Argumentation Technology

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Abstract

This paper introduces the Special Issue on Argumentation Technologies, with a discussion of the role of argumentation in modern computing, and identification of the challenges which must be met before the widespread deployment of argumentation technologies.

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1 Introduction

With the rise to prominence of the Internet, we are moving to a new understanding of the nature of *computation* [7]. From the times of Leibniz and Babbage until the late 1950s, computation was understood as *calculation*, or the manipulation of numbers. Through the next decade (and still perhaps in the wider world), computation came to be understood as *information processing*, or the manipulation of data. With the rise of artificial intelligence, logic programming and expert systems, the idea arose of computation as *cognition*, or the manipulation of concepts. With the growth of the Internet and the World-Wide-Web, a new metaphor is appropriate: computation as *interaction*, or the joint manipulation of concepts and actions by discrete entities, both human and software agents.

To the extent that such agents are autonomous, then no one agent can impose its will upon another. To the extent that they are intelligent, agents will need to *persuade* one another to adopt particular beliefs or courses of action, or *negotiate* with one another to divide scarce resources between them. Such activities are examples of argument, which we might define as rational, or reason-based, interaction between autonomous and intelligent agents to achieve particular goals. Argumentation, the study of argument, goes back a long time. Aristotle, for example, wrote on the topic around 350 BCE [1], starting a scholarly discourse that continued, with the help of Islamic and Roman Catholic philosophers, through the middle ages down to modern times. The study of argument by Indian philosophers has a similarly-long history.

2 Applications of Computer Argumentation

Applications of argumentation technologies have developed over the last two decades. The first applications were primarily to expert systems and tutorial systems, explaining their

recommendations or decisions [3]. Because of the prominence of medical applications in early expert systems, it was perhaps natural that the main center for the initial development of argumentation technologies was the AI Lab at the Imperial Research Cancer Fund (now Cancer Research UK) in London, UK, Europe's largest cancer charity, founded and led by Professor John Fox. Applications developed there included systems to advise doctors on patient-specific medications, including the arguments for and against each proposed medication; and systems to advise doctors and patients on the diagnostic testing and treatment of breast cancers. These and other medical applications are reviewed in the paper by Fox and colleagues in this volume. It was a short step from these applications to systems undertaking automated argument generation concerning, for example, the toxicity properties of new chemicals, or the possible health and safety risks of some new venture. In the absence of complete or accurate information, argumentation is a means to identify and organize what can be justifiably concluded, and to present it, systematically, to human users or to merge it with the justified conclusions of other machines. The US Government's DARPA-funded Project GENOA was a similar attempt using argumentation to analyze all the information relevant to decision-making during a foreign geopolitical crisis [12].

These first-generation applications typically relied on relatively simple argumentation theories, which is not surprising given that the formal theory of argumentation is still only in its infancy. For the current state of argumentation theory, see the recent reviews by Chesñevar, Maguitman and Loui [5], by Prakken and Vreeswijk [8], and by Bench-Capon and Dunne [2]; this third review introduces a special issue of the journal *Artificial Intelligence* on computational argumentation. A range of technologies are involved in applying argumentation theories to real-world application domains. In addition to technologies to support the representation, elicitation, storage, manipulation and presentation of arguments, technologies and frameworks are needed to generate and consider arguments, to engage in argumentation interactions (with other machines, or with humans), to mediate between arguments, and to resolve them. This special issue of *IEEE Intelligent Systems* contains papers that cover many aspects of these technologies, often focusing on particular application domains.

A total of 18 papers were submitted to this special issue and each was reviewed by three anonymous referees. Eight papers were accepted for inclusion in the special issue, and are introduced below.

Intrinsically, argumentation is a process that takes into account conflicting information. When multiple arguments for and against a particular claim are presented, it is important to reconcile these conflicts and calculate whether a given claim is acceptable. In the first paper of this issue, Dorian Gaertner and Francesca Toni present an algorithm for doing exactly this, in the context of an assumption-based argumentation framework.

The following two papers use argumentation to support various tasks in the medical domain. John Fox and his colleagues discuss the application of argumentation in medical applications at Cancer Research UK. In particular, argumentation is viewed as a means for inspecting and manipulating evidence, and for supporting decision-making. Also in the health domain, Irene Mazzotta and colleagues present a system that aims at persuading users to adopt healthy eating habits. The interesting thing about this work is the incorporation of *emotional* persuasion strategies. These strategies were elicited by analysing a corpus of natural language messages, which highlighted that emotional strategies are employed by human persuaders far more frequently than purely rational ones. Emotional argumentation has received little attention in the literature to-date. But an understanding of emotions in argument is going to be crucial for building systems that argue with humans.

Knowledge-based systems today often require a collaborative effort to engineer formal ontologies describing a domain. One of the central problems in collaborative ontology engineering is the fact that views on how to best describe a domain often conflict. Christoph Tempich and his colleagues present a framework and tools for supporting agreement in ontology engineering discussions. The paper also reports on a number of case studies using these tools.

Recently, there has been increasing work on the semantic annotation of natural language argument (e.g. see Araucaria [10] and ArgDF [9]). This raises the question of how to structure user interaction with this kind of content, especially where multiple annotated arguments are represented by different authors. Chris Reed and Simon Wells offer an interesting approach, in which the user mediates a "virtual discussion" between software agents that represent different viewpoints. The discussion takes place through a dialogue-game protocol, which also enables the user to express his/her own opinion in the process of interacting with the system, thus facilitating further knowledge elicitation.

Argumentation also provides an intuitive and rich metaphor for interaction among distributed autonomous or semi-autonomous entities, such software agents and Web services. Paolo Torroni and his colleagues present the *ArgSCIFF* architecture, which provides a framework for exploiting argumentation as a means for rich and flexible interaction between Web services. The framework relies on an argumentation machinery based on the SCIFF Abductive Logic Programming framework. Jamal Bentahar and colleagues then present another framework, based on Horn theory, for argumentation in Web Services composition. This time, the focus is on enabling Web services to persuade one another to join a community of web services and negotiate the terms of service composition in a peer-to-peer fashion.

Further highlighting the significant potential of argumentation as a means for interaction among services, Pavlos Moraitis and Nikolaos Spanoudakis present a third framework of this kind. This framework aims at addressing the conflicting views on dealing with user impairment in an ambient intelligence context. When a user suffers from a combination of impairments, various assistant-agents engage in argument-based interaction to agree on the user's needs.

3 Challenges

The review paper by Bench-Capon and Dunne [2], mentioned above, provides an excellent outline of the key challenges facing argumentation theory in computer science and artificial intelligence. In addition to the theoretical challenges listed there, significant practical challenges to greater adoption of argumentation methods and systems also exist, some of which will also require prior or simultaneous theoretical development.

We see six key practical challenges. First, frameworks and tools for diagrammatic representation of arguments, and for automated reasoning over such representations, are still in their infancy. Although published work on argument-diagramming dates from Richard Whately's representation of 1836, John Henry Wigmore's legal charts of 1917, and Stephen Toulmin's influential model of argument of 1958, it is only recently that computer scientists have explored this issue. As demonstrated within pure mathematics by euclidean geometry and by category theory, human graphical reasoning over diagrams may involve very sophisticated formal inference; such reasoning over argumentation diagrams will need to be automated if large-scale argumentation systems are to be successfully deployed. See [11] for a recent review of work in this area.

Second, proven argumentation-specific software engineering frameworks, methods and tools for designing and creating argumentation applications do not yet exist. While it may turn out that some combination of standard agent-oriented software engineering (AOSE) methods and knowledge-elicitation and knowledge-engineering methods will prove appropriate for the engineering of argumentation systems, this is by no means obvious *a priori*. To our knowledge, there has been no work in this area. As with the development of AOSE methods and tools (which are themselves still in an early stage of development), this would require a mix of theoretical and practical work, with each aspect informing the other.

The development of an initial standard for the exchange of arguments between machines, the *Argument Interchange Format* (AIF) [4], is a major step towards automated exchange of arguments between intelligent software agents. Following from this work, a

third challenge is to develop a sophisticated understanding of the properties of different agent interaction protocols and communication languages under different circumstances, and a good sense of when to use which protocol or language. This challenge will required considerable work – both theoretical and applied – to answer questions such as: *What protocol should two agents use to undertake a negotiation, for example, and why? Should a negotiation always require the same protocol, or should the protocol depend on the type of negotiation, the number of participants, the nature of the resource or task being allocated, the time allowed, etc?* Associated with the properties of protocols and languages is a need for an understanding of the strategies and tactics appropriate for participants under such protocols. Part of the understanding here will arise from a better semantic understanding of the nature of argumentative interactions between multiple autonomous agents.

Fourth, as with knowledge-engineering in general, in most real-world application domains there is a surfeit of arguments, and hence an argumentation-engineering bottleneck in computational representation of arguments. Solutions to this bottleneck are required if argumentation systems are to be widely deployed and adopted. It may be that the use of user-generated content and content-annotation — such as *folksonomies* in semantic classifications — may provide a solution to this challenge. The development of theoretical and software components that may enable this have commenced [9] building on the AIF and exploiting Semantic Web technologies. It is also likely that the development of domain-specific frameworks, argument inference and tools, as in [13], may assist with this challenge.

Several of the challenges above are part of a larger scalability challenge, which is fifth in our list. If argumentation systems are to provide support, for example, to millions of people engaged in a deliberation about some matter of public policy, considerable work is needed to ensure that applications can scale. Prediction markets provide a means to organize the quantitative views of large numbers of people on some issue, such as the likelihood of a rise in interest rates or the chance of an influenza epidemic; we desire similar systems to organize their arguments and justifications for their views. Finally, the links between argumentation and other disciplines needs attention if argumentation systems are to find a permanent place in the ecosystem of intelligent computer systems. Examples include the relationships between: argumentation and quantitative formalisms for representing uncertainty, such as probability theory and Dempster-Shafer theory; argumentation and game theory, in systems with multiple, competing participants; argumentation and political theory, for example in systems for supporting deliberative democracy; and, argumentation and organization theory, for example in systems to support collaborative work.

4 Conclusion

In addition to much else, Aristotle was also the founder of logic, which is the study of representations of certain kinds of arguments. If he and his colleagues had had to apply for research grant funding, they would not have been able to point to early commercial spin-offs from their research. But spin-offs have eventually arrived. The development of the modern computer has been greatly influenced by developments in formal logic, and conversely [6]. But if logic is the means by which computers think, then argumentation is the means by which intelligent computers interact, both with one another and with humans. We foresee a very bright future for argumentation and argumentation technologies.

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