

The AI Logic of Aristotle*

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Abstract

This paper presents a reading of Aristotle’s work on logical reasoning from the perspective of contemporary Artificial Intelligence. This view goes beyond the (traditional) study of his work on strict logical reasoning within his formal systems of Syllogistic Logic and Demonstration Science. We argue that his ideas on the (argumentative) essence of Logical Reasoning and his understanding of (the role of) Reasoning in the Large (in science but also in a diverse set of areas, such as Metaphysics, Rhetoric and Ethics) are pertinent for the needs of today’s AI, particularly so when we consider the “wholeness of AI” and the need for a wholistic approach of balanced solutions to its challenges.

1 Introduction

Aristotle¹ is generally accepted as the father of logic. The ideas that he raised in his study of logical reasoning carried the development of science over the centuries. Any scientific theory’s mathematical formalization is one that falls under his idea of Demonstrative Science. Today, in the era of Artificial Intelligence (AI), this title of the fatherhood of logic has a renewed significance. Behind it lies his original idea that human reasoning could be studied as a process and that perhaps there exist universal systems of reasoning that underly human reasoning irrespective of the content of what we are reasoning about. This is a daring idea as it essentially says that the human mind can study itself and indeed that it has the capacity to unravel its own self. Irrespective of whether this is possible or not, it is a thought that is a prerequisite for the existence and development of Artificial Intelligence.

In this article, we examine Aristotle’s work on human thought. We look into his work on systematizing reasoning but also on how reasoning relates to science and human endeavour more generally, from a modern perspective of Artificial Intelligence and ask if this can help enlighten our understanding of AI and Science more generally.

Before we begin this short journey into Aristotle let us set out, for the purposes of this article, what we mean by AI. A well-accepted description of what is AI, as understood by the modern AI pioneers of Turing and McCarthy [20, 14], is that it is a study of Intelligence and its realization in an artifact non-human medium. Simple as this statement may be, it contains an important element, namely that it refers to human intelligence, implicitly requiring that AI is human compatible. We therefore also need to say what we mean by (human) intelligence, and we will take this to be the cognitive function of structured thought or reasoning at large. It is also generally accepted that the purpose of AI is to help enhance and extend this cognitive capacity of human intelligence.

*The writing of this article has not been assisted by any AI system. Our main sources on Aristotle are various entries of the Stanford Encyclopedia of Philosophy, Loeb Classical Library and [1, 13, 3, 8]. Many of the ideas in this paper are also found in the draft article [10].

¹The author of this article is not an expert on Aristotle. As such any details concerning the statements made about Aristotle are subject to scrutiny by Aristotelian scholars.

2 Reasoning in Aristotle

Aristotle’s central notion of reasoning is captured in the following statement found repeated in several places of his writings:

“Ἔστι δὴ συλλογισμὸς λόγος ἐν ᾧ τεθέντων τινῶν ἕτερόν τι τῶν κειμένων ἐξ ἀνάγκης συμβαίνει διὰ τῶν κειμένων.”

Figure 1: Aristotle’s definition of Syllogism

This statement tells us what reasoning is. In a free translation, it states that reasoning is an argument (λόγος), a reason, for some conclusion to hold based on some information that we take as given, usually referred to as premises. Apart from telling us that reasoning is a process that connects the truth of some information (the premises) to the truth of another piece of information (the conclusion) this definition contains two very important qualifications about this connection. Firstly, the statement requires that the argument supports the conclusion so strongly that it will necessarily follow (ἐξ ἀνάγκης συμβαίνει) or hold from the given premises: once we accept the premises the reasoning (argument) renders the conclusion absolutely necessary. In the scholarly study of Aristotle, this is referred to as the Demonstrative Necessity of the conclusion from the premises. It underlies the notion of Demonstrative Science where scientific results follow via (several steps of) demonstrative necessity reasoning starting from primary principles. In the development of modern logic this is reflected in the strictness of formal logical conclusions that are undisputed under the given premises. This strictness of formal logic has come to be the bedrock of reliability of logical reasoning in Mathematics and Theoretical Science, resulting also, over the years, to the high respect that we generally ascribe to mathematical or scientific results and positions or opinions backed by these.

The second point to notice in this logical connection of premises to conclusion, is the fact that this (necessary) connection is described using the work “συμβαίνει” pointing to the fact that this connection is one that will happen in the world in which we are reasoning about (i.e., the world from where the premises come from). In fact, Aristotle considers the case where the link of information in his syllogism is causal, i.e., in the world we are reasoning the premises cause or bring about the conclusion. It could thus be argued, that this simple observation, reveals that Aristotle is not studying reasoning in the abstract but how it relates to phenomena and problems in the real-world. In modern terms, he is not an abstract mathematical logician but rather a logician of pragmatic concern, much like we find today in logic-based or symbolic AI.

Aristotle was clearly influenced by the mathematics of his time, but he did not keep his work on logical reasoning simply for mathematics. Quite the contrary, he relates this to his study of natural phenomena, human behaviour in politics, rhetoric, ethics, and his work on philosophy. He appears to want to have a general understanding of reasoning and human intellect that he can use in his studies across all fields. This makes him an original intellectual of AI, if not the protozoon of AI. Would Aristotle have stopped at the study of reasoning simply for the sake of reasoning and did not involve himself with the bigger question of how logical or rational reasoning relates to other issues in life, then there would be no strong reason to connect him to AI. Instead, he conceives the “rational self”, a part of any human that has a very high value and significance in life. Reasoning can regulate many parts of our individual and social lives and Aristotle encourages us to become as rational as possible – as good reasoners as possible. He wrote “the entire life of man is the imprint of his thought.”. It is almost as if he wants to understand humans as thinking machines!

3 Aristotle’s AI Logic

Can we then identify a general logical form that underlies Aristotle’s concerns and ideas of reasoning in the large? Clearly, we will not find a formal logical system like that of his syllogistic logic. Nevertheless, we can look for central elements that characterize, in Aristotle’s view, logical reasoning. One such element is that of Argumentation. In his statement of a syllogism (see above Figure 1) the logical connection between premises and conclusions is identified as an argument (λόγος). It is the argument that gives or constructs the conclusion of reasoning. But the central position of argumentation in his study of reasoning in the large comes from his work on argumentation itself. This is found primarily in the books of Topics where in the very first sentence of the first book he sets out the essence of argumentation as, what we can identify, a logical reasoning process:

***Ἡ μὲν πρόθεσις τῆς πραγματείας μέθοδον εὔρειν ἀφ’ ἧς
δυνησόμεθα συλλογίζεσθαι περὶ παντὸς τοῦ
προτεθέντος προβλήματος ἐξ ἐνδόξων, καὶ αὐτοὶ λόγον
ὑπέχοντες μὴθὲν ἐρούμεν ὑπεναντίον.***

Figure 2: Aristotle’s Reasoning via Argumentation in Topics

In free translation this says:

“The purpose of the present treatise is to discover a method by which we shall be able to reason about any problem set before us, from generally accepted opinions and shall ourselves, when sustaining an argument, avoid saying anything self-contradictory.”

This passage not only indicates the central role of argumentation in reasoning, but it also specifies the primary requirement for an argument to be good, valid or indeed we can say logical, namely that it is not self-contradictory. It essentially says that Logical Reasoning is non-self-contradictory argument justification of a conclusion.

Aristotle then goes ahead to analyze in detail how to carry out argumentation in debate and other contexts. In the books of Topics, he gives a precise analysis of how to argue for different types of positions, giving prescriptions for good practical argumentation. This has influenced the study of argumentation over the centuries with modern studies of human argumentation inspired and drawing from this pioneering study of Aristotle. For example, the very recent work in [18] propose a model for human inference in argumentation grounded on a detailed study of Aristotle’s work in Topics and other scholars following this. In general, Aristotle with his work on Argumentation essentially points out that this is a suitable framework for modeling Human Reasoning thus motivating the study of human reasoning under the prism of argumentation in various disciplines, particularly within Cognitive Science (see e.g., [15] for the link of human reasoning to argumentation and [17] for the connection of Aristotle to modern theories of argumentation). Furthermore, recent studies [12] from the area of Computation Argumentation in AI show that argumentation is a universal form of reasoning, able to capture classical formal deductive reasoning as a special case.

From the point of view of AI, this link of human reasoning to argumentation can serve several needs of AI theory and practice. Argumentation can form a logical foundation or Calculus for Human-centric AI [5]. It can provide the basis for explanations of predictions and decisions by AI systems, so that these can be contested and debated [23, 22]. Importantly, argumentation is the natural choice of a symbolic reasoner in a neuro-symbolic integration [9] for Agentic AI [7].

In one type of such integration, Large Language Models connect the Natural Language problem requirements to symbolic forms so that these synthetic agent systems can operate more reliably by delegating part of their processing to the argumentation symbolic reasoner.

Argumentation is also the natural choice for addressing the extremely important problem of Value Alignment in AI [21, 2]. In this the challenge is for AI systems to conform to the set of values, particularly moral values, as expected by the human problem stakeholders and users. Such ethical and other requirements need to be captured in a flexible way to allow for the exceptional case of dilemmas where a more careful analysis of the problem is needed before taking a final solution. Here in Ethics, Aristotle shows us how thinking relates to practical wisdom (phronesis – φρόνησις) for good ethical behaviour and we can use his ideas of rational reasoning in ethics to identify what we could call his AI Logic.

The first thing to point out is the observation by Aristotle that if we want to apply reasoning in areas, outside mathematics, such as ethics, then we need to consider premises that cannot be taken as statements of absolute necessity. Such statements instead have a merit of universality which is described by Aristotle as (ὡς ἐπὶ τὸ πλῆθος), translated by some scholars as “for the most part”. Under such premises logical demonstration is softer than the unconditional strict demonstrative necessity in his formal syllogistic logic and mathematics. Indeed, these softer logical proofs may need to be qualified for the conclusion to hold.

For Aristotle this means that the practice of ethical behaviour, as in the case of the modern quest for ethical value alignment in AI, should be governed by reasoning with guidelines which are context sensitive. He explicitly refers to the need of the introduction of the notion of leniency in justice [16], where he realizes that the law as written down is not an exact statement of absolute necessity and that there can be situations, when we are administering the law, that we can see its failing, and where then leniency is needed to be applied. Leniency is applied to correct the failing law. He states this quite explicitly: “ἐπανόρθωμα νομίμου δικαίου”, i.e., in free translation, that leniency is a “corrective process of the law”. From a reasoning point of view Aristotle’s leniency refers to a corrective reasoning mechanism that today we would recognize, within the realm of AI, as that of defeasible reasoning. In particular, it points us back to the flexible non-strict reasoning via argumentation, that we have discussed above, where essentially all proposals of such logics, developed in the first four decades of AI and called under the name of non-monotonic logics, could be reformulated within the framework of argumentation-based reasoning [11, 6, 4].

Does Aristotle make this same modern connection between defeasible reasoning and his dialectic argument? It is surprising that we do not find in Aristotle an explicit connection of his discussion of the defeasible reasoning of leniency in ethics, or the defeasible reasoning with the non-strict premises of the “for the most part” form, with his momentous study of Dialectic Argument. Why would this be so?

Another determining element of the type of logic that we can identify from Aristotle’s ethical reasoning and decision making is that, as he famously urges us, of reasoning to the “middle ground”. In this, reasoning is very different to that of looking for optimal solutions recognizing that this can only be done if we restrict attention to some specific particular dimension(s) of a problem, something that is not realistic in real-life problems such as that of ethical behaviour. Middle ground solutions point us away from a logic of absolute certainty and bring us closer to conclusions that are sufficiently acceptable, and balanced over a whole and diverse set of problem criteria. The optimality of solutions thus shifts to that of optimal balance, but this should not be interpreted in the same absolute way as that of demonstrative necessity and science. Instead, the optimality here is that of the ability to sustain a good balanced solution over a continuously changing class of problems. As Herbert A. Simon, a pioneer of AI, suggests in [19],

we should reason, as nature does, to satisficing solutions that smoothly adapt to changes in a dynamically evolving problem environment. Aristotle recognizes this need of dynamically stable reasoning over problem histories, by emphasizing that reasoning well to balanced conclusions is a continuous process that we would develop habitually over our lives.

4 Conclusions

We saw how reading across Aristotle, beyond simply his works in Organon, we can grasp, valuable ideas on the logical foundations of Artificial Intelligence. We can see, from an original thinker on systematizing thought and its application to real-life problem solving, how logical reasoning for general intelligence needs to be flexible in the face of conflicting information, yet coherent, leading to satisficing optimal for wholistic conclusions, cognitively explainable in a human compatible way. This type of reasoning is served well by the logic of Dialectic Argument whose underlying normative condition for (logically) valid conclusions is that these are reasonably justified through arguments that are based on clear premises (commonly accepted facts and specific assumptions) and that can counter conflicting alternatives in an internally coherent way. Furthermore, an AI Logic according to Aristotle should be based on knowledge and strategy of reasoning that it is learned habitually through a continuous experience that would allow the results of logical reasoning to adapt and evolve in a dynamic environment.

One could reasonably ask, why should Aristotle after two and more millennia be relevant for today's AI scientific and technological development, as presented in this article? Is it because of the fascination of the author with Aristotle who paints him in the form that he wishes for? Is it because AI is ontologically a different type of science that has not been explored until very recently? Or maybe because two thousand years is really not a very long time in the macro scale of the development of human intelligence and knowledge? Particularly so, when we take into account the skewness that Demonstrative Mathematics and Science has brought about our understanding of intelligence to the extent that not so long ago, we would be arguing that humans are not rational thinkers because they do not follow (exactly) the reasoning forms of strict formal logic that underpins Mathematics and Science?

Aristotle is an **original thinker** of our system of thought, of the essence of thinking and of its (primary) role in understanding our world both physical, mental and societal. Two thousand years or so is just a blink in the evolutionary scale of things. The importance of looking afresh at Aristotle is indeed in his originality in asking the question "how does human thinking work?" His work is a mutation point in the "species" of thought. Going back to this mutation point can help us see more clearly what other genres of systems of thought can evolve without being obscured by the formal logical evolutionary path of mathematics and science that came to dominate our view of what is good logical thought.

Aristotle's legacy of the "dream of reason" drove the past enlightenment eras. Today, with the new era of AI, Aristotle comes again to help us with his original idea of reasoning for middle ground, holistic and habitual solutions to real-life problems. Reason away from narrow and short-term interest and consider instead reasoning to sustainable long-term benefits. The importance of this idea goes beyond the design and development of future AI. It covers the future of all science and how we want to harness the power of thought in our human cosmos.

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