the generic knowledge that the average value should be selected as representative of several measurements of a given quantity.

6.2 Recursive argumentation on backing

We examine here two distinct ways (of course, not the only possible ones) of constructing an argument for a piece of generic knowledge, called *expansion* and *abstraction shift*, respectively.
In the case of *expansion*, the piece of knowledge to be justified represents the synthesis, at a coarse level, of a more detailed and articulated derivation process, involving a larger number of finer-grained pieces of knowledge and leading from the same premises to the same consequent. In this case, constructing the argument means expliciting the original derivation chain, along with all the pieces of knowledge involved in it. Such derivation chain may of course be represented by a justification graph. For instance, in the athlete example, the arc from the blood and urine test results to the use of drug XY could be expanded by detailing the physiological knowledge underlying it, as shown in figure 3, where it is explicited that the high value of P1 suggests the presence of the stimulating substance S1 within the circulatory system, whereas the high value of P2 suggests an abnormal renal activity, which in turn suggests the presence of substance S2. Finally, the joint presence of S1 and S2 suggests the use of drug XY.

In the case of *abstraction shift*, the considered piece of generic knowledge may be regarded as a factual assertion at a higher level of abstraction: at this level, it is possible

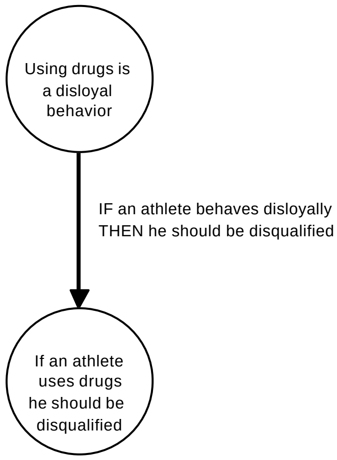

Figure 4: A second level argument obtained by abstraction shift

therefore to build a new argument where the piece of knowledge becomes a claim to be justified. For instance, in the athlete example, in order to justify the arc leading from drug XY to disqualification it is possible to resort to a justification graph at a higher abstraction level (see figure 4), where the piece of knowledge associated to an arc in the graph of figure 2, play now the role of a factual assertion in the new, more abstract, reasoning context. The argument represented by the graph of figure 4 is based on the assertion that using drugs is a disloyal behavior and uses as generic knowledge the basic principle that any disloyal behaviour should be punished by disqualification. This leads to derive as an asserted claim the fact that the use of a drug should necessarily lead to disqualification.

6.3 First principles

The process of recursive argumentation can not continue indefinitely: soon or later, it will be unavoidable that some assertions and some generic knowledge will be assumed by the reasoner as definitely primitive, so that the need of further justifications will be excluded. Of course, it is the responsibility of the reasoner to select and make explicit which first principles are used in his argumentation activity. For instance, in the above example, the principle

that any disloyal behavior should be punished could be considered primitive in a sport competition context.
It should be remarked that the fact that a reasoner assumes an assertion as primitive does not mean that it should be accepted as primitive also by the contender, but rather that the reasoner is not available any more to argument about it. Thus, if a debate comes to a question concerning first principles, any further interaction between the contenders is impossible and the debate can be considered unsolvable without the intervention of an external authority. In the above example, if one would argue that unloyal behavior should be allowed in sport competitions, this would lead to an irremediable conflict that could not be solved by further debate but only by an external intervention of a recognized authority that can enforce that indisputably loyalty is (or, possibly, is not) fundamental in sport competitions.

7. Discussion and conclusions

The main contributions of our proposal with respect to other works on argumentation are sketched in the following.
As to our knowledge, the concept of argument life-cycle has not been explicitly addressed in past literature on argumentation. In fact, though it is generally recognized that arguments are used in a debate between conflicting reasoners and that the argumentation activity may involve attacks and revisions of arguments, scarce attention has been paid to formalize the evolution of arguments through such interactions. Our explicit definition of a model for argument life cycle is a first step in this direction: of course it should be remarked that the model proposed here is very basic and that further refinements can be expected by future research work.
The use of justification graphs is aimed to satisfy the requirements listed in section 2, mainly by supporting a conceptually rich and articulated representation of arguments, which provides clear distinctions between factual evidence and generic knowledge, and between defeasible and undefeasible knowledge.
This contrasts with the flat representation of arguments as plane sets of logical formulas, adopted in several approaches - for example: [5][4][7][8]. Such kind of representation is simply unable to support the distinctions mentioned above, which are, however, of primary importance both at practical and formal level and that received a major attention in earlier works on argumentation [2].
A more articulated argument representation is provided by inference graphs [9], where however, the distinctions mentioned above are considered only partially and implicitly.
The basic concepts of *rebutting* and *undercutting* have been widely adopted in past literature [9][4] as the basis for the definition of argument evaluation and attack mechanisms. In a word, it is said that an argument A1 *rebuts* an argument A2 if the claim of A1 is the negation of the claim of A2, whereas it is said that an argument A1 *undercuts* an argument A2, if the claim of A1 is the negation of one of the components of A2. Starting from these concepts, several authors [4][7][8] have proposed an acceptability classification for arguments which distinguishes: tautological arguments, arguments that can not be undercut by others, arguments that can not be rebutted by others, arguments not including internal inconsistencies, arguments including internal inconsistencies. However, such kind of approach suffers from two kinds of limitations.
First of all, they suggest the idea that, when a reasoner wants to attack an argument, it is necessary to build a rebutting or undercutting argument against it, so adopting a global perspective. However, this is not the most general case, since also a local perspective should be considered, as discussed in section 5. A contender should be allowed to criticize an argument by simply pointing out that some parts of it are not sufficiently justified and require further detailed justifications, without being forced to build an argument for the negation of the criticized assertions.
Second, it should be remarked again that the proposed acceptability classification fails to consider some important practical aspects which are crucial for the comparison of arguments, especially if they have been produced by different reasoners. For instance, the fact that a rebutting or undercutting argument can be built against another one strictly depends on the set of data considered: it might paradoxically happen that a reasoner who is particularly active in collecting evidences from the world is unable to build logically strong arguments just because data are intrinsically contradictory, whereas another reasoner, considering a smaller and partial amount of data, might be able to build logically unattackable arguments. The latter consideration suggests that purely logical evaluations of arguments, though necessary, may not be sufficient in practice and should be accompanied by other evaluations such as those concerning data reliability and completeness.
Our description concerning various forms of criticism to data and knowledge, though rather preliminary and informal, is a first step in this direction and is therefore intended to be complementary with respect to the more consolidated treatment of logical evaluation of arguments from a global perspective.
In most works on argumentation, the existence of conflicting arguments is faced by resorting to some confidence measures stating a strength ordering among arguments [7] or by resorting to an aggregation operator which simply produces a combined argument, that can be classified as contradictory [5]. In both cases, no revision of arguments is undertaken.
Our approach, on the other hand, is based on the (very practical) idea that arguments should be revised in presence of criticisms and that the elements of an argument may in turn become the subject of argumentation. The practical relevance of so-called meta-argumentation has been remarked in [5], where it received, however, a very limited and purely syntactical treatment.

As to our knowledge, this perspective has not received further attention in subsequent works.
Our classification of different forms of argument corroboration, suggests the directions that can be followed in order to better explore this further dimension of the argumentation activity.

References

[1] P. Baroni, G. Guida, and S. Mussi, Modeling uncertain relational knowledge: the AV-quantified production rules approach, *Proc. ECSQARU 95 3rd European Conf. on Symbolic and Quantitative Approaches to Reasoning and Uncertainty*, Fribourg, CH, 1995, 18-27

[2] L. Birnbaum, M. Flowers, R. McGuire, Towards an AI model of argumentation, *Proc. of 1st American Nat. Conf. on Artificial Intelligence*, Stanford, CA, 1980, 313-315

[3] D. Dubois, H. Prade and P. Smets, Representing partial ignorance, *IEEE Trans. on Systems, Man and Cybernetics*, vol. 26, n. 3, 1996, 361-377

[4] M. Elvang-Goransson, P. Krause, J. Fox, Dialectic reasoning with inconsistent information, *Proc. of UAI 93 9th Conf. on Uncertainty in Artificial Intelligence*, Washington, DC, USA, 1993, 114-121.

[5] J. Fox, P. Krause and S. Ambler, Argument contradictions and practical reasoning, *Proc. of 10th European Conf. on Artificial Intelligence*,1992,623-627.

[6] J. Fox, P. Krause and Argumentation as a general framework for uncertain reasoning, *Proc. of UAI 93 9th Conf. on Uncertainty in Artificial Intelligence*, Washington, DC, USA, 1993, 428-434.

[7] P. Krause, S. Ambler, M. Elvang-Goransson, J. Fox, A logic for argumentation for reasoning under uncertainty, *Computational Intelligence*, 11, 1995, 113-131

[8] S.Parsons and N.R. Jennings, Negotiation through argumentation-a preliminary report, *Proc. of ICMAS 96, 2nd Int. Conf. on Multi Agent Systems*, Kyoto, 1996.

[9] J.L. Pollock, Justification and defeat, *Artificial Intelligence*, 67, 1994, 377-407.

[10] S. Toulmin, *The uses of argument*, Cambridge University Press, Cambridge, 1956