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Citation

Visser, J., Zografistou, D., Lawrence, J., & Reed, C. (2024). Argumentation in the Intelligence Domain. *Proceedings Of The Tenth Conference Of The International Society For The Study Of Argumentation*, 915-923. Retrieved from <https://hdl.handle.net/1887/4107909>

Version: Publisher's Version

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Note: To cite this publication please use the final published version (if applicable).

Argumentation in the Intelligence Domain

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ABSTRACT: Aiming to explain past events or predict future events, intelligence analysts reason about collections of often unreliable, ambiguous and incomplete evidence to support or reject alternative hypotheses. Argumentation plays an important role in both the collaborative reasoning process within teams of analysts, and the final documents in which the outcomes of the analysis are reported. We explore the commonalities between standpoints and arguments on the one hand and hypotheses and evidence on the other.

KEYWORDS: analysis of competing hypotheses, argument diagramming, argument interchange format

1. INTRODUCTION

Aiming to explain past events or predict future events, intelligence analysts reason about collections of often unreliable, ambiguous and incomplete evidence to support or reject alternative hypotheses. Argumentation plays an important role in both the collaborative reasoning process within teams of analysts, and the final documents in which the outcomes of the analysis are reported. In this contribution, we explore the commonalities between standpoints and arguments on the one hand and hypotheses and evidence on the other. Our primary focus in this paper is on Analysis of Competing Hypotheses (ACH) (Heuer et al., 2005), a tradecraft standard meant to structure the analytical work of intelligence personnel. ACH aims to identify a complete set of alternative hypotheses, systematically evaluates evidence as consistent or inconsistent with each alternative hypothesis, and proceeds by rejecting hypotheses, rather than trying to confirm what appears to be the *prima facie* most likely one.

What constitutes a hypothesis within the Intelligence Community (IC) tends to not be strictly defined. Hypotheses can be interpreted as a feasible explanations of past events or scenarios underpinning future events – respectively, for sense-making about the past and for forecasting about the future. When applying the ACH technique, the analyst would be prompted to systematically assess each item of evidence against each of the alternative hypotheses to reach the best explanation. Evidence may, for instance, consist of a witness report describing a trail of smoke moving in an easterly direction, and aerial surveillance imagery showing what could be tracks in an east-to-west direction. Alternative hypothesis explaining this scenario could include H1 several damaged enemy tanks moving east, H2 a short forest fire moving with the wind to the east, H3 a herd of animals migrating to the west. By employing the ACH technique, the analyst is prompted to consider each piece of

evidence and assess whether it is consistent or inconsistent with each of these alternative hypotheses.

We will describe the relation between analysis in the intelligence domain and argumentation. More concretely, we will explore the mapping between concepts in the ACH technique and argumentative modelling using the ontology of the Argument Interchange Format (Chesñevar et al., 2006). We also outline the role of Argument Schemes in this mapping and how they can contribute to the analysis. In Section 2, we will provide some further explanation about ACH. In Section 3, we will give a high-level overview of the AIF. In Section 4, we describe the mapping between ACH and AIF. In Section 5, we conclude the paper.

2. ANALYSIS OF COMPETING HYPOTHESES (ACH)

Analysis of Competing Hypotheses, ACH (Pherson & Heuer Jr, 2020; Heuer, 2005), is a structured analytic technique for the Intelligence Community (IC). The main idea behind ACH is to help intelligence analysts choose the best among multiple alternative hypotheses about a critical issue. A *hypothesis* in the context of ACH is a potential explanation or conclusion that is to be tested (Heuer, 1999).

Pherson and Heuer (2020) outline the ACH method in terms of nine consecutive steps. 1) Identification of all possible hypotheses under consideration. 2) Listing of relevant information. 3) Creation of a matrix and analysis of the diagnosticity of information. 4) Review any divergent assessments. 5) Refinement of the matrix by reconsidering the hypotheses. 6) Drawing of tentative conclusions about the relative likelihood of each hypothesis. 7) Analysis of the sensitivity of the tentative conclusions. 8) Report of conclusions. 9) Identification of indicators or milestones for future observation.

In an ACH analysis, evidence and alternative hypotheses are arranged in a *diagnosticity matrix*, with column headers indicating the hypotheses being investigated, and row headers indicating the available pieces of evidence that form a case. The cells of this matrix capture the relation between evidence and hypotheses, in terms of whether a piece of evidence is consistent or inconsistent with each hypothesis. Table 1 gives an example of an ACH matrix.

Table 1. Example ACH matrix

	<i>h1</i>	<i>h2</i>	<i>h3</i>	<i>h4</i>
e1	+	n/a	-	n/a
e2	-	-	+	n/a
e3	+	-	n/a	+
e4	-	+	n/a	-

In this example, we use the values '+' and '-' to indicate that the evidence is, respectively, consistent or inconsistent with the hypothesis. Value *n/a* means that the involved evidence is not relevant for this hypothesis. Here, *e1* is used to support hypothesis *h1*, it is against *h3* and is irrelevant to *h2* and *h4*; evidence *e2* supports *h3*, it is against *h1* and *h2* and so

on. Roughly, the idea about the evaluation of this matrix is that the most acceptable hypothesis is the one least inconsistent with the available evidence (includes the smallest number of ‘-’ symbols in its column). Another evaluative property related to ACH matrices is *evidence diagnosticity*, that is, the identification of the points which are most influential in judging the relative likelihood of the hypotheses. For example, in table 1, the prevailing hypotheses are *h3* and *h4*. However, in this work we don’t deal with evaluation issues. Our main focus is on the semantics and the conceptual limitations of the method, which we will discuss in more details in section 4.

3. ARGUMENT INTERCHANGE FORMAT

Arguments come in various guises, and exactly what counts as an argument depends on the particular perspective, approach, theory, or model chosen. We could think of instances of Modus Ponens as a basic type of argument: from *p* and if *p* then *q*, we infer that *q* must also hold. Similarly, Aristotelean syllogisms are arguments: All men are mortal, Socrates is a man, so Socrates is mortal. Less explicitly complete arguments can count too: “*bring an umbrella, because it may rain*” is perfectly intelligible. The Argument Interchange Format (AIF) (Chesñevar et al., 2006; Rahwan et al., 2007) is designed to provide the theory-neutral means for representing all such different understandings of ‘argument’ in a formal ontology, thus providing an interlingua that can be used to translate between different theoretical perspectives and models.

The AIF can be seen as a representation scheme constructed in three layers. At the most abstract layer, the AIF provides a hierarchy of concepts which can be used to describe arguments: constellations of propositions that function as premises and conclusions in a reasoning structure to justify or refute a claim or standpoint. The AIF hierarchy describes an argument by conceiving of it as a network of connected nodes that are of two types: information nodes that capture data (such as datum and claim nodes in a Toulmin (2003) analysis, or premises and conclusions in a box-and-arrow analysis in the style of Freeman (1991), for example), and scheme nodes that describe passage between information nodes (similar to the application of warrants or rules of inference). Scheme nodes in turn come in several different guises, including scheme nodes that correspond to support or inference (or ‘rule application nodes’), scheme nodes that correspond to conflict or refutation (or ‘conflict application nodes’), scheme nodes that correspond to rephrase and scheme nodes that correspond to value judgements or preference orderings (or ‘preference application nodes’).

At this topmost layer, there are various constraints on how components interact: information nodes, for example, can only be connected to other information nodes via scheme nodes of one sort or another. Scheme nodes, on the other hand, can be connected to other scheme nodes directly (in cases of, for instance, arguments that have inferential components as conclusions, e.g. in patterns such as Kienpointner’s (1992) ‘warrant- establishing arguments’). Inference captured by multiple incoming scheme nodes thus naturally corresponds to convergent argumentation, while a structure in which multiple premises support a single incoming scheme node corresponds to linked argumentation (Walton, 2006).

Figure 1 visualises the taxonomy of AIF. The Upper ontology abstracts the basic building blocks of AIF argument graphs, types of nodes and edges, whereas the Forms ontology constitutes a reification of the abstract concepts in the Upper ontology by allowing for the conceptual definition of the elements of AIF graphs.

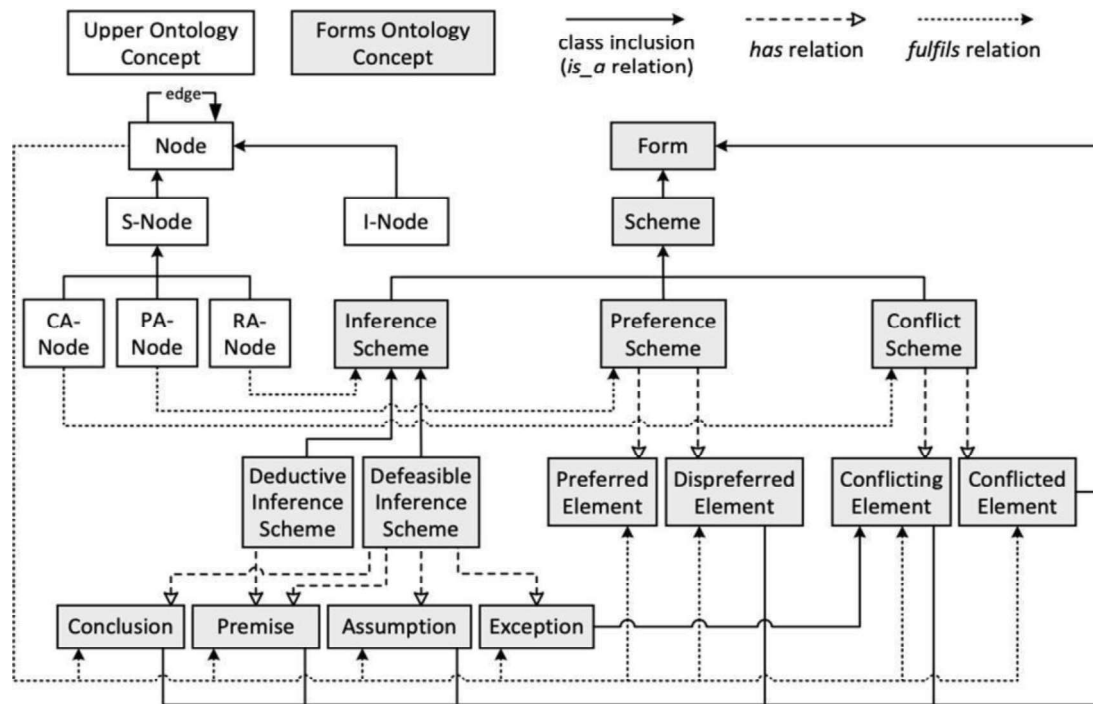


Figure 1. A schematic diagram of the abstract layer of the AIF.

A second, intermediate layer provides a set of specific argumentation schemes (Walton et al., 2008) (and value hierarchies, and conflict patterns). Thus, the uppermost layer in the AIF ontology lays out that presumptive argumentation schemes are types of rule application nodes, but it is the intermediate layer that cashes those presumptive argumentation schemes out into Argument from Consequences, Argument from Cause to Effect and so on. Intermediate layer is essentially defined by the Forms ontology. At this layer, the form of specific argumentation schemes is defined: each has a conclusion description (such as ‘A may plausibly be taken to be true’) and one or more premise descriptions (such as ‘E is an expert in domain D’). Walton’s set of argumentation schemes (Walton, 1996; Walton et al., 2008) in particular has been developed in full for the AIF (Rahwan et al., 2007).

Finally, the third and most concrete level supports the integration of actual fragments of arguments, with individual argument components (such as strings of text) instantiating elements of the layer above. At this third layer, an instance of a given scheme is represented as a rule application node with the terminology of rule application (RA), used to represent inferences and arguments, conflict scheme application (CA), used to represent conflicts between elements of AIF, rephrase (MA), used to represent semantic

proximity between propositional content (restatement, paraphrase, etc), and preference application (PA), used to represent the preference of one I- or S-node over another.

The rule application nodes, in particular the RA-nodes, are said to fulfil one of the presumptive argumentation scheme descriptors at the level above.¹ As a result of this fulfilment relation, premises of the rule application node fulfil the premise descriptors, the conclusion fulfils the conclusion descriptor, presumptions can fulfil presumption descriptors, and conflicts can be instantiated via instances of conflict schemes that fulfil the conflict scheme descriptors at the level above. Rephrase plays a slightly different role, that of connecting information nodes of similar propositional content. Any constraints from the intermediate layer are inherited, while the instantiated argument structure at this concrete level constitutes a subset of the possibilities in principle offered by the higher levels.

4. MAPPING BETWEEN ACH AND AIF

In order to develop an ACH-driven navigation tool for graphs of structured arguments, we first need to understand the argumentative principles underpinning ACH. This means, to interpret the different ACH concepts with the language of argumentation and identify the underlying structural patterns related to the technique. This section outlines the mapping between ACH and argumentation using the terminology of AIF (Chesñevar et al., 2006) for describing it.

Despite the research interest that ACH has attracted over the past years (Murukannaiah, Kalia, Telangy, & Singh, 2015; Jones, 2018; Chang, Berdini, Mandel, & Tetlock, 2018; Wheaton & Chido, 2006; Valtorta, Dang, Goradia, Huang, & Huhns, 2005), the method has also received criticism (van Gelder, 2008; Dhimi, Belton, & Mandel, 2019). Among the shortcomings of ACH, is, for example, its methodological vagueness about the way of selecting hypotheses, under what criteria the consistency or inconsistency of evidence is decided, and how evidence diagnosticity is to be established. Judging further how transparent and well explained the results are presented in the matrix, points at several further deficiencies. First, ACH does not reveal the more complex reasoning structures relating evidence and hypotheses, encapsulating this under the concise symbols of '+' and '-'. It also does not provide a systematic way to challenge how valid or fallacious the final or intermediate conclusions are. Finally, it cannot be inferred how evidence and hypotheses are related to each other. For example, what do *competing* or *alternative hypotheses* mean? Are hypotheses mutually exclusive if they just give different explanations for the evidence without necessarily being directly conflicting, is it both, or are they structurally unrelated? Argumentation provides all those mechanisms to reconstruct and surface the reasoning behind the creation of the matrix, to explicitly define relations among elements in the matrix, as well as to challenge the inferred conclusions, helping ACH overcome those limitations.

¹ The notion of descriptor is defined in the intermediate layer, to show how the abstract notions of the topmost layer are reified. As a result, presumptive argumentation scheme descriptor, premise descriptor, conclusion descriptor etc. are the specific components that define an argument scheme in the intermediate layer which are then instantiated via *fulfilment* relations in the concrete layer.

We start by unfolding what it means for a piece of evidence to be consistent with a hypothesis. Although the term *consistency* hasn't been given an explicit definition, the default is to say that evidence is consistent with a hypothesis, if the first can be used to prove or support the second logically. In other words, that there is an inferential chain that starts with the evidence and ends at the hypothesis following a number of logic steps. Thus, each '+' symbol in the matrix is mapped to a serial argument of sequential inference applications, as shown in Figure 2.



Figure 2. Consistent evidence in AIF

Figure 2 shows the consistency between $e1$ and $h1$ of Table 1. The middle node with the dots in its text represents the intermediate steps in the reasoning chain. The diagram has been created with the OVA tool² which uses the AIF representation for creating argument graphs. As a result, the grey nodes correspond to I-nodes (propositional nodes, as described in section 2.2) and the green nodes are instances of RA-nodes (default inference). Note that, in order to reconstruct the intermediate stages that lead to a hypothesis, it is presupposed that this information is available or can be reconstructed. If this is not the case, evidential consistency is translated to a direct RA-node starting from the evidence and directly leading to the hypothesis.

Inconsistency appears in ACH when evidence disproves a hypothesis. In argumentation terms, this means that a piece of evidence attacks the hypothesis either directly or indirectly, by attacking some of the intermediate premises or inference relations leading to this hypothesis. Figure 3 shows the AIF structures to which inconsistencies of evidence $e2$ and $e4$ with $e1$ are mapped. The diagram depicts what was mentioned above and in particular, that $e2$ is a direct evidence against $h1$, whereas $e4$ an indirect attacker. Again, an attack to some of the intermediate inference steps presupposes that this information is available and can be reconstructed. In case it is not available, the mapping of inconsistency will always result in a direct attack from evidence to the hypothesis.

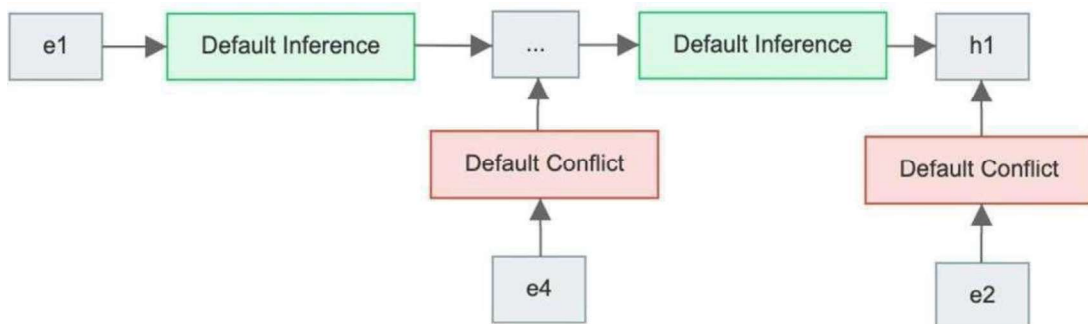


Figure 3. Inconsistent evidence in AIF

² <http://ova.arg.tech/>

Normally, ACH analyses real-world cases and, consequently, the mapping creates arguments in the same context. By classifying them into Waltonian argument schemes (Walton et al., 2008), the mechanism of critical questions is directly incorporated in the analysis, providing a way to systematically challenge inferred conclusions at any level in the reasoning chain. This way of thinking is very important in Intelligence Analysis. It can help analysts scrutinise conclusions before putting them on the table and enhance the iterative cycle of considering alternative explanations and searching for new evidence to support or refute them, thus improving the analytical rigour of the analysis. As will be shown later, argument schemes and critical questions can also add a valuable extension in the argument navigation tool.

We now investigate how hypotheses are being related to each other and what kind of structures exist among them. In (Pherson & Heuer Jr, 2020) it is mentioned that hypotheses are *mutually exclusive*. In ACH terms, this means that it is only one that can be proven as true. In argumentation terms, this could be conceived as being mutually contradicted, or in other words, that they attack each other. However, in ACH, mutual exclusivity doesn't necessarily mean contradiction. Imagine for example two cases of a murder investigation. In the first case the competing hypotheses are $h1 = \text{"Relative } X \text{ committed the murder"}$ and $h2 = \text{"Relative } X \text{ did not commit the murder"}$. In the second case, competing hypotheses are: $h1 = \text{"Relative } X \text{ committed the murder"}$ and $h2 = \text{"Relative } Y \text{ committed the murder"}$. In case 2, assume that we have the following bit of evidence e : *"The murder was committed by some relative of the victim"*. In both cases $h1$ and $h2$ are mutually exclusive, as they can't both be true at the same time (in the first case we can't have that X both did and did not commit the crime, and in the second, it is either X or Y who is the murderer). However, if we look at their propositional content, in case 1, the two hypotheses are conflicting (directly attacking each other), while in case 2, these two propositions are not intrinsically contradictory. Their conflict is contextual as they just give two alternative explanations of the same evidence. For the navigation purposes, we use these two relations to define the notion of *alternative hypotheses*.

The structural relation between alternative hypotheses in AIF terms is depicted in Figure 4. In Figure 4(b), direct inferences from e to $h1$ and $h2$ are used for saving space, but these can equally be chains of inferences as illustrated before. Again, for simplifying the navigation, the relation between alternative hypothesis is not defined in a transitive way. For example, in case 2, if there is a third hypothesis $h3$ which is an alternative for $h2$ (there is a different common evidence supporting them), it does not mean that $h3$ is also an alternative hypothesis for $h1$.

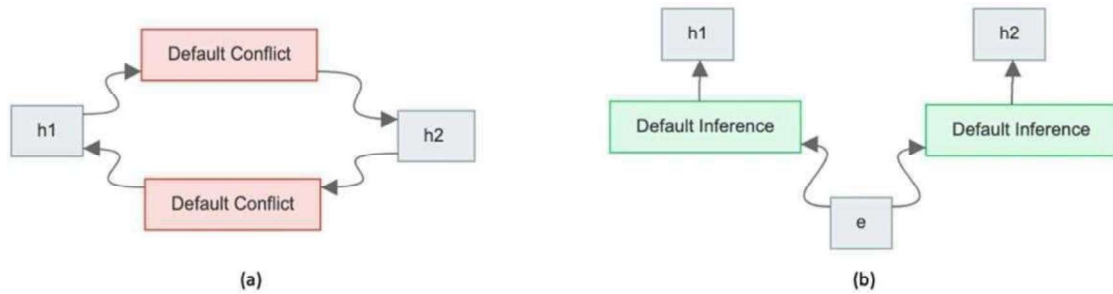


Figure 4. Alternative hypotheses in ACH-Nav diagrammed in AIF. In (a) hypotheses are directly attacking each other. In (b) hypotheses explain differently the same evidence

Finally, given that hypotheses play a central role in the ACH-Nav tool as will be shown later, and the whole navigation is built around this notion, we need to distinguish them from the remaining propositions in the argument graph and annotate them separately. To do this in AIF, we leverage the mechanism of YA-nodes from AIF+ (Reed et al., 2008) and use the type *Hypothesising* for the illocutionary force that has the particular proposition as its target content. From a linguistic perspective, the same proposition can be a hypothesis in one context and evidence in another: there is nothing intrinsic about the information itself that makes it one or the other. Therefore, labelling a proposition as a hypothesis should be decoupled from its actual content and this is exactly the role of YA-nodes: to capture the *intention* behind the utterance of a locution in a dialogical setting (Budzynska & Reed, 2011). An example of a hypothesis annotation is shown in Figure 5. The yellow middle node represents an instance of YA, the blue node on the right is the locution (L- node) and the grey node on the left represents the propositional content (I-node) of the hypothesis.

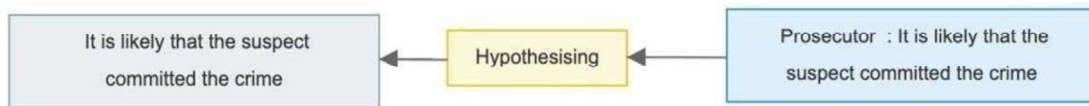


Figure 5. Hypothesis annotation in AIF as a YA scheme of type *Hypothesising*

5. CONCLUSION

As a contribution to the study of argumentation in the intelligence domain, we have described the relation between the central concepts and reasoning in the structured analytical technique of Analysis of Competing Hypotheses (ACH) and the Argument Interchange Format (AIF). One significant opportunity supported by this exploration is the prospect of developing a bidirectional formal mapping between ACH and AIF. This in turn would support the addition of edit-interaction with ACH as a means of rapid creation of high-level AIF structures in a software tool such as ACH-Nav (Zografistou et al., 2022). This increase in flexibility not only brings structured argument construction into the Intelligence Community directly, but also delivers *theory neutrality* (Reed & Rowe, 2005)

into this application domain. This is a particularly important step for a community which relies upon a wide variety of tools and techniques and approaches but requires an underlying consistency and coherence in knowledge representation.

ACKNOWLEDGEMENTS: The work described in this paper was supported in part by Dstl under the Serapis framework (SUBCT/FNC-UOD/SERAPIS/58011/EA).

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