Group Decision and Negotiation
https://doi.org/10.1007/s10726-021-09738-x

Artificial Intelligence Techniques for Conflict Resolution

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Accepted: 9 April 2021

Abstract

Conflict resolution is essential to obtain cooperation in many scenarios such as politics and business, as well as our day to day life. The importance of conflict resolution has driven research in many fields like anthropology, social science, psychology, mathematics, biology and, more recently, in artificial intelligence. Computer science and artificial intelligence have, in turn, been inspired by theories and techniques from these disciplines, which has led to a variety of computational models and approaches, such as automated negotiation, group decision making, argumentation, preference aggregation, and human-machine interaction. To bring together the different research strands and disciplines in conflict resolution, the Workshop on Conflict Resolution in Decision Making (COREDEMA) was organized. This special issue benefited from the workshop series, and consists of significantly extended and revised selected papers from the ECAI 2016 COREDEMA workshop, as well as completely new contributions.

Keywords Conflict resolution · Agent-based negotiation · Automated negotiation · Argumentation · Game theory

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Published online: 28 May 2021

1 Introduction

Today's world is social and complex in nature. Societies have evolved and many problems faced by individuals can no longer be solved in solitude. We require cooperation with others to pursue our own goals, in many complex scenarios like politics and businesses, as well as in our day to day life. As we all hold different goals and interests, conflict emerges as a natural part of our lives. Successful cooperation requires solving conflicts among interested parties. The importance of conflict resolution has driven research in many fields like social science, anthropology, psychology, mathematics, biology and, more recently, artificial intelligence. Computer science and artificial intelligence have, in turn, been inspired by theories and techniques from these disciplines, which has led to a variety of computational models and approaches, such as automated negotiation, group decision making, argumentation, preference aggregation, and human-machine interaction.

The focus of this special issue is on theoretical and practical computational approaches for solving and understanding conflict resolution using artificial intelligence techniques. More specifically, the focus is on novel studies concerning models and applications of conflict resolution between software entities or *agents*, software agents and humans, and/or humans facilitated by computational models and tools.

There are a variety of challenges in resolving conflicts between (human or software) agents such as uncertainty about other parties, fairness of the outcomes, involvement of self-interested parties, complex preferences, reasoning on the conflicting arguments, repeated interaction, trust, and many others (Baarslag et al. 2017). One of the main approaches for resolving conflicts of interest is through negotiation. Negotiation has become a well-established research field within the area of artificial intelligence and multi-agent systems, where researchers focus on formalization of negotiation process [i.e., creating domain and preference models for the underlying negotiations, and designing protocols governing the interaction between the parties (Marsa-Maestre et al. 2014)] as well as the design of intelligent negotiating agents [i.e., bidding strategies (Baarslag et al. 2015), opponent models (Baarslag et al. 2016), and acceptance strategies (Razeghi et al. 2020)]. To facilitate the research on negotiation, an international competition ANAC (Jonker et al. 2017) has been organized yearly and organizers introduce new challenges each year. For instance, ANAC 2019 introduced five negotiation challenges: automated negotiation with partial preferences, repeated human-agent negotiation, negotiation in supply-chain management, negotiating in the strategic game of Diplomacy, and in the Werewolf game (Aydoğan et al. 2020).

A different but related approach of resolving conflicts in multi-agent systems is through argumentation (Rahwan et al. 2003). Argumentation is typically more expressive and allows for a dialogue to reason about preferences, and is often achieved through use of formal logics (Walton et al. 2019). This multi-disciplinary field of research also organizes an international competition on computational models of argumentation, ICCMA (Thimm et al. 2016) to encourage the development of efficient solvers for argumentation and to provide challenging benchmarks. Both research communities have their own workshops such as ACAN and ArgMAS to share and discuss on their ongoing research in their field.

Another very popular approach for resolving conflicts between self interested agents is through the use of game theory, from the simple ultimatum game, to the alternating offers game pioneered by Rubinstein and others (1982). Since then, game-theoretic negotiation has been extensively researched as a way to resolve conflicts within multi-agent systems. However, as we will see in this special issue, game-theoretic approaches for conflict resolution are not necessarily limited to negotiation, and can be useful e.g. when finding mutually beneficial outcome through trusted third parties.

To bring together the different research strands and disciplines, the Workshop on Conflict Resolution in Decision Making (COREDEMA) was organized. Disciplines, such as the anthropology, psychology, economy, biology, statistics, mathematics, and computer science itself, bring different perspectives on conflict resolution, and different state of-the-art theories and techniques related to artificial intelligence. The workshop particularly emphasized the role of computational models and applications of conflict resolution in relation to decision making and action selection. This special issue benefited from the workshop series, and consists of significantly extended and revised selected papers from the 2nd ECAI Workshop on Conflict Resolution in Decision Making (COREDEMA 2016). The post-proceedings of the workshop were published in Aydoğan et al. (2017). The articles in this special issue use various approaches towards conflict resolution as discussed above, including argumentation, negotiation, and game theory. In the end, 50% of the selected papers were accepted for inclusion in this special issue. On a personal note, we had some set-backs publishing this special issue, especially with the unfortunate passing of Editor-in-Chief Gregory Kersten during the collation of the articles. We would like to take this opportunity to express our appreciation of Gregory for his commitment and contributions to GDN as an editor for 4 years.

With regard to the content of this special issue, the paper *"A Non-Cooperative Game-Theoretic Approach for Conflict Resolution in Multi-Agent Planning"* essentially uses a trusted third parties to decide on a solution which is both fair for all agents, and constitutes a Nash equilibrium, i.e. where no agent has an incentive to deviate from the solution. In more detail, the authors consider a multi-agent planning setting where each agent is responsible for their own part of the plan, but conflicts can arise if agents do not coordinate e.g. due to use of shared resources. This is inspired by the International Planning Competition (IPC). For example, in the the Transport domain, agents need to organise fleets of airplanes to deliver passengers to different destinations. Conflicts arise when agents want to use the same resource (i.e. airplane) at the same time. In this work it is assumed that agents are self-interested, i.e. they wish to maximise their own utility e.g. minimise delays. At the same time, they need to come up with a conflict free solution. Their approach is through a 2-stage non-cooperative game. In the first stage or 'general-sum game', each agent submits their set of possible plans, where a plan consists of a set of actions and their execution order. Then, for each joint plan, the 'scheduler' finds a feasible solution for executing the joint actions by introducing delays. The scheduler finds a feasible outcome (if one exists) which satisfies three criteria. First, the delays should constitute a Nash equilibrium, i.e. there should be no better solution for any individual agent, given the schedule of the other agents. Second, the solution should be Pareto efficient, i.e. there should be no solutions which could be better for some agents and no worse for others. Finally, the schedule should be fair in the egalitarian sense, i.e. the loss of utility due to the delays should be shared amongst the agents as much as possible. The schedule returned by the scheduler is then used to compute the utility for the agents for this schedule. Then, the first-stage 'general-sum' game chooses the joint plans which constitute a Nash equilibrium. They provide two algorithms for computing the scheduling game solution, and evaluate their approach, coined FENOCOP, on variants from the IPC. They conclude that their approach is appropriate for solving the type of planning problems they are considering.

In the paper entitled *"Nonlinear negotiation approaches for complex-network optimization: a study inspired by Wi-Fi channel assignment"*, the authors turn to negotiation to solve the problem of channel assignment in Wi-Fi networks. Wi-Fi networks operate in channels of unlicensed radio-frequency spectrum bands, which can be highly contested and therefore congested. This paper deals with the problem of clients wishing to connect to Wi-Fi access points that are configured in a certain network topology. Each of the many access points has to be assigned the overlapping resource of a frequency channel so that interference is minimized among the network while throughput is maximized. The authors use two advanced automated negotiation techniques: a hill-climbing mediated negotiation and a simulated annealing mediated negotiation. Empirical results show that the simulated annealing mediated negotiation outperforms a baseline particle swarm optimizer in the most complex scenarios under study. This is a natural domain for negotiation, as there are both selfish and common goals at play: each node aims to optimize its connection performance, while coordination is necessary to take into account the global network performance.

Apart from negotiation and game theoretic approaches, argumentation is another way of resolving conflicts as discussed previously. Accordingly, this special issue includes two argumentation-based studies entitled, *"An incremental algorithm for computing the grounded extension of dynamic abstract argumentation frameworks"* and *"Combining social choice theory and argumentation: enabling collective decision making"*. In the former work, Alfano, Greco and Parisi emphasize the dynamicity of the argumentation in practice where some arguments/attacks are added or removed over time, and accordingly propose an incremental algorithm to efficiently compute the grounded argumentation semantics. They report their experimental results showing the superiority of their algorithm by comparing it with one of the fastest solver computing the grounded semantics from scratch, namely CoQuiAAS. In the latter work, Ganzer-Ripoll *et. al* present a target-oriented discussion framework in which participants can make some arguments regarding a debate and express their opinions on the exiting arguments as well as on the outcome of the debate. They propose a novel algorithm using social choice aggregation function to compute the overall opinion and determine the group decision. They provide the analysis of their experiments in order to show the performance of their algorithm when solving a real-world collective decision problem, particularly *Parlement et Citoyens*.

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