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Argumentation: Reasoning Universalis

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Abstract:
Can argumentation form the basis for any form of reasoning, informal or formal logical reasoning? We examine this question from the particular perspective of the recent developments in logic-based Artificial Intelligence (AI). We propose that argumentation provides the wider framework encompassing uniformly all reasoning, with strict or formal logical reasoning being a special boundary case. We also attempt to link this unifying role of argumentation with Aristotle's original investigation of methods and formalisms for the systematic study of human reasoning.
Keywords: Reasoning, argumentation, Aristotle.

1. Introduction

Logic is traditionally separated into two forms: **Formal Logic** at the foundations of Mathematics and Science and **Informal Logic** as the study of human reasoning at large. These two forms of logic are generally considered to be very different. Yet they are both concerned with understanding the nature of human thought and, in fact, they share the same roots in Aristotle's work.[1] In this work we are interested in the question of whether formal and informal logic can be placed under a single framework and, if so, to understand their distinguishing features. In other words, we are interested in finding a universal form of reasoning that would be able to capture both informal and formal reasoning. In answering this question we will also attempt to link our proposal to the origins of the study of reasoning in Aristotle and how Aristotle's study can help in forming a unified view of reasoning. In a sense, the distinction of the two forms of logic seems to have evolved with the development of these over the last few centuries, especially with the development of Classical Logic and its foundational role in Mathematics and Science, drawing them more and more apart.[2]

In order to be concrete we will consider that Formal Logic is represented by Classical Logic or simply Propositional Logic. For the case of Informal Logic it is more difficult to select a representative example. Informal Logic relates to reasoning by humans at large in everyday tasks but also to critical thinking, rhetoric and debate. Whatever form we consider it is important to realize that in the study of

Informal Logic, within the humanities and particularly in Philosophy, scholars have essentially been equating informal reasoning with **Argumentation**. The entry on Informal Logic in the Stanford Encyclopedia of Philosophy (https://plato.stanford.edu/entries/logic-informal/) presents the overriding goal of informal logic as the task of providing a general account of argument as the basis of systems of informal logic. It then continues to state:

> In the pursuit of its goals, informal logic addresses topics which include, to take only a few examples, the nature and definition of argument, criteria for argument evaluation, argumentation schemes, fallacies, notions of validity, the rhetorical and dialectical aspects of arguing, argument diagramming ("mapping"), cognitive biases, the history of argument analysis, artificial intelligence (AI), and the varying norms and rules that govern argumentative practices in different kinds of contexts.

One field which studies Informal Logic, in the sense of human reasoning at large, is that of Artificial Intelligence (AI), where the aim to formalize and automate common sense reasoning was set as an early foundational problem. This resulted in the search for and development of a plethora of new logics for AI, called **non-monotonic logics**, starting with the logic of Circumstantiation for formalizing the Situation Calculus, a system for common sense reasoning about the effects of actions and the change they bring about [15]. These new logics aimed to capture the non-monotonicity feature of human inference recognizing that it should be possible to abandon, in contrast to the monotonic inference of formal classical logic, earlier inferences in the face of new relevant information. Non-monotonicity was needed to render the inference flexible, in the same manner as human do when drawing inferences, to missing or ambiguous information and tolerant to (apparently) contradictory information.

Nevertheless, these new non-monotonic logics were developed based on the same formal and strict underpinnings of Classical Logic making it difficult to deliver on their promise of "AI systems with common sense" and "human-like natural intelligence". Then in the 1990s, it was shown (see e.g. [1]) that using argumentation it was possible to reformulate (and in some cases extend) most, if not all, known logical frameworks of non-monotonic reasoning in AI. This AI approach to argumentation, sometimes referred to as **Computational Argumentation**, was motivated and to some extent grounded on earlier foundational work [26], [20], [21] on human argumentation in Philosophy and Cognitive Science. The result of reconciling non-monotonic logics through argumentation resulted in a strong focus on Computational Argumentation as a way of capturing human reasoning in AI along the same frame of interest as that of Informal Logic. For example, argumentation can provide a principled approach to knowledge representation and reasoning about actions and change [18], [8]. Based on this we can build computational models of narrative comprehension akin to the way humans perform this task [2].

Similarly, following recent work in the Psychology of Reasoning that strongly supports the link of argumentation to human reasoning (e.g. [16], [17]) we can synthesize a framework of computational argumentation informed by cognitive principles to obtain a framework, called **Cognitive (Machine) Argumentation**, as a suitable framework to model human reasoning in its various forms. This framework has been shown to capture well the human empirical data from several different experiments that are traditionally used in Cognitive Science to evaluate cognitive models of human reasoning. These empirical evaluation domains include "Syllogistic Reasoning" with experiments on how humans reason on the original Aristotelian syllogisms, the "Selection Task" where humans are tested on the way they reason about conditionals and the "Suppression Task" where the non-monotonic nature of human reasoning is observed [23], [24], [25]. Cognitive argumentation accounts for the empirical data in these domains in a cognitively adequate way that also reflects well the variation of human reasoning across the population.

We will therefore accept that human or informal reasoning is a matter of argumentation and ask whether argumentation can also encompass formal logic. Hence we will be interested in whether argumentation can be given some formal structure and how this might also cover formal classical deductive reasoning. We will argue that this is possible so that both informal but also formal logic can be captured uniformly within the same formal structure of argumentation. Argumentation will thus form the wider notion of reasoning, **Reasoning Universalis**, encompassing all forms of reasoning with strict or formal logical reasoning being a special boundary case.

The next section, Section 2, reviews the formalization of argumentation as a reasoning system and gives its basic AI computational model. Section 3 presents how the formal propositional logic of deduction is captured within the above formalization of argumentation. It then discusses how this Logic of Argumentation extends smoothly beyond classical formal reasoning with premises which can be inconsistent under classical logic but admissible in an informal reasoning setting. Section 4, attempts to show a connection between this modern formalization of argumentation and the work of Aristotle in the books of Topics. Section 5 concludes with a brief discussion of the possible relevance of Aristotle's work to today's logic-based AI.

2. Formal Argumentation

Argumentation is a process of considering the alternative positions that we can take on some matter with the aim to justify or refute a standpoint on the matter. It can take place socially within a group of entities in a debate where entities argue for different standpoints, or within a single entity where the entity contemplates or reasons internally about the various standpoints on the matter, in order to decide on and self justify its own stance on the matter.

Argumentation has the general form of a **dialectical** process of (i) starting with some argument(s) directly supporting some desired standpoint or conclusion, then (ii) considering various counter-arguments against the initial argument(s) and (iii) defending against these counter-arguments, typically with the help of other arguments as allies of the initial arguments. The process repeats by considering further counter-arguments against these new allied defending arguments, until we have formed a **coalition of arguments** that "stands well" as a **case** for the standpoint or conclusion of interest.

We therefore have an "argumentation arena" where arguments attack and defend against each other in order to support their claims. This arena of argumentation can be captured by a formal **argumentation framework** which in an abstract form can be simply given as a tuple, $\langle \mathcal{A}rgs, \mathcal{A}TT \rangle$, where $\mathcal{A}rgs$ is a set of arguments and $\mathcal{A}TT$ is an attack (typically non-symmetric) relation between the arguments in $\mathcal{A}rgs$. Note that in this abstract formulation of argumentation we have no information on how the arguments and the attacking relation between them arises. In other words, at the most abstract level the only essential elements for the dialectic process and the result of argumentation are these two notions of the existence of arguments and the attacks between them. In practice though, the consideration of constructing the arguments and the attacks between them cannot be avoided and it is an important element of the whole process of argumentation. For example, we note that in this minimal abstract formalization of argumentation frameworks, the attack relation, $\mathcal{A}TT$, serves both the purpose of identifying conflicts between arguments but also to specify the relative strength between them so that we can identify whether an argument is strong enough to defend against another one by attacking it back under $\mathcal{A}TT$.

Given an argumentation framework we can then formalize, through some normative condition, the notion that a subset of arguments "stands well" as a case of arguments. In fact, the dialectical process of argumentation indicates how to give such a suitable semantics to formal argumentation. The dialectic argumentation semantics is defined via a relation $ACC(\Delta, \Delta_0)$ between any two sets of arguments Δ, Δ_0. This relation specifies the **acceptability** of the set of arguments Δ under the context where the set Δ_0 of arguments is considered as given and so a-priori acceptable. Informally, the relative acceptability between sets of arguments captured by "$ACC(\Delta, \Delta_0)$" is defined recursively to hold when the argument set **Δ can render all its attacking (or counter-arguments) non-acceptable in the context of accepting Δ_0 together with Δ.** This natural and intuitive description of the acceptability relation between sets of arguments can be formally defined as the least-fixed point of an associated formal operator satisfying the following (see [14] for the technical details):

$ACC(\Delta, \Delta_0)$ holds, **iff** $\Delta \subseteq \Delta_0$, or,
for any A such that $(A, \Delta) \in \mathcal{ATT}$ (i.e. A attacks Δ),
$A \subseteq \Delta_0 \cup \Delta$, and there exists D such that:
$(D, A) \in \mathcal{ATT}$ (i.e. D counter-attacks or defends against A), and
$ACC(D, \Delta_0 \cup \Delta \cup A)$ holds.

Then the **acceptable or case** subsets of arguments are defined as those that are acceptable in the context of the empty set, i.e. the subsets Δ for which $ACC(\Delta, \emptyset)$ holds in the least fixed point of this relation.

The technical details of the definition of this semantics of argumentation are not important for this paper. The technical form of the above definition is included here only for the reader to have some appreciation that at the abstract level, argumentation can be given a strict and well defined meaning and that it is this meaning that permeates through all forms of reasoning.

Informally, the above least-fixed point definition says that for any counter-argument to Δ we need to have a defending argument against this counter-argument which is acceptable within the context of Δ. Indeed, acceptable subsets of arguments can be computed following the fixed point definition of acceptability as illustrated here by Figure 1.

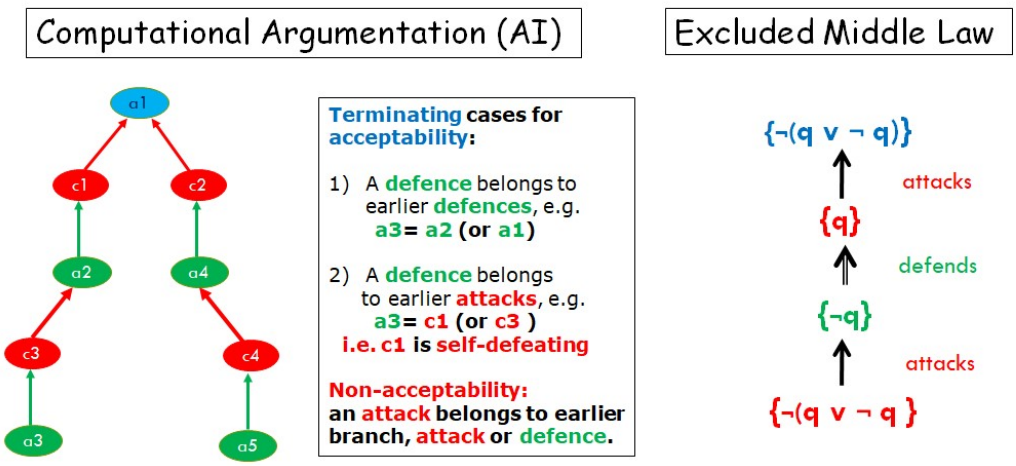

Figure 1: Dialectic Acceptability/Non-Acceptability of Arguments. The left part shows the general abstract case. The right part shows a concrete case in propositional logic.

This also helps us understand the formal semantics of argumentation as we can connect these trees to the dialectic process of arguing for and against a position. The left hand part of this figure, under the heading of Computational Argumentation in AI, shows this dialectic process to construct acceptable arguments in terms of labelled trees. One starts with an argument at the root of these computational trees (such as a_1 in the figure) supporting a position of interest. We then consider counter-arguments to the root argument, as indicated by the red arrows from arguments $c_1$and c_2 in the figure, and then for each one of these a corresponding defending argument. Defending arguments are shown in green attacking with green arrows the attacking arguments, e.g. in the figure a_2 defends against c_1 and a_4 defends against c_2. The process then repeats by considering new attacking arguments against each one of the newly introduced defending arguments and in turn considering defending arguments against each one of the new attacking arguments.

The purpose of these trees is to help us construct an acceptable subset of arguments containing the argument at the root of the tree (which would typically support a desired conclusion). Red nodes in the tree indicate attacking counter-arguments whereas green nodes indicate defending arguments. The collection of defending arguments together with the root argument form the "pro case" while the collection of the attacking arguments form the "con case".

The termination conditions for the acceptability (respectively the non-acceptability) of the root argument are shown in the box of the left part of Figure 1. They show that the process terminates when a defense (respectively an attack) node belongs to the union of arguments in the branch of the tree above the defense (respectively the attack) argument[3] When all branches of the tree terminate with a defense argument we have that the root argument is acceptable, whereas if one branch terminates with an attack argument the root argument is non-acceptable. This simple process can then be automated and used in real-life applications of AI [11].

3. Formal Logic as a Case of Argumentation

We can now present how this semantics of argumentation can be used to reformulate the formal logical reasoning of classical Propositional Logic in terms of argumentation. Indeed, it is possible to define **Argumentation Logic (AL)** [12] as a realization of the above abstract argumentation framework and show that this captures classical deductive reasoning. The arguments in AL are made up of sets of propositional formulae and the attack and defense relations are defined through the incompatibility between formulae and their negation. Arguments that are formed solely from formulae within a given theory T under which we are reasoning are stronger than arguments which are not of this form, i.e. arguments that contain at least one formula outside the premises T.

It is then possible to show that Argumentation Logic is logically equivalent to classical deductive reasoning whenever the given theory T that we are reasoning from is classically consistent [10]. This means that when the (propositional) premises T are classically consistent then formal logical entailment, in the classical sense of truth in all models, coincides with **sceptical entailment** in Argumentation Logic, defined as follows:

> A formula ϕ is a **sceptical conclusion** in AL if and only if the argument $a = \{\phi\}$ is acceptable and the opposite argument $a' = \{\neg\phi\}$ is non-acceptable.

The non-acceptability of the argument a' of the negation of the formulae means that the negation is not possible under any circumstance and hence the positive conclusion is an absolute winner, i.e. necessarily follows.

Non-surprisingly, as in most works that aim to bring formal logic closer to human reasoning, e.g. the early example of Intuitionistic Logic [19], the central element for this result of reformulating formal logical reasoning in terms of argumentation lies in the way that Reductio ad Absurdum is captured within the framework of argumentation. This is done by identifying structurally **self-defeating** (or fallacious) arguments and relating these to indirect logical proofs, i.e. proofs requiring *Reductio ad Absurdum*, within Propositional Logic.

Informally, a self-defeating argument, S, is one that "turns on itself" by rendering one of its attacking arguments acceptable in its own context of S. This means that the self-defeating argument renders the arguments that it needs for its defence, against some attacking counter-argument, non-acceptable. More formally, we can define a self-defeating argument S as one for which there exists a counter-argument A such that $\neg ACC(A, \emptyset)$ and $ACC(A, S)$ hold. So, although the attack A is in general (i.e. when we do not take any argument to be as given) non-acceptable, under S, this attack is rendered acceptable. Hence S brings about its own defeat and non-acceptability. The simplest example of a self-defeating argument is one that attacks itself, since in its own context its self-attack is acceptable.

For a more elaborate example of a self-defeating argument let us consider an example from the argumentation-based reformulation of formal logic, related to how we can derive the excluded middle law in Argumentation Logic. This is illustrated in the right part of Figure 2 where we see that the negation of the law, i.e. $\neg(q \vee \neg q)$, is shown to be non-acceptable, as the computational tree has a branch that terminates with an attacking argument. The tree shows that the root argument is attacked by the formula q, as from q we can directly derive $q \vee \neg q$. This attack by q can only be defended by taking on the opposing position of $\neg q$. But this defense is attacked by the root formula of $\neg(q \vee \neg q)$ since we can directly derive $q \vee \neg q$ from $\neg q$. We therefore have that an attack belongs to the branch above it and so the argument $\neg(q \vee \neg q)$ renders its required defense non-acceptable and thus, indirectly, it also renders itself non-acceptable.

Posing a hypothesis as a premise in a **Reductio ad Absurdum** proof corresponds to considering a context in which the hypothesis as an argument is accepted. Then the hypothesis leading to an inconsistency corresponds to the dialectic argumentation process leading to the non-acceptability of a (necessary) defending argument in the context of the posited argument. This correspondence is exact when the propositional theory of given premises is classically consistent in which case the non-acceptability of a formula argument also means the acceptability of the complement of the formulae, in the same way that Reductio ad Absurdum is used to derive the complement of the posited hypothesis. For the general case where the given theory under which we are reasoning is inconsistent then this latter step does not hold and we can have that both a formulae and its complement are non-acceptable. This signifies that we cannot have a position on such formulae. Nevertheless, this does not mean that the whole reasoning of Argumentation Logic trivializes but only that for some isolated formulae we are completely agnostic.

In summary, classical formal reasoning is captured as a special case of argumentation were a logical conclusion emerges as the result of contemplating arguments for and against the conclusion. Argumentation Logic is constructed by adopting a set of direct proof rules as basic argument schemes together with the recognition of self-defeating arguments to cover the indirect proofs through Reductio ad Absurdum. Then the acceptability semantics of argumentation and the sceptical form of entailment under this semantics realized in this concrete framework is equivalent to classical deductive reasoning.

3.1. Beyond Classical Reasoning: Back to Informal logic

The above correspondence between classical Propositional Logic and Argumentation Logic shows that classical truth models correspond to cases of acceptable subset of formulae, but this breaks down when the given premises are classically inconsistent. Acceptable cases of Argumentation Logic continue to exist and the logic does not trivialize. Hence, Argumentation Logic with its paraconsistent[4] form of argumentative reasoning can be understood as a smooth conservative extension of strict classical logical reasoning, in cases where indeed the given premise information is contradictory [13]. One interesting consequence of this is that (some of) logical paradoxes are dissolved. For example, for the Barber Paradox we have that in AL the two complementary sentences that "the Barber shaves himself" and that "the Barber does not shave himself" are both non-acceptable, showing that the logic is agnostic about who shaves the barber. But, in contrast to classical logic this does not affect the logical reasoning for any other person in the universe of discourse.

Generally, in such cases of inconsistent premises we can build arguments from subsets of the given premises that attack each other and therefore form alternatives. In addition, we may have information on the relative strength between these premises that would then feed into the definition of attack (and defense) between such arguments that are grounded on the given premises. Such information comes from the content of the premises with which we are reasoning, i.e. it is specific to the domain about which we are reasoning. This is typical in the realm of informal reasoning e.g. within common sense reasoning, where general or individual human biases give preference to some statements over others. Furthermore, the whole such reasoning is context sensitive as these preferences may change from one context to another. Hence, with informal reasoning, although this is captured under the same framework of argumentation as formal reasoning, the various constructs of argument schemes, attacks and defenses depend on the content of arguments and the dynamically changing environment in which the reasoning takes place.

Let us illustrate this by a simple example of text comprehension. Consider the following start of a piece of text that we reading:

- Mary was very busy at the office.
- Her phone rang.

Did Mary want to answer the phone? An argumentation process to answer this question in favour of not wanting to answer would require to construct an argument supporting this conclusion and acceptably defending it against its counter-arguments. One such argument might use as its premises the common sense knowledge that "normally, when people are busy they do not want to answer their phone". Grounding these with the information that Mary was busy we get an argument supporting the conclusion that Mary does not want to answer the phone. Let us call this the "Busy Argument (BA)". Another argument that would be present in our mind is a general one based on the common sense knowledge that "normally, people want to answer their phones". Let us call this the "General Argument (GA)'. These two arguments are in conflict and would therefore form counter-arguments for each other. In general we may consider them to be of equal strength and therefore formally they attack each other as shown on the left of Figure 2. This figure shows pictorially how this argumentation based interpretation of the text is captured within a formal argumentation framework $< Args, ATT >$ (Nodes in the picture show the arguments in $Args$ and the red arrows show the ATT relation between these arguments).

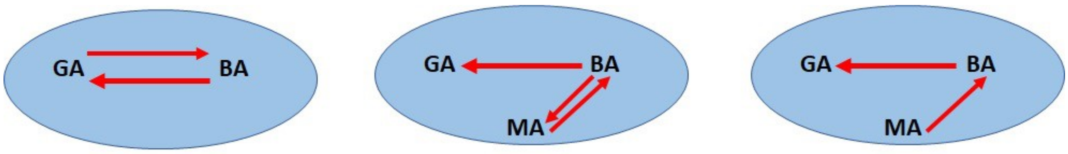

Figure 2: Argumentation Frameworks corresponding to the "phone story" text

But the author by including the qualification of "very" awakens, perhaps in the minds of only some human readers, a preference of the "busy argument" over the "general argument". Then the "general argument" as a weaker argument would not attack, within the formal argumentation framework, the "busy argument" and so the corresponding argumentation framework would now not include the arrow from GA to PA.. This means that the "busy argument" can defend against the counter-argument but not vice versa and hence we can draw the skeptical conclusion of "not wanting to answer the phone".

Let us assume that the story continues as follows:

- Mary was very busy at the office.
- Her phone rang.
- It was her mother phoning.

Now a new argument, let us call it the "Mother argument (MA)", enters the argumentation arena, based on the common sense knowledge that "normally, people want to communicate with their mothers". In general, the bias giving preference to this argument may not be strong enough to overcome the earlier "busy argument" supporting the contrary position of not wanting to answer the phone. The corresponding formal argumentation framework is shown in the middle of Figure 2 where we have assumed that the two arguments of PA and MA are of equal strength and thus they attack each other. In such a case even if PA is considered stronger that GA (as shown in the middle of the figure) the absolute sceptical conclusion of "not wanting to answer the phone" is lost and this is now only a plausible or credulous conclusion as we have acceptable subsets of arguments for both this conclusion and its converse of "wanting to answer the phone", namely the set $\{PA\}$ for not wanting to answer and the set $\{GA, MA\}$ for wanting to answer. The argument MA comes to defend GA against the strong attack against this by PA.

Suppose that the text continues with the following two sentences:

- Mary's mother fell ill last week.
- She was still (very) ill in the hospital.

The author has now revealed more details of the context that render the "Mother argument" clearly stronger that the "busy argument". In the corresponding argumentation framework, as shown on the right side of Figure 2, we now only have an attack from MA to PA. In this, the argument PA is not acceptable any more and hence "wanting to answer the phone" becomes a sceptical conclusion.

Using this argumentation-based text interpretation it is possible to construct, along the lines described above, what in Cognitive Psychology is called the **mental or comprehension model** [9] and understand the process of revision of this model as the text unfolds through the non-monotonicity of reasoning through argumentation [4], [3]. [5]. It is interesting to note that once we lock ourselves into a specific comprehension model (at any particular point in the text) the conclusions that this model contains can be seen as formal logical conclusions of the explicit information in the story and the world knowledge that we have used to construct the arguments and the model. In other words, the informal logic dialectic argumentation that we use to construct the comprehension model is one and the same as the formal dialectic argumentation process when projected down on the specifics used for constructing the model. Hence, the informal logic of comprehension has a formal logical interpretation under the strict form of argumentation for capturing formal logic, as we have described in the previous sections. Argumentation thus glues together informal and formal logic in both directions.

4. Aristotle: The origins of Systems of Reasoning

We will now briefly look into Aristotle's work on dialectic argument and study this from a contemporary argumentation perspective. Specifically, we will examine the resemblance between the basic acceptability semantics, that as we have argued above unifies informal and formal reasoning, with the method of Aristotle for dialectic argumentation found in the books of *Topics*.

In these books Aristotle considers the wider context of what today we associate with informal reasoning and laid argumentation as the foundational element of his investigation. Aristotle states from the very start that the purpose of *Topics* (100a18-20) is:

> To discover a method by which we shall be able to reason from generally accepted opinions about any problem set before us and shall ourselves, when sustaining an argument, avoid saying anything **self-contradictory** (copied from Rigotti and Greco [7]).

His study of dialectic argument is extensive and quite thorough in an attempt to provide a pragmatically effective method of applying argumentation to support a position or a claim. He categorizes the different possible positions in terms of four types of "predicables" and goes into great length to give, for each different type of predicable, elaborate prescriptions (topoi) or strategies of how to go about supporting, attacking and defending each particular type of position. From a contemporary point of view these topoi can be linked to the notion of *argument schemes* [27], [28] that associate premises to a position or to the contrary of a position, together with the pragmatics or heuristics to follow when carrying out the process of argumentation, as for example in the pragma-dialectal approach to argumentation in [6].

It is prudent to note that irrespective of the particular details of each topos the overall general condition on the process of dialectic argumentation is to **avoid a contradiction** on "our side" or to arrive at a contradiction on the "opposing side". This is the only *normative condition* on the process as we can clearly see in the above statement of Aristotle. It oversees the process as a requirement with which the process needs to be compliant. But its role is not merely that of a passive checker on the process. In some strong sense it actively drives the process of dialectic argumentation.

At the very general level the strategy of dialectic argumentation in Aristotle is to bring the opposite view into a situation which is unacceptable because it is self-contradictory. Aristotle describes how this strategy can be executed through a process between a *Questioner* and an *Answerer*. This process can be understood as a semi-formal computational structure consisting of three stages:

(a) **Opening:** The Questioner presents a statement to which the Answerer can reply either yes or no. The overall aim of the Questioner is to force the Answerer to accept that his answer is self-contradictory and thus not reasonable. (b) **Interrogation:** The Questioner introduces questions to the Answerer to establish beliefs that the Answerer holds. The aim of the Questioner in this stage is to gather such beliefs from the Answerer that would allow him to build a strong argument against the Answerer's claim. (c) **Conclusion:** Once the Questioner has all the information s/he needs s/he reveals to the Answerer the counter argument, which s/he builds through a *syllogism* based on premises that the Answerer has accepted. The fact that this is build through a syllogism means that this is quite a strong argument and cannot be dismissed. Hence the Answerer has no option than to accept that his initial position is in contradiction with his other beliefs, i.e. his case is self-contradictory and therefore defeated by the dialectic process of argumentation.

As mentioned above, in this adversarial process, the goal for the Answerer is to prevent the Questioner from succeeding by reasonably rejecting the premises that would lead to self-contradiction. The difficulty for the Answerer lies in realizing the counter-argument that the Questioner has in mind to build so that s/he can be careful on the beliefs he accepts during the second interrogation stage.

We can then observe a resemblance between this method of Aristotle for dialectic argumentation and the notion of acceptability and non-acceptability of arguments that we have presented above as the unifying foundation of contemporary informal and formal reasoning. The central task in Aristotle to bring the Answerer into a *self-contradiction* is analogous to the identification of self-defeating arguments under the formal notion of acceptability of arguments. Just like the dialectic method of Aristotle concludes with the exposition of a contradiction in the beliefs held by the Answerer, in the same way the computational trees of acceptability (see Figure 2 and termination conditions for non-acceptability) closes with an attacking argument playing also the role of a needed defense argument in the same dialectic branch of the tree, thus rendering the defending argument as self-defeating and non acceptable. Let us illustrate this correspondence through an example, shown in Figure 3.

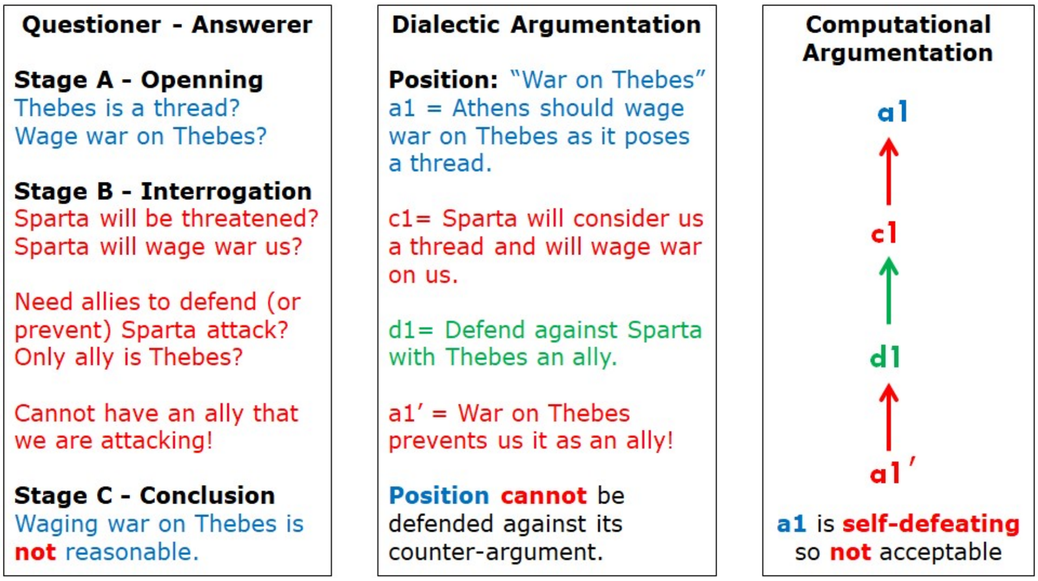

Figure 3: Example of Aristotle's Dialectic Argument

In the leftmost box of the figure we see the questions asked by the Questioner. We assume that the Answerer has answered "yes" to all these questions. The Questioner can then re-construct an explicit dialectic argumentation process (seen in the middle box of the figure) where the attacking counter-argument of $c1$ is revealed together with the fact that the proposed defense $d1$ against this, i.e. to use "Thebes as an ally", is in conflict with the original position of the answerer of "waging war on Thebes" and therefore could not form a coalition with the initial argument of $a1$. The rightmost part of the figure shows the abstract computational structure of this argumentation process and how it ends up with the non-acceptability of the initial argument supporting the original position of the answerer[6]. We can thus see the direct correspondence between Aristotle's dialectic method of argumentation with the computational model of argument trees in modern argumentation.

5. Conclusions: Reasoning in AI

We have presented how argumentation can form a universal basis for reasoning. The single notion of an acceptable (set of) argument(s) as one that can defend against its counter-arguments can uniformly capture informal and formal logical reasoning. Different forms of reasoning are thus attributed to the "intensity" of the argumentation process to consider to a varying degree a complete set of arguments and counter-arguments.

One of the main tasks of today's AI is to understand, formalize and effectively compute human reasoning. Hence, if we accept the universality of argumentation for reasoning, i.e. that *Reasoning is Argumentation*, then argumentation presents itself as a suitable candidate for the logical foundations of AI. We are then naturally led to *re-enact Aristotle's study of argumentation* in the *Organon* and particularly in the books of *Topics*. Just like Aristotle studied how to conduct argumentation in an effective way and proposed different *topoi* as guidelines for achieving this we can carry out an analogous study for the effective realization of computational argumentation in AI. To do so we need to consider, as Aristotle did, the dynamic and uncertain nature of the environment in which argumentation takes place where the computational process of argumentation should adapt to new information and in many cases be guided to actively seek new relevant information. There is of course one major difference: Aristotle's argumentative reasoning was to be carried out by the "machine of the human mind/brain" whereas in AI the machine is a poor artifact of the human mind/brain. Nevertheless, we can draw from the study of argumentation over the centuries in philosophy, the psychology of reasoning and other disciplines to help us in this task of finding an effective process of reasoning through argumentation. Combining this with the study from a modern perspective of Aristotle's extensive work on the good practice of argumentation, as for example in the recent work of [7], can provide us with valuable insights for the development of AI.

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Notes

1. All statements in this paper relating to Aristotle are to be understood as hypotheses posed by the author in the context of his extremely limited knowledge of Aristotle's work. They are therefore subject to disproval by any Aristotelian scholar. They are made in an attempt to understand how Aristotle, as the first logician and his general study of systematizing human reasoning, relates to current attempts in AI to formalize and automate human reasoning.
2. The recent book, entitled "The Dialogical roots of Deduction" [5] provides a unique exposition of the evolution of logical reasoning and how its genealogical connection with the process of dialectics survives into today's various forms of logical reasoning.
3. These conditions complement the base termination conditions of the non-existence of an attacking (respectively defending) argument.
4. It is evident that Argumentation Logic is related to Paraconsistent Logics [22] which similarly consider how we can define forms of reasoning that do not trivialize under inconsistent premises.
5. The construction of a comprehension model depends also on other factors, e.g. that of coherence where only conclusions in the main thread of the story are considered, but these are extra-logical processes outside the scope of this paper.
6. Strictly speaking the attacking argument $a1'$ is not the same as $a1$ but has the same effect of terminating the branch at an attack level. The only way to defend against $a1'$ is either by an argument against its premise of waging war on Thebes or an argument against Thebes being an ally. In either case this new defense will be attacked either by $a1$ or by $a3$ resulting in the non-acceptability of the branch.