

On the Properties of the Relation between Argumentation Semantics and Argumentation Inference Operators

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Abstract. The problem of finding properties that characterizes the relation between argumentation semantics and argumentation inference operators has beginning to surface in the last years. Several works have addresses this concern proposing different “postulates” that reflect the intuitions in this respect. Argumentative reasoning is by nature defeasible and that distinct feature must have a deep influence on the resulting constrains. We believe that the very essence of argumentation should affect the manner in which the required properties are described.

Keywords. Reasoning, Defeasible Argumentation, Argumentative Inference Properties.

1. Preliminaries

To reason is a human activity, and the word *reasoning* can be found defined in a dictionary as: “The action of thinking about something in a logical, sensible way.” Thus, to reason is to exploit, by *thinking*, our understanding of that *something* to obtain consequences that are useful to guide our behavior. Some consequences are immediate, others are implicit, and others yet others are entertained with certain amount of risk. This intuitive description has been a more or less obvious part of any attempt to understand this complex process, *i.e.*, to shed light on the sort of steps that are taken to obtain conclusions.

In Western Philosophy, the systematic study of reasoning can be traced back to Greek classical times; from the works of the pre-Socratic philosophers to present day, the understanding of this process has been slowly progressing allowing to introduce tools that reflect different aspects of it. Aristotle [40,3] developed the first systematic rendering of the principles of correct reasoning, taking a first step in a path that continues to the present day. The nineteenth century witnessed the development Symbolic Logic [39] and its incredible expansion over the Foundations of Mathematics providing advances that, among other things, led to the creation of what today is called Computer Science [44].

From a Computer Science (CS) point of view, the notion of process has been characterized as an instance of a computer program that is being executed by a processor. Intuitively, reasoning is a process that needs a precise characterization to be useful in the exploitation of a knowledge resource. The area of Knowledge Representation and

Reasoning (KR), a part of Artificial Intelligence (AI), aims to realize intelligence in a computer system under the following conjunct assumptions:

- *The Physical Symbol System Hypothesis*: A physical symbol system has the necessary and sufficient means for general intelligent action [30]; and,
- *The Church-Turing Thesis*: Every effective computation can be carried out by a Turing machine [15].

In the words of Newell and Simon “*A physical symbol system is an instance of a universal machine. Thus the symbol system hypothesis implies that intelligence will be realized by a universal computer.*” It must be made clear that both statements are assumed as a basis for a line of inquiry, and not must be interpreted in any other way.

The representation of knowledge related to complex problems using suitable logical formalisms, and their use in producing useful results has been one of the major concerns of the area of KR. In 1980, a special issue of the Artificial Intelligence Journal (AIJ) was published (Vol. 13, 1-2) containing a collection of papers dedicated to Nonmonotonic Reasoning, arguably leading to an impressive growth in the research of these questions. In that issue of AIJ, several foundational works were introduced, among which are Reiter’s Default Logic [38], McCarthy’s Circumscription [25], and McDermott and Doyle’s Nonmonotonic Logic [26]. Soon others followed increasing the scope of research, in the case of Moore’s Autoepistemic Logic [29], to mention an important one, it addressed some concerns with Nonmonotonic Logic. The work of Loui on argumentation [24], and the seminal contributions of Pollock on defeasible reasoning [33,34], and Defeasible Logic [32], advanced a line of research that continues to this day.

Another central concern was the development of computationally oriented systems that consider the theoretical and practical underpinnings of the proposed systems. Logic Programming is one of the most resounding successes achieved by integrating many of the findings made by the Nonmonotonic Reasoning community; it also led to the implementation of many emerging applications, such as decision support systems for space shuttle controllers, molecular biology, and team building to tackle crucial management tasks [11] (the collection [21] contains several articles related to all these advances). A comprehensive account of the advances in the use of Logic Programming as a tool for representing domain knowledge, and the structuring of the reasoning about that representation is presented in [2].

The problem of producing effective reasoning processes based on argumentation was also pursued from the early beginnings. The work of Lin and Shoham [23] presenting a theory of argument systems, Nute [31] discussing an implementation of defeasible reasoning in Prolog [31], Simari and Loui [41,42] considering defeasible reasoning and argumentation, Dung [16,17] introducing abstract argumentation frameworks, Bondarenko et al. [10,9,43] presenting Assumption-Based Argumentation, Prakken [35], Modgil and Prakken [27,28] introducing ASPIC+, Besnard and Hunter [6,7,8] considering argumentation systems based on classical logic, and Defeasible Logic Programming (DeLP) [18,19,20] offering an argumentation system in a logic programming setting. The research carried out in argumentation systems where arguments are built from a formal representation has been described in several works; for instance, see [14,36,4,7,37], and [5] for the introduction to a recently published special issue dedicated to structured argumentation systems.

2. Reasoning

As we mentioned, reasoning is a process; that is, given a resource containing a representation of knowledge —often called a *knowledge base*— about an application domain, the process of reasoning performs a series of actions to obtain conclusions from the knowledge base. Any computer realization of such a process involves the implementation of an inference mechanism; this mechanism comprises the effective construction that corresponds to an inference operator that reflects a theoretical characterization.

The syntactic knowledge base must have a connection with the domain it reflects, and this connection provides the semantics of the representation; therefore, there must be a tight association between the representation and the domain it represents. In this regard, two important properties of a logical system that have been studied are *Soundness* and *Completeness*. Given an inference operator, if the operator satisfies soundness then it is only able to obtain formulas that respect the semantics; on the other hand, if the operator satisfies completeness only formulas that respect the semantics can be obtained. For instance, there exist many deductive systems for FOL that are sound (all provable formulas are true in all models) and complete (all formulas which are true in all interpretations are provable).

For the purpose of characterizing a particular inference operator, the task of considering properties that the operator should satisfy becomes of great interest. For instance, to satisfy completeness, in FOL it is necessary to specify a proof theory, *i.e.*, a set of axioms and a set of inference rules, that can prove all the formulas that are true in all interpretations. Several proposals have been advanced by the argumentation research community regarding the issue of properties. We will explore several of them below.

3. Existing Work

Caminada and Amgoud in [12], presented some properties as *rationality postulates* that structured argumentation systems based on a language that contains strict and defeasible rules should strive to satisfy to avoid results that are not intuitive.¹ We briefly present these postulates below.

Rationality Postulates

To motivate the discussion, we will concisely introduce the elements of the formalism and the postulates presented in Caminada et al. [12]. We refer the interested reader to the aforementioned work where the authors develop a thorough discussion of details.

Definition 1 (Theory) A defeasible theory \mathcal{T} is a pair $\langle \mathcal{S}, \mathcal{D} \rangle$ where \mathcal{S} is a set of strict rules and \mathcal{D} is a set of defeasible rules.

Definition 2 (Closure of a set of formulas) Let $\mathcal{P} \subseteq \mathcal{L}$. The closure of \mathcal{P} under the set \mathcal{S} of strict rules, denoted $Cl_{\mathcal{S}}(\mathcal{P})$, is the smallest set such that:

- $\mathcal{P} \subseteq Cl_{\mathcal{S}}(\mathcal{P})$
- if $(\phi_1, \dots, \phi_n \rightarrow \psi) \in \mathcal{S}$ and $\phi_1, \dots, \phi_n \in Cl_{\mathcal{S}}(\mathcal{P})$ then $\psi \in Cl_{\mathcal{S}}(\mathcal{P})$.

¹These structured argumentation systems are described as *rule-based systems* in [12]

If $\mathcal{P} = Cl_{\mathcal{S}}(\mathcal{P})$ the \mathcal{P} is said to be closed under the set \mathcal{S} .

Postulate 1 (Closure) Let \mathcal{T} be a defeasible theory, $\langle Arg, Def \rangle$ an argumentation system built from \mathcal{T} . Output is its set of justified conclusions, and E_1, \dots, E_n its extensions under a given semantics. $\langle Arg, Def \rangle$ satisfies closure iff

- i) $Concs(E_i) = Cl_{\mathcal{S}}(Concs(E_i))$ for each $1 \leq i \leq n$.
- ii) Output = $Cl_{\mathcal{S}}(\text{Output})$.

Postulate 2 (Direct Consistency) Let \mathcal{T} be a defeasible theory, $\langle Arg, Def \rangle$ an argumentation system built from \mathcal{T} . Output is its set of justified conclusions, and E_1, \dots, E_n its extensions under a given semantics. $\langle Arg, Def \rangle$ satisfies direct consistency iff

- i) $Concs(E_i)$ is consistent for each $1 \leq i \leq n$.
- ii) Output = is consistent.

Postulate 3 (Indirect Consistency) Let \mathcal{T} be a defeasible theory, $\langle Arg, Def \rangle$ an argumentation system built from \mathcal{T} . Output is its set of justified conclusions, and E_1, \dots, E_n its extensions under a given semantics. $\langle Arg, Def \rangle$ satisfies indirect consistency iff

- i) $Cl_{\mathcal{S}}(Concs(E_i))$ is consistent for each $1 \leq i \leq n$.
- ii) $Cl_{\mathcal{S}}(\text{Output}) = \text{is consistent}$.

The authors observe that the reasoning process supported by an argumentation system that fails to satisfy these postulates produces certain reasoning anomalies. For instance, failing to satisfy *Closure* would lead to leave out conclusions that apparently should be obtained; violating *Direct Consistency* would lead the reasoning engine to obtain absurdities from the argumentation system; and finally, giving out *Indirect Consistency* would not allow to apply *modus ponens* on strict rules.

We choose to present the previous work first because represents a clear example of a line of research concerned with expressing constrains over an argumentation inference operator. The construction of structured argumentation systems needs to have a formal specification of such inference operator and that specification should satisfy adequate properties similar to the ones presented above. We now briefly introduce other proposals that have been advanced dealing with the same concern in mind from different perspectives and motivated in particular systems.

The work presented in [13] by C. Chesñevar et al. on modeling inference in argumentation, uses a labelled deductive system to formalize two inference operators. One of these operators model the construction of arguments and the other models the dialectical process of warranting consequences. Several Horn and Non-Horn properties are studied and contrasted achieving an analysis of the satisfiability of them by the two operators.

In [22], N. Gorgiannis and Hunter use classical logic as a basis for instantiating abstract argumentation frameworks, introducing certain properties described as postulates that is desirable that a particular attack relation should satisfy. Additional postulates are provided that permit to obtain certain characterisation results for the attack relations. The authors make a comprehensive study of the status of these postulates considering various combinations of attack relations and extension semantics.

Recently, L. Amgoud presented in [1] a set of postulates for argumentation systems based on deductive logic under Dung’s semantics. The paper considers rationality postulates that these systems should satisfy. Five postulates are introduced: *consistency* and *closure* under the underlying logic’s consequence operator of the set of conclusions of the arguments of each extension; *closure under sub-arguments*; *exhaustiveness of the extensions*; and a *free precedence* postulate ensuring that the formulas of the knowledge base that are not involved in inconsistency are conclusions of arguments in every extension. The author considers the links between the postulates and explores under which conditions the postulates are satisfied or not.

The discussion regarding the observations introduced above is not included in this abstract, but will be addressed in the talk. Argumentative reasoning is by nature defeasible and that distinct feature must have a deep influence on the resulting constraints. We believe that the very essence of argumentation should affect the manner in which the required properties (or postulates) are described. Hopefully, this talk will end with an animated discussion of this important topic.

References

- [1] Leila Amgoud. Postulates for Logic-Based Argumentation Systems. *International Journal of Approximate Reasoning*, Elsevier, 2013 (in press).
- [2] Chitta Baral. *Knowledge Representation, Reasoning and Declarative Problem Solving*. Cambridge University Press, 2003.
- [3] Jonathan Barnes, editor. *The Complete Works of Aristotle, Vol I and II*. Princeton Univ. Press, 1984.
- [4] Trevor J. M. Bench-Capon and Paul E. Dunne. Argumentation in artificial intelligence. *Artificial Intelligence*, 171(10-15):619–641, 2007.
- [5] Philippe Besnard, Alejandro García, Anthony Hunter, Sanjay Modgil, Henry Prakken, Guillermo Simari, and Francesca Toni. Introduction to Structured Argumentation. *Argument & Computation*, 5(1):1–4, 2014.
- [6] Philippe Besnard and Anthony Hunter. A Logic-Based Theory of Deductive Arguments. *Artif. Intell.*, 128(1-2):203–235, 2001.
- [7] Philippe Besnard and Anthony Hunter. *Elements of Argumentation*. MIT Press, Cambridge, MA, 2008.
- [8] Philippe Besnard and Anthony Hunter. Constructing argument graphs with deductive arguments: a tutorial. *Argument & Computation*, 5(1):5–30, 2014.
- [9] Andrei Bondarenko, Phan Minh Dung, Robert A. Kowalski, and Francesca Toni. An abstract, argumentation-theoretic approach to default reasoning. *Artif. Intell.*, 93:63–101, 1997.
- [10] Andrei Bondarenko, Francesca Toni, and Robert A. Kowalski. An assumption-based framework for non-monotonic reasoning. In *Logic Programming and Nonmonotonic Reasoning, Lisbon, Portugal*, pages 171–189. The MIT Press, Boston, MA, 1993.
- [11] Gerhard Brewka, Thomas Eiter, and Mirosław Truszczyński. Answer Set Programming at a Glance. *Commun. ACM*, 54(12):92–103, 2011.
- [12] Martin Caminada and Leila Amgoud. On the Evaluation of Argumentation Formalisms. *Artificial Intelligence*, 171(5-6):286–310, 2007.
- [13] Carlos I. Chesñevar and Guillermo R. Simari. Modelling inference in argumentation through labelled deduction: Formalization and logical properties. *Logica Universalis*, 1(1):93–124, 2007.
- [14] Carlos I. Chesñevar, Ana G. Maguitman, and Ronald P. Loui. Logical models of argument. *ACM Computing Surveys*, 32(4):337–383, 2000.
- [15] B. Jack Copeland. The Church-Turing Thesis. In Edward N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. Fall 2008 edition, 2008.
- [16] Phan M. Dung. On the Acceptability of Arguments and its Fundamental Role in Nonmonotonic Reasoning and Logic Programming. In *Proc. of the 13th. International Joint Conference in Artificial Intelligence (IJCAI), Chambéry, Francia*, pages 321–357, 1993.

- [17] Phan M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning and logic programming and n -person games. *Artificial Intelligence*, 77:321–357, 1995.
- [18] Alejandro J. García. *Programación en Lógica Rebatible: Lenguaje, Semántica Operacional y Paralelismo*. PhD thesis, Dep. de Cs. de la Computación, Universidad Nacional del Sur, December 2000.
- [19] Alejandro J. García and Guillermo R. Simari. Defeasible logic programming: An argumentative approach. *Theory Practice of Logic Programming*, 4(1):95–138, 2004.
- [20] Alejandro J. García and Guillermo R. Simari. Defeasible logic programming: Delp-servers, contextual queries, and explanations for answers. *Argument & Computation*, 5(1):63–88, 2014.
- [21] Michael Gelfond. Answer sets. In F. van Harmelen, V. Lifschitz, and B. Porter, editors, *Handbook of Knowledge Representation*, Foundations of Artificial Intelligence, Ch. 7, pages 285–316. Elsevier, 2008.
- [22] Nikos Gorogiannis and Anthony Hunter. Instantiating abstract argumentation with classical logic arguments: Postulates and properties. *Artif. Intell.*, 175(9-10):1479–1497, 2011.
- [23] Fangzhen Lin and Yoav Shoham. Argument systems: A uniform basis for nonmonotonic reasoning. In *Proceedings of the 1st International Conference on Principles of Knowledge Representation and Reasoning (KR'89)*. Toronto, Canada, pages 245–255. Morgan Kaufmann, 1989.
- [24] Ronald P. Loui. Defeat Among Arguments: A System of Defeasible Inference. *Computational Intelligence*, 3(3), 1987.
- [25] John McCarthy. Circumscription – A Form of Non-monotonic Reasoning. *Artificial Intelligence*, 13:27–39, 171–172, 1980.
- [26] Drew V. McDermott and Jon Doyle. Non-monotonic logic i. *Artif. Intell.*, 13(1-2):41–72, 1980.
- [27] Sanjay Modgil and Henry Prakken. A general account of argumentation with preferences. *Artif. Intell.*, 195:361–397, 2013.
- [28] Sanjay Modgil and Henry Prakken. The aspic+ framework for structured argumentation: a tutorial. *Argument & Computation*, 5(1):31–62, 2014.
- [29] Robert C. Moore. Possible-world semantics for autoepistemic logic. In *Workshop on Nonmonotonic Reasoning, New Paltz, NY*, pages 344–354. AAAI Press (Menlo Park, CA), 1984.
- [30] Allen Newell and Herbert A. Simon. Computer Science as Empirical Inquiry: Symbols and Search. *Commun. ACM*, 19(3):113–126, 1976.
- [31] Donald Nute. Defeasible reasoning: a philosophical analysis in PROLOG. In J. H. Fetzer, editor, *Aspects of Artificial Intelligence*, pages 251–288. Kluwer Academic Pub., 1988.
- [32] Donald Nute. Defeasible logic. In D.M. Gabbay, C.J. Hogger, and J.A. Robinson, editors, *Handbook of Logic in Art. Intelligence and Logic Programming, Vol 3*, pages 355–395. Oxford Univ. Press, 1994.
- [33] John L. Pollock. Defeasible Reasoning. *Cognitive Science*, 11:481–518, 1987.
- [34] John L. Pollock. A general-purpose defeasible reasoner. *Journal of Applied Non-Classical Logics*, 6(1):89–113, 1996.
- [35] Henry Prakken. An abstract framework for argumentation with structured arguments. *Argument & Computation*, 1(2):93–124, 2010.
- [36] Henry Prakken and Gerard Vreeswijk. Logics for defeasible argumentation. In D. Gabbay and F. Guenther, editors, *Handbook of Philosophical Logic*, pages 218–319. Kluwer Academic Pub., Dordrecht, The Netherlands, 2002.
- [37] Iyad Rahwan and Guillermo R. Simari. *Argumentation in Artificial Intelligence*. Springer, Heidelberg, Germany, 2009.
- [38] Raymond Reiter. A Logic for Default Reasoning. *Artificial Intelligence*, 13(1,2):81–132, April 1980.
- [39] Stewart Shapiro. Classical logic. In Edward N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. Winter 2013 edition, 2013.
- [40] Christopher Shields. Aristotle. In Edward N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. Spring 2014 edition, 2014.
- [41] Guillermo R. Simari. *A Mathematical Treatment of Defeasible Reasoning and its Implementation*. PhD thesis, Washington University, Department of Computer Science (Saint Louis, Missouri, EE.UU.), 1989.
- [42] Guillermo R. Simari and Ronald P. Loui. A mathematical treatment of defeasible reasoning and its implementation. *Artificial Intelligence*, 53:125–157, 1992.
- [43] Francesca Toni. A tutorial on assumption-based argumentation. *Argument & Computation*, 5(1):89–117, 2014.
- [44] Alan M. Turing. On Computable Numbers, with an Application to the *Entscheidungsproblem*. *Proceedings of the London Mathematical Society, Series 2*, 43:230–65, 1936–37.