

Algorithms and Arguments

Artificial Intelligence and Informal Logic

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Outline

- 1 Introduction
 - What AI has to say to AT and what AT never said about AI
 - Previous works with Italo Testa and further research
- 2 The rebuttal of the AI-thesis
 - The reconstruction of an argument supporting the AI-thesis
- 3 Many algorithms, many arguments
- 4 A narrow and a broad notion of algorithm
 - The narrow notion
 - The broader notion
- 5 Pragmatics and interaction
- 6 Synergies between AT and AI

Previous work

Previous work in collaboration with Italo Testa

- This talk is a development of previous work developed in collaboration with Italo Testa and published in Italian
- Cantù, Paola and Testa, Italo (2012). Algoritmi e argomenti. La sfida dell'intelligenza artificiale. *Sistemi Intelligenti*, 24(3 (2012):395–414.
- Major developments concern section 2 and section 6 of this talk (compare sections 2,3 and 7 of the article).

AI and AT are worlds apart

AI and AT are worlds apart

- AI and AT developed at the same time (between the Fifties and the Sixties) and investigated human argumentative reasoning.
- But AI and AT held opposite views:
 - AI argumentative reasoning can be simulated (weak thesis) / replicated (strong thesis) by machines
 - AT argumentative reasoning is a characterizing feature of human rationality (intelligence) that cannot be reduced to inferential, mechanic computation.
- But there are no arguments against the AI thesis (neither weak nor strong version) in AT literature

Compare AI and AT

- 1 AI: the secret enemy
- 2 Many arguments, many algorithms
- 3 A broader notion of algorithm
- 4 Pragmatics and interaction are not enough
- 5 Recent changes and preexisting similarities

Compare AI and AT I

1. AI: the secret enemy

- Was the opposition to AI a further reason for the development of AT?
- Explicit aim for the revival of rhetoric and informal language: include ordinary language argumentation processes.
- Implicit aim (what AI never said): confute the AI thesis by rebutting several of its premises (a counterfactual reconstruction of an AT rebuttal of the AI weak thesis).

Compare AI and AT II

1. Further research on the rebuttal of the AI thesis

- Today I will trace several arguments against the single premises
- and present a more complex reconstruction of the argument against the AI weak thesis
- but also against the AI strong thesis
- this sheds more light on AT, and offers a framework to better understand and distinguish between different schools of thought in AT: e.g. better understanding informal logic as opposing computation as well as the monologic and artificial character of formal languages

Compare AI and AT III

2. Many arguments, many algorithms

- Focusing on the notion of algorithm, we highlighted an analogy between a plurality of notions of algorithm in AI and a plurality of notions of argument in AT.

Compare AI and AT IV

3. A broader notion of algorithm

- We then suggested some lines along which a broader notion of algorithm might be defined, in analogy with the broader notion of argument. The broader notion of algorithm is conceived as expressing as a pre-existing intuitive notion that the notion of Turing-computability had only partially formalized, rather than as an extension of a previous restricted notion (analogy with numbers).

Compare AI and AT V

4. Pragmatics and interaction are not enough

- We remarked that the AT criticism of the restricted notion of algorithm was based on a broad notion of argument and wondered whether the same rebuttal would hold against a reformulation of the AI thesis based on a broader notion of algorithm. We suggested that a generic appeal to pragmatics or to interaction is not enough to characterize argumentative rationality (intelligence) as a feature of human reasoning that cannot be simulated by machines.

Compare AI and AT VI

5. Recent changes and preexisting similarities

- I will further investigate the relation between AT and AI, and briefly comment on the fact that they seem to get along so wonderfully in recent years. Did something change, or were the similarities bigger than expected? Apart from the change in the notion of algorithm, what else changed? And were there some unnoticed similarities? I will mention: the criticism of the limits of formal logic, the concern for relevance, externalization.

The argument I

Premises

- (1) human reasoning can be considered as a mechanical computation
- (2) every computable function can be computed by a Turing machine
- (3) human argumentative reasoning is algorithmic

Conclusion

AI-thesis human argumentative reasoning can be simulated by a Turing machine

Premise (1) I

Premise (1)

- (1) human reasoning can be considered as a mechanical computation
 - (1a) Ratiocination is computation (Hobbes)
 - (1b) Argumentation is a form of human reasoning
 - (1c) Calculus can solve human disputes (Leibniz's *calculus*)

Against (1c) I

(1c) Calculus can solve human disputes (Leibniz's *calculemus*)

*For certainly no value-judgements of other sorts can be discussed in purely mathematical terms. Jurisprudence, for instance, elucidates for us the special logic of legal statements, yet it eludes mathematical treatment; nor are ethical and aesthetic problems formulated more effectively by being made the subject for a calculus. (Toulmin, *The Uses of Argument*: 173)*

Against (1c) II

(1c) Calculus can solve human disputes (Leibniz's *calculemus*)

Leibniz and those after him, from Boole to Turing or McCarthy, added computation as a major category in understanding reasoning. Now, this is not necessarily congenial to argumentation: Leibniz' famous 'Calculemus' calls for replacing interactive disputation by mechanical computing. (van Benthem 2008 in Rahwan and Simari, 2009: vii)

Premise (2) I

Premise (2)

- (2) Every computable function can be computed by a Turing machine
 - (2a) Turing-Thesis. Any effective — or mechanical — method can be carried out by the Universal Turing Machine
 - (2b) Definition. A function is said to be computable if and only if there is an effective method for determining its values.
 - (2c) Definition. An algorithm is a computable function.
 - (2d) Simulation Fallacy. Any process that can be given a mathematical description (or a “precise enough characterization as a set of steps” , or an algorithmic description) can be simulated by a (Turing) machine.

Criticism of premise (2)? I

- AT was not specifically interested in criticizing premise (2), given that it did not consider computation as relevant for argumentation.
- But Toulmin's development of "procedural schemes" as models of arguments suggests that he considered algorithms as procedures that are not purely formal. His criticism of 'formalism' is related to the idea that there are procedures that we follow in practice that might be reconstructed by a logical calculus, but need not follow the same rules of inference.

Criticism of premise (2)? II

- He suggests that we use algorithms in drawing inferences, yet not necessarily those that can be computed by a Turing machine. Toulmin criticizes the formal mathematical interpretation of algorithm.

Toulmin

Arguments in applied mathematics, though formally identical with arguments in pure mathematics, are none the less substantial rather than analytic, the step from data to conclusion frequently involving an actual type-jump. We can ensure the formal adequacy of our arguments by expressing them either in the form (D; W; so C)—a warrant being in effect a substitution-rule, authorising the simplest of all mathematical steps—or alternatively in the form of a mathematical argument taken from the appropriate calculus. (toulmin, the uses of argument: 193–194)

Against (2c) I

(2c) Definition. An algorithm is a computable function.

These arguments may leave mathematically-minded readers with a sense of loss. The dream of formal “algorithms” for guiding scientific procedures has a charm that will not quickly dissipate. For those who value mathematical exactitude above all other kinds of precision as the model for scientific inquiry, the alternative message of “different methods for different topics” will be a disappointment. (Toulmin 2011: 96)

Against (2d) I

(2d) Simulation Fallacy. Any process that can be given a mathematical description (or a “precise enough characterization as a set of steps” , or an algorithmic description) can be simulated by a (Turing) machine.

Against (2d) II

Moreover, in the second place, it does not seem to me that any contrivances at present known or likely to be discovered really deserve the name of logical machines. It is but a very small part of the entire process, which goes to form a piece of reasoning, which they are capable of performing. For, if we begin from the beginning, that process would involve four tolerably distinct steps. even if human reasoning were based on algorithms, it could not be considered as a mechanical computation: "There is, first, the statement of our data in accurate logical language. [...] Then secondly, we have to throw these statements into a form fit for the engine to work with—in this case the reduction of each proposition to its elementary denials. [...] Thirdly, there is the combination or further treatment of our premises after such reduction. Finally, the results have to be interpreted or read off. This last generally gives rise to much opening for skill and sagacity; [...] I cannot see that any machine can hope to help us except in the third of these steps; so that it seems very doubtful whether any thing of this sort really deserves the name of a logical engine" (Venn 1881, pp. 120-121).

Premise (3) I

Premise (3)

- (3) human argumentative reasoning is algorithmic
 - (3a) human arguments can be reconstructed as algorithms
 - (3b) human argumentative reasoning is an algorithmic process

Against (3a) I

3a) human arguments can be reconstructed as algorithms

- only some arguments (deductive)
- certainly not the arguments concerning judgements of value
- no arguments (because no argument is strictly deductive)
- arguments can be reconstructed in the form of algorithms (ex post) but are not algorithmic processes
- the verification of the correctness of an argument might be an algorithmic process (verify whether the conclusion follows from the premises), but not the search for an interesting or relevant conclusion from some given premises

Against (3b) I

3b) human argumentative reasoning is an algorithmic process

- arguments can be reconstructed in the form of algorithms (ex post) but are not algorithmic processes

It may well be, where a problem is a matter for calculation, that the stages in the argument we present in justification of our conclusion are the same as those we went through in getting at the answer, but this will not in general be so. (Toulmin, The Uses of Argument: 17)

Against (3b) II

- the verification of the correctness of an argument might be an algorithmic process (verify whether the conclusion follows from the premises), but not the search for an interesting or relevant conclusion from some given premises

Conclusion I

AI-thesis applied to argumentative reasoning

AI-thesis (weak) human argumentative reasoning can be simulated by a Turing machine

AI-thesis (strong) human argumentative reasoning can be replicated by a Turing machine

What is an algorithm?

- What is an algorithmic structure? Is there a broader notion of algorithm? If algorithms are defined neither as computable functions nor as other kind of effective methods that can be computed by machines, but in a more informal way, then their notion might still bear some similarities with the notion of argument.
- Given that there can be narrower and broader notions of argument, couldn't there be narrower and broader notions of algorithm too?
- And couldn't there be similarities between the two broader notions of argument and algorithm?

Two notions of argument: ARG₁ and ARG₂

- There are several definitions of argument, that can be grouped in at least two distinct classes of definitions:
 - ARG₁ a narrow notion of argument (formal, deductive, context-independent)
 - ARG₂ a broad notion of argument (informal, not only deductive, context-dependent)

ARG₁ \longrightarrow ARG₂

Table : ARG₁ \longrightarrow ARG₂

| | ARG ₁ | ARG ₂ | |
|------------|------------------|------------------|----------------|
| language | formal | natural | (Govier 1985) |
| context | syntax/semantics | pragmatics | (Walton 1990) |
| inferences | deduction only | plurality | (Johnson 1999) |

ARG₂ as a generalization of ARG₁

- The first notion might be considered as a restriction of the second, rather than as a concept that is radically opposed to it.
- ARG₁ might be useful to formalize certain arguments that fall under the notion of ARG₂, or at least certain parts of them.
 - Natural might mean “only partially formalizable” rather than “necessarily not formal”. (Cf. P. Cantù and I. Testa, *Teorie dell'argomentazione*, Milano: Bruno Mondadori, 1996)

Two notions of argument: ALG_1 and ALG_2

- 1 Analyze if a distinction between a narrow and a broad notion has ever been introduced in the case of algorithms:
 - ALG_1 \rightarrow Algorithm: formal characterization (computation) \rightarrow narrow meaning
 - ALG_2 \rightarrow Algorithm: informal characterization (computation, problem solving, decision processes) \rightarrow broad meaning
- 2 Compare the two obtained notions of algorithm with the two mentioned notions of argument.
- 3 Verify if the comparison might shed some light on the basic problems concerning the nature of human reasoning, and/or be fruitful for the development of argumentation theory and for the foundation of its interactions with artificial intelligence.

ALG₁: a narrow notion I

ALG₁ → a narrow notion (Markov 1954, Knuth 1968, 1973)

- An algorithm is a set of instructions determining a procedure

(**finiteness**) that allows, given certain inputs, to reach the goal (decision, computation, problem solving), i.e. provide the desired output in a finite number of steps,

and that satisfies the following conditions

(**generality**) the possibility of starting out with initial data, which may vary within given limits

(**conclusiveness**) the orientation of the algorithm towards obtaining some desired result, which is indeed obtained in the end with proper initial data

ALG₁: a narrow notion II

- (**effectiveness**) all of the operations to be performed in the algorithm must be sufficiently basic that they can in principle be done exactly and in a finite length of time by the executer (Turing-machine)
- (**definiteness**) the prescription should be precise, leaving no place to arbitrariness, and universally comprehensible
- (**determinism**) given a particular input, it will always produce the same output, and the procedure will consist of the same sequence of steps

A broader notion: ALG_2 I

- A broader notion (ALG_2) is needed to describe the following cases:
 - 1 **Before machines.** The restricted notion of algorithm mentioned above is the result of recent efforts to formulate algorithms that can be computed in a reasonably short time and in a reliable way by computers or robots. ALG_1 was obtained as a formalization of ALG_2 . The notion of algorithm need not be related to the notion of a machine. Algorithms were used before the invention of machines. (Chemla 2005)

A broader notion: ALG_2 II

- 2 Humans.** For example, it is common to define algorithms as recipes or procedures to carry out some task (Sipser 2006): e.g. cooking recipes or washing machine instructions. In such cases algorithms are sets of instructions written for human receivers, and thus might be open to different interpretations (non-definite algorithms).
- 3 Non-deterministic Turing-machines.** Recent developments of computation theory have suggested that there might be classes of algorithms that cannot be computed by a Turing-machine, even if they might be computed by different kinds of machines: e.g. non-deterministic algorithms are computable by non-deterministic Turing-machines. (Blass and Gurevich 2003).

A broader notion: ALG_2 III

- 4 **Multi-agent systems.** A different notion of algorithm (interactive algorithm) is developed with respect to the development of a different notion of machine: multi-agent systems that can learn from experience and interact in a network. (Blass and Gurevich 2003).

A tentative definition of ALG_2 as a generalization of ALG_1

A broader notion of algorithm is needed to include these kinds of algorithms and might be obtained from ALG_1 if one abandons the conditions of **definiteness** and **determinism**, and does not specify too strictly the condition of effectiveness.

- ALG_1 can be seen as a restriction of ALG_2 .
- ALG_1 can be used to formalize and analyze certain aspects of ALG_2 .

Similarities between arguments and algorithms

Table : Similarities between arguments and algorithms

| | FORMAL | NATURAL | SYNTAX | PRAGMATICS | → MONISM | → PLURALISM |
|------------------------|--------------|----------------|------------|---------------|---------------|------------------------|
| <i>ALG₁</i> | machines | | finiteness | | deterministic | |
| <i>ARG₁</i> | formal lang. | | no context | | deduction | |
| <i>ALG₂</i> | | humans | | no finiteness | | non-deterministic |
| <i>ARG₂</i> | | ordinary lang. | | contexts | | various infer. schemes |

Pragmatics and Interaction I

- Argumentation theory was partly developed in the belief that there is much more in an argument (ARG_2) than there is in an algorithm (ALG_1), and this helped avoiding to admit that the reasoning of the human mind could be emulated by the computation of a machine.
- But if one considers a broader notion of algorithm (ALG_2), the question might be raised anew: is there something in (ARG_2) that cannot be captured by (ALG_2)?
- This is even more urgent, given the development of non-classical logics (non-monotonic, defeasible, ...) and of multi-agent systems.

Pragmatics and Interaction II

- Is it really possible to admit that arguments can be fruitfully analyzed by means of algorithms without admitting that human argumentation practices can be emulated by the interaction of multi-agent systems?
- If arguments are reconstructed as ALG_2 , then the idea of a social and pragmatic interaction might already be captured by the notion of algorithm itself: so, if one wants to claim that human argumentative practices contain some specificity (the rationality of argumentation), then one should exhibit some features (other than pragmatics and interaction) that cannot be captured by the activity of a multi-agent system.

No fear anymore I

- In the Introduction to *Argumentation in Artificial Intelligence* (ed. by Rahwan and Simari, Springer, 2009), J. van Benthem reassures logicians, philosophers and argumentation theorists by arguing that
- AI theorists do not believe anymore that machines can emulate humans, but rather that they can contribute to the improvement of the human understanding of humans:

Original visions of AI tended to emphasize hugely uninspiring, if terrifying, goals like machines emulating humans. [...]

Understanding argumentation means understanding a crucial feature of ourselves, perhaps using machines to improve our performance, helping us humans be better at what we are.

No fear anymore II

- notwithstanding the opposition to Leibniz's *calculemus*, AI has to acknowledge that computation has changed:

Leibniz and those after him, from Boole to Turing or McCarthy, added computation as a major category in understanding reasoning. Now, this is not necessarily congenial to argumentation: Leibniz' famous 'Calculemus' calls for replacing interactive disputation by mechanical computing. But modern computation itself is distributed and interactive, so we are in tune again. (van Benthem 2008 in Rahwan and Simari, 2009: vii)

Research synergies

- Topics: Argument and multi-Agent Systems, decision calculi for practical reasoning, computational models for legal and rhetorical arguments, the persuasion machine, semantics for abstract argumentation, investigation on the argument's structure, . . .
- Publications: Rahwan, I. and Simari, G. R. (2009). *Argumentation in Artificial Intelligence*. Springer. Reed, C. and Norman, T. J. (2004). *Argumentation Machines: New Frontiers in Argument and Computation*. Springer.
- International Conferences: commA, ArgmAs, cmnA
- Journals: *Argument & Computation*

Changes

If one considers

- Changes in computation theory: $ALG_1 \longrightarrow ALG_2$
- Changes in AI: single machine \longrightarrow multi-agent system
- Changes in the logic: monotonic logic \longrightarrow non-monotonic logics, defeasible logics, ...
- Changes in AI cognitive approach (from high-level tasks to low-level tasks: perception and motor tasks \rightarrow situated intelligence)
then one could reformulate the AI-thesis applied to argumentation as following:
- A multi-agent system might simulate the interactive argumentative reasoning of several human beings.

Similarities

- **Procedural Form.** Firstly, the broader notion of argument is not incompatible with a representation by means of diagrams, graphs, procedural forms, and other inferential schemes that can be expressed by algorithms (e.g. Toulmin's interpretation of an argument as a procedural form).
- **Pragmatics.** Secondly, the attention devoted to pragmatics in argumentation theory is now emerging in computation theory too, especially in the development of algorithms that need to be interpreted by multi-agent systems, whose resources and background knowledge depend on the amount of interaction between the system and the environment and between the agents themselves.
- **Multi-agent systems.** Finally, the interest for the interpretation of the assertions of the interlocutor in the argumentative practice might be fruitfully compared to the interpretation of the information received from an agent in a complex system. The non-deterministic and indefinite aspects of the broader notion of algorithm might usefully be applied to the reconstruction of certain aspects of human argumentative practices.

Further similarities

- the criticism of the limits of formal logic (Minsky 1986: 167) / Informal logic
- the criticism of symbolic formalism (Winograd 1990: 172) / Perelman
- the concern for relevance (Dreyfus, Searle, ...) / (Johnson e Blair 1977), Hamblin 1970, Grice 1967
- the criticism of the cognitive approach (mentalism) (Dreyfus, Searle) / rule of externalization (Pragma-dialectics)