A Study of AIF Argument Networks Anomalies and a Characterization of its Solutions

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Abstract. The Argument Interchange Format (AIF) is a communal project with the purpose of developing a way of interchanging data between tools for argument manipulation and visualization. The AIF project also aims to develop a commonly agreed upon core ontology that specifies the basic concepts used to express arguments and their mutual relations. However, the flexibility provided by the AIF core ontology may lead to ambiguous or undesired interpretations. If ambiguous and anomalous situations are allowed, the purpose of using AIF as a common lingua for the research and development of argumentation systems might be jeopardized. The goal of this work is to identify anomalies that can arise and propose solutions for them.

1 Introduction

AIF arises as a communal project in order to relate and consolidate the work of the different research lines associated to computational argumentation [2]. It works under the consensus that a common vision on the concepts and technologies in these lines promotes the research and development of new argumentation tools and techniques. In addition to practical objectives, such as developing a way of interchanging data between tools for argument manipulation and visualization, the AIF project also aims to develop a commonly agreed upon core ontology that specifies the basic concepts used to express arguments and their mutual relations. The purpose of this ontology is not to replace other (formal) languages for expressing arguments but rather to serve as an interlingua that acts as the centerpiece to multiple individual reifications [1].

AIF core ontology [2] provides very flexible constructs for building and relating arguments. Instances of the core ontology concepts, like conflicts, inferences, preferences and information can be almost freely related creating a graph of concepts called argumentation networks. Several works in the literature take advantage of these features and extend AIF in order to represent dialogues [7, 12], argumentation schemes [11], clinical guidelines [5] and food safety reasoners [4].

However, the flexibility provided by the AIF ontology may lead to ambiguous or undesired interpretations. For instance, there can be several interpretations for a network containing a conflict node with two incoming edges from information nodes and two outgoing edges to other information nodes; or it is possible to present a reasoning application node connected to itself. In the current AIF representation [2] these situations are addressed when the core ontology is reified. Each reification can impose its own decision choices regarding to these issues. Therefore, an AIF components configuration may have different meanings depending on the reification.

Despite the specific semantics that a reification may impose to AIF core ontology, from our point of view, the basic semantics of an argumentation network should be unambiguous. If ambiguous and anomalous situations are allowed, the goal of using AIF as a common lingua for the research and development of argumentation systems might be jeopardized.

Therefore, the contribution of this work is to identify anomalies that can arise from certain argument networks of the AIF core ontology, and propose solutions to those situations. In particular, we propose some restrictions over the core ontology. For each restriction we will formally define a refined version of the AIF argument networks. As we will show, most of the ambiguous situations studied in this work arise from incoherent constructs or from constructs that can be represented in a different way using the same components. Hence, forbidding these situations in the core ontology will not significantly affect the representational power of argumentation networks.

Since its proposal, the use of AIF has increased. In [11], AIF is used to express arguments for the World Wide Argument Web: a large-scale Web of inter-connected arguments posted by individuals on the World Wide Web in a structured manner; and in [10] that proposal is used for a Mass Argumentation on the Semantic Web. In [12] AIF is also used for modeling argumentation dialogues. There are also several articles that show how to translate a particular representation to AIF, or use AIF to translate a particular representation to another. For instance, in [8] a mapping between Oren's, Dung's and Nielsen's frameworks is identified. As an application of this mapping, they show how Evidential argumentation frameworks may be represented as a subset of AIF, allowing any other argumentation framework described using this AIF subset to be mapped into Dung's and Nielsen's frameworks. In [1], the connection between the elements of the AIF ontology and the ASPIC framework for argumentation is shown. In a recent paper [13], it is shown how AIF can support flexible interchange between OVA and Arvina, two predominant styles of interacting using argumentation in deliberative domains.

It is due to the impact that AIF has and will have in the community of argumentation, that we consider that it is very important to study, improve and enhance AIF. In the current AIF core ontology, information is structured in a hierarchical fashion with respect to the node types. However, interaction is not structured, thus, for instance, a meta-reasoning node can be at the same level as another node not involved in meta-reasoning. Here we will propose two approaches that provide a hierarchical structure to organize meta-reasoning information.

The rest of the paper is organized as follows. In Section 2 a brief introduction to AIF is given. In Section 3 we will introduce several situations that may lead to ambiguous or undesired interpretations. Then, in Section 4 meta-reasoning specifications are analyzed. Finally, in Section 5 conclusions and related work are introduced.

2 Background: The argument interchange format (AIF)

The AIF core ontology is a set of argument-related concepts, which can be extended to capture a variety of argumentation formalisms and schemes. This core ontology assumes that argument entities can be represented as nodes in a directed graph called an *argument network*. A node can also have a number of internal attributes, denoting things such as author, textual details, certainty degree, acceptability status, etc. The AIF core ontology (Figure 1) falls into two natural halves: the Upper Ontology [2] and the Forms Ontology (which was introduced in [11]). In the ontology, arguments and the relations between them are conceived of as an argument graph. The Upper Ontology defines the language of nodes with which a graph can be built and the the Forms Ontology defines the various argumentative concepts or forms (e.g. argumentation schemes). The work in this paper concerns only to the Upper Ontology.

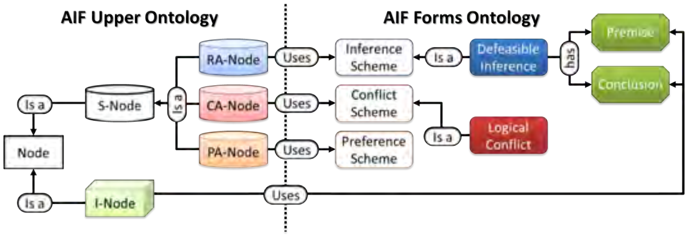


Fig. 1. AIF Core Ontology

The upper ontology distinguishes between information, such as propositions and sentences, and schemes, general patterns of reasoning such as inference or attack. Accordingly, the ontology defines two types of nodes: information nodes (I-nodes) and scheme nodes (S-nodes), depicted with boxes and cans respectively in Figure 1. Information nodes are used to represent passive information contained in an argument, such as a claim, premise, data, etc. On the other hand, Scheme nodes capture the application of schemes (i.e. patterns of reasoning). Such schemes may be domain independent patterns of reasoning which resemble rules of inference in deductive logics but broadened to include non-deductive inference. The schemes themselves belong to a class of schemes and can be classified further into: rule of inference scheme, conflict scheme, and preference scheme, etc. Therefore, these Scheme nodes can be further classified in rule application nodes (RA-nodes), which denote applications of an inference rule or scheme, conflict application nodes (CA-nodes), which denote a specific conflict, and preference application nodes (PA-nodes), which denote specific preferences. Nodes are used to build an AIF argument network, which is defined as follows.

Definition 1 (Argument Network [11]). *An AIF argument network is a digraph* $G = (V, E)$*, where:*

- $V = I \cup RA \cup CA \cup PA$*, is the set of nodes in* G*, where* I *are the I-Nodes,* RA *are the RA-Nodes,* CA *are the CA-Nodes, and* PA *are the PA-Nodes; and*
- $E \subseteq V \times V \setminus I \times I$*.*

Observe that the set of edges is constrained, disallowing connections between I-Nodes. This assures that the relationship between two pieces of information is specified explicitly via an intermediate S-node. Besides this restriction, nodes can be connected freely to each other in an argument network. As we will show in the following section, this freeness may lead to undesired representations.

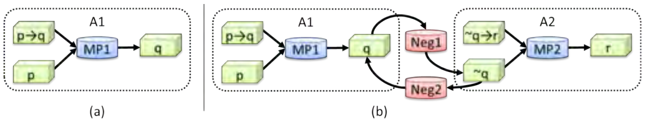
The AIF core specification does not type its edges. Edge semantics can be inferred from the types of nodes they connect. The informal semantics of edges (as proposed in [2]) are listed in the following table:

	to I-Node	to RA-Node	to PA-Node	to CA-Node
from I-Node		I-node data used in applying an inference	I-node data used in applying a preference	I-node data in conflict with information in node supported by CA-node
from RA-Node	inferring a conclusion (claim)	inferring a conclusion in the form of an inference application	inferring a conclusion in the form of a preference application	inferring a conclusion in the form of a conflict definition application
from PA-Node	preference over data in I-node	preference over inference application in RA-node	meta-preferences: applying a preference over preference application in supported PA-node	preference application in supporting PA-node in conflict with preference application in PA-node supported by CA-node
from CA-Node	incoming conflict to data in I-node	applying conflict definition to inference application in RA-node	applying conflict definition to preference application in PA-node	showing a conflict holds between a conflict definition and some other piece of information

From an argument network it is possible to identify arguments. A simple argument [11] can be represented by linking a set of I-Nodes denoting premises to an I-Node denoting a conclusion via a particular RA-Node. Formally:

Definition 2 (Simple Argument [11]). *Let* $G = (V, E)$ *be an AIF argument network with* $V = I \cup RA \cup CA \cup PA$*. A simple argument in* G *is a tuple* (P, R, C) *where* $P \subseteq I$*,* $C \in I$*, and* $R \in RA$*, such that* $\forall p \in P\ \exists (p, R) \in E$ *and* $\exists (R, C) \in E$*.*

Next, in Figure 2 we depict two argument networks involving simple arguments based in propositional logic. In particular, Figure 2(a) depicts a simple argument, while Figure 2(b) depicts two simple arguments in conflict. As stated for the core ontology, boxes represent I-Nodes and cans represent S-Nodes, RA-Nodes in blue and CA-Nodes in red. In Figure 2 the $MP1$ and $MP2$ nodes are RA-Nodes, which denote the application of the modus ponens inference rule. In addition, the CA-Nodes $Neg1$ and $Neg2$ in Figure 2 represent the conflict among the pieces of information through propositional negation.



(a) (b)

Fig. 2. AIF Argument Networks and simple arguments

The abstract AIF ontology presented here is purely intended as a language for expressing arguments. In order to do anything meaningful with such arguments (e.g. visualize, query, evaluate and so on), they must be expressed in a more concrete language so that they can be processed by additional tools and methods. For instance, in Figure 2 the components are instantiated using propositional logic. Another example of this instantiation is made in [11], where the authors reified the abstract ontology in RDF, a Semantic Web-based ontology language which may then be used as input for a variety of Semantic Web argument annotation tools. In a similar vein, [10] has formalized the AIF in Description Logics, which allows for the automatic classification of schemes and arguments. In [1], one of the aims is to show how AIF argument graphs can be evaluated, that is, how a certain defeat status can be assigned to the elements of an argument graph using the argumentation theoretic semantics of [3].

3 Anomalies

In this section we will characterize several situations that may lead to ambiguous or undesired interpretations. Most of these situations are related to the interaction among S-Nodes. In particular, we will identify the anomalous configurations that may arise when a S-Node has multiple outgoing edges, a S-Node has no incoming edges, a S-Node has no outgoing edges, cycles among S-Nodes, and S-Nodes with self-connections. For each of these situations we will introduce a possible solution in order to reach a desirable position.

3.1 Multiple Outgoing Edges

The first anomaly that we identify is related to S-Nodes having more than one outgoing edge. To illustrate this issue we will present several examples where S-Nodes have multiple outgoing edges.

In Figure 3 a RA-Node with several outgoing edges reaching to its conclusions is presented. There, the semantics of the construct is "the application of a rule with premises $Ip1, \ldots, IpN$ leads to conclude the pieces of information $Ic1, \ldots, IcM$".

Fig. 3. A RA-Node with multiple outgoing edges.

In the above depicted situation it is clear that all $Ic1, \ldots, IcM$ are inferred after the application of the rule. However, this interpretation does not follow the intuition behind the notion of simple argument (see Definition 2). If we apply Definition 2 to a situation like the one shown in Figure 3, we will obtain several independent simple arguments, one for each I-Node inferred. This goes against the expected interpretation for this construct, which is to obtain a single argument with multiple conclusions. Thus, even if the interpretation of this construct is clear, it goes against the argumentative concepts from an AIF argument network. In addition, recall that a RA-Node represents the application of an inference rule. Therefore, complying to Definition 2, the correct representation for a situation similar to the one depicted in Figure 3 will consider one RA-Node for each conclusion. That is, to have one RA-Node for each argument.

The semantics of a CA-Node with multiple outgoing edges is not as clear as for RA-Nodes. Figure 4(a) below shows a problematic situation because more than one interpretation is possible. Are $Ip1$ and $Ip2$ together in conflict with $Ic1$ ($Ic2$) alone? That is, can $Ip1$ and $Ip2$ be collectively accepted with $Ic1$ ($Ic2$)? On the other hand, are $Ip1$ and $Ip2$ in conflict with $Ic1$ and $Ic2$ at the same time? Alternatively, is $Ip1$ ($Ip2$) individually in conflict with $Ic1$ ($Ic2$)? Clearly, there is no single interpretation for this construct.

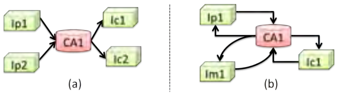


Fig. 4. CA-Nodes with multiple outgoing edges.

There exist even more ambiguous situations than the one presented in Figure 4(a). Figure 4(b) shows a CA-Node with multiple outgoing edges. Clearly, the depicted situation is subject to multiple interpretations. For instance, if $Ip1$ is not acceptable, are $Im1$ and $Ic1$ still in conflict? Both answers lead to possible interpretations of the construct.

In most argumentative formalisms and argument mapping tools, inferences lead to a single conclusion [9]. On the other hand, conflicts usually relate two pieces of information, and the conflict relation is directional [9]. That is, given $I1$ and $I2$, it can be the case that $I1$ is in conflict with $I2$, $I2$ is in conflict with $I1$, or $I1$ is in conflict with $I2$ and vice-versa. Therefore, to represent these relations in AIF, there is no need to use S-Nodes with multiple outgoing edges. For instance, in Figure 2(b) a bidirectional conflict between two I-Nodes is represented using two CA-Nodes, one for each direction.

Our proposal to handle these anomalies is to restrict S-Nodes to have only one outgoing edge. An AIF argument network that follows this restriction will be called a single-outgoing argument network (so-network), and is formalized in the following definition.

Definition 3 (Single-Outgoing Argument Network). *Let $G = (V,E)$ be an argument network where $V = I \cup RA \cup CA \cup PA$. The network G will be a single-outgoing argument network (so-network) iff $\forall n \in V \setminus I$ if $\exists (n, d) \in E$ then $\nexists (n, r) \in E$ with $d \neq r$.*

Note that the so-networks do not impose any restriction on multiple outgoing edges from I-Nodes. This is because there is no ambiguity in this situation. Clearly, a piece of information can at the same time be in conflict with other pieces of information, or can be a premise for several inferences. In addition, so-networks will not be able to represent situations like the one depicted in Figure 5. However, constructions like that are mostly unreal. Therefore, this restriction, in our opinion, does not impose a representational problem.

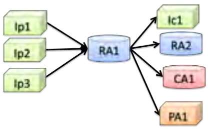


Fig. 5. A RA-Node with outgoing edges to different node types.

3.2 No Incoming/Outgoing Edges

A S-Node without any incoming edge may be subject to anomalous or redundant interpretations. In Figure 6(a) we show S-Node sub-types as presented in [2], where these nodes do not have incoming edges.

Fig. 6. A S-Node of each sub-type without incoming/outgoing edges.

Note that there is no clear interpretation of the individual constructs presented in the figure. For instance, a possible interpretation for the CA-Node in Figure 6(a) is that everything is in conflict with I2 (including itself), but it that can be also represented using incoming edges to the CA-Node. Similar is the case of the PA-Node and the RA-Node. Therefore, this way of representing that certain node is related to everything in the network is redundant. Also observe that the construct involving the RA-Node can be thought as the representation of an axiom. Thus, we have two different interpretations for the same representation.

Similar is the case of S-Nodes without outgoing edges, as can be seen in Figure 6(b). For instance, a possible interpretation for the PA-Node is that $I6$ is preferred to everything else in the network. However, that representation is redundant since the PA-Node can have outgoing edges to every element in the network (similarly to the case of no incoming edges). Therefore, we also reach to a redundant situation. Note that this analysis can be analogously made for the CA and RA-Nodes in Figure 6(b).

In order to avoid these situations S-Nodes should be restricted to have at least one incoming edge and one outgoing edge. Observe, that with this restriction we do not harm the representational power of the core ontology, we just fix it to avoid redundancy. An argument network that satisfies this restriction will be called a complete-scheme argument network (cs-network).

Definition 4 (Complete-Scheme Argument Network). *Let* $G = (V,E)$ *be an argument network where* $V = I \cup RA \cup CA \cup PA$*. The network* G *will be a complete-scheme argument network (cs-network) iff* $\forall n \in V \setminus I\ \exists (n, d) \in E$ *and* $\exists (r, n) \in E$*.*

3.3 Cycles

Using the AIF core ontology components it is possible to produce S-Node cycles. The problem with S-Node cycles is that the status (activation, preference, acceptability, etc.) of the nodes involved and connected to the cycle cannot be clearly established. These cycles will difficult any attempt to automatically compute the status of an argumentation network nodes. Thus, S-Node cycles may harm one of AIF main objectives: the computer friendliness of the representation.

In Figure 7 we show a S-Node cycle that involves three S-Nodes. This argumentation network represents a situation where the application of an inference rule RA1 with premise I1 activates the application of another inference rule RA2. This latter rule has I2 as premise and, when applied, activates I4 and a conflict between I3 and the activation of the first inference rule RA1.

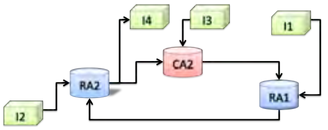


Fig. 7. S-Node cycle.

In this situation it is clearly impossible to determine if any of the S-Nodes in the cycle are actually applied (in the case of inference rules) or active (in the case of the conflict and piece of information I4). A particular case of S-Node cycles occurs when S-Nodes are connected to themselves. Clearly, these configurations come from fallacious specifications and introduce the same problems as S-Node cycles.

A possible way to handle cycles among S-Nodes is to treat them similarly to cycles in argumentation acceptability semantics calculus. However, that can not be easily done because S-Node cycles may involve inference chains. Another possible solution is to directly forbid S-Node cycles. This seems to be somehow restrictive, but it must be noted that S-Node cycles are mostly generated by fallacious specifications. In addition, it is worth to mention that this kind of cycles can be easily detected on single-outgoing argument networks, therefore, alleviating the problem. Nevertheless, next we define the scheme-acyclic argument networks (sa-networks) which correspond to argument networks without S-Node cycles.

Definition 5 (Scheme-Acyclic Argument Network). *Let $G = (V,E)$ be an argument network where $V = I \cup RA \cup CA \cup PA$. The network G will be a scheme-acyclic argument network (sa-network) iff for any $n \in V \setminus I$ there is no path from n to n in G such that for every node i in the path it holds that $i \in V \setminus I$.*

4 Hierarchies for Meta-Reasoning

AIF core ontology is flexible enough to allow the representation of meta-reasoning specifications. This meta-reasoning can be “inferred” from the connection among S-Nodes. However, in the core ontology it is not an easy task to determine how many meta-reasoning is involved in a particular node. This issue can harm the computation and information interchange using argumentation networks.

Here we propose to adjunct hierarchical information to each node. This information will determine in which level of meta-reasoning the node is involved. Thus, using this information a system will be able to determine how to treat an arbitrary node in a network depending on its capabilities and objectives. Next, we will present two possible representations for this information, each of which regards to a different interpretation of meta-reasoning.

4.1 Multi-Level Approach

In this approach each node has a level, similarly to [6]. This level represents how many meta-reasoning is involved in a node. I-Nodes level will always be 0, and S-Nodes level will be one level over the maximum level of the nodes connected to their outgoing edges. In addition, this approach also follows the meta-reasoning spirit of [14].

In Figure 8 we present an example of an AIF argumentation network where each node is placed on its corresponding level of reasoning.

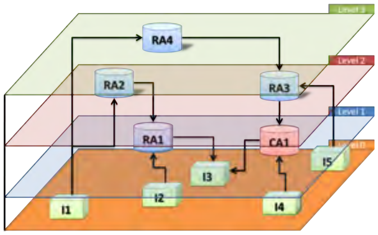


Fig. 8. An example of nodes with multiple levels of meta-reasoning.

This approach is only suitable for scheme-acyclic argument networks. This is because, in the presence of cycles among S-Nodes, it is not posible to determine the level of meta-reasoning involved in a node. In Figure 9 we show an example of this situation.

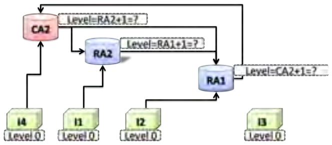


Fig. 9. S-Node cycles in the multi-level approach.

4.2 Three-Level Approach

In this approach we will have three levels of representation. The first level is called level 0, and contains basic information like sentences, facts, premises or conclusions. The second level is level 1; it contains every reasoning mechanisms used to reason with information (*i.e.* to reason only with elements of level 0). The third level, called level 2, contains mechanisms to reason with the reasoning mechanisms (*i.e.* reason with elements of levels 1 and 2). Basically, I-Nodes are in level 0, S-Nodes with outgoing edges to I-Nodes are in level 1, and S-Nodes with outgoing edges to other S-Nodes are in level 2. When a S-Node has an outgoing edge to an I-Node and another to a S-Node, that node will be level 2. Next, in Figure 10 we show the same nodes as in Figure 9, but placed using the three-level approach.

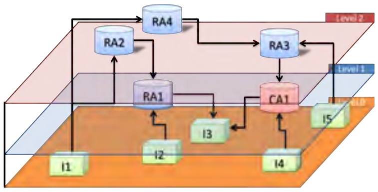


Fig. 10. An example of nodes placed in the three level approach

Using this approach it is possible to represent S-Nodes cycles. Note that every node involved in this kind of cycle will be at level 2. Also observe that all meta-reasoning nodes will be in the same level. This issue may be a constraint to some systems and does not follow the structure proposed in [14].

5 Conclusions and Related Work

In this work we have pointed out some anomalies that can arise from certain argument networks of the AIF core ontology, and have also developed possible solutions to these situations. In particular, we have recommended some restrictions over the core ontology. For each restriction we have formally defined a refined version of the AIF argument networks.

We have shown that particular configurations of AIF components may have different interpretations, going against AIF objectives. In addition, we have shown that some concepts can be represented in several ways, leading to redundancy which is undesired. The restrictions introduced in this work aim to avoid those anomalous situations. From our point of view, these restrictions do not represent a meaningful loss in terms of representational power. This is because the leftover configurations are mostly produced by fallacious specifications, and in some cases they can be represented by using another components configuration.

Moreover, the argumentative formalisms and tools that have already been mapped to AIF do not handle the anomalous configurations above mentioned. This is mainly because they work with AIF networks that result from mapping their formalisms components to AIF. These networks do not contain any of those anomalies since they are not present in the original formalisms. For instance, in the mapping between ASPIC+ and AIF proposed in [1] S-Nodes have only one outgoing edge, and there are no cycles among S-Nodes. Thus, the restrictions for AIF networks proposed in this paper do not harm the existing mappings between argumentative tools and AIF. In fact, they bring AIF closer to these tools, since they facilitate the translation of an arbitrary AIF network compelling with the restrictions to the corresponding tool.

Regarding to related work, there are some previous works that propose modifications to the original AIF core ontology (*e.g.* [11], [12] and [4]). Like ours, their goal is to make AIF more suitable for the needs of the argumentation community. However, these modifications are mainly extensions that add new components to the ontology, without restricting any of the anomalous specifications that were studied in this paper. The most significant modification introduced to the AIF core ontology was made in [11]. There, the authors introduced the Forms ontology (F-Nodes) to describe how an I-Node or a S-Node follows certain argumentative scheme. That work is in fact an extension to the AIF core ontology, allowing to represent more information regarding to the arguments. Nevertheless, this additional information does not solve any of the problems that we have addressed here, moreover, with the F-Nodes some anomalies could even be intensified.

The solutions we introduced here are by no means definitive, specially those regarding to meta-argumentation. Our policy was to adapt AIF core ontology without affecting the types and objectives of the components in the ontology. AIF should provide a very flexible set of components, where every possible configuration leads to a meaningful and unambiguous semantics. In our opinion, if the latter is compromised, we should restrict the core ontology to address that, even if it leads to some loss of representational power.

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