The Automated Negotiating Agents Competition, 2010–2015

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■ *The Automated Negotiating Agents Competition is an international event that, since 2010, has contributed to the evaluation and development of new techniques and benchmarks for improving the state of the art in automated multi-issue negotiation. A key objective of the competition has been to analyze and search the design space of negotiating agents for agents that are able to operate effectively across a variety of domains. The competition is a valuable tool for studying important aspects of negotiation including profiles and domains, opponent learning, strategies, and bilateral and multilateral protocols. Two of the challenges that remain are how to develop argumentation-based negotiation agents that, in addition to making offers, can inform and argue to obtain an acceptable agreement for both parties; and how to create agents that can negotiate in a human fashion.*

Negotiation is a common process for resolving conflicts, and the potential for commercial use of automated negotiating agents is high (for example, conflict resolution for frequent problems for companies with hundreds of thousands of clients). Challenges lie in the complexity of the negotiation domain, in the strategies for bidding and accepting, for opponent modeling, and so on. Competitions have proved their value as useful and open benchmarking tools to evaluate and compare agents in a common setting (for example, the successful Annual Computer Poker Competition and the various Trading Agent Competitions). For this reason, we created in 2010 the annual International Automated Negotiating Agents Competition (ANAC) in conjunction with the International Conference on Autonomous Agents and Multiagent Systems (AAMAS) to facilitate research in automated negotiation.

ANAC focuses specifically on the development of successful automated negotiators in realistic environments with incomplete information (Baarslag et al. 2013). The principal goals of the competition include encouraging the design of negotiating agents that can proficiently negotiate in a variety of circumstances using different learning and adaptation strategies, objectively evaluating different negotiation strategies, building a community to push forward the state of the

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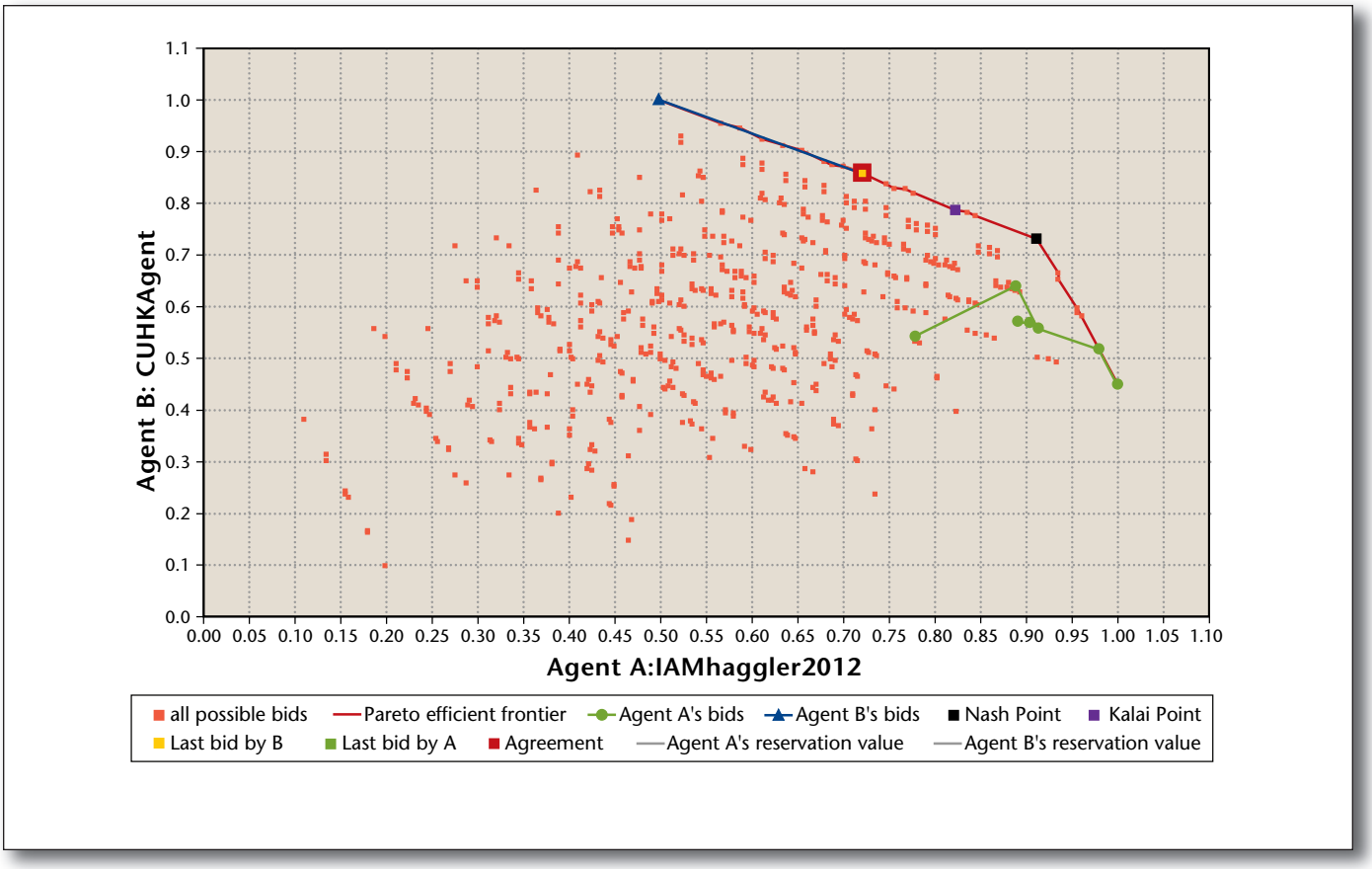

Figure 1. A Negotiation Session Conducted Between Two ANAC Agents in Genius.

The points represent all of the outcomes that are possible in the scenario. The solid line is the Pareto efficient frontier, which connects all of the win-win outcomes.

art in the development of automated negotiators and negotiation scenarios, and making them available as standardized negotiation benchmarks.

The ANAC competition applies the negotiation platform Genius (Lin et al. 2014), which allows easy development and integration of existing negotiating agents. In this simulation environment, agents exchange offers to reach an agreement in various negotiation scenarios. With Genius, individual negotiation sessions can be simulated, as well as tournaments between negotiating agents (figure 1).

Six Years of ANAC Competitions

The first ANAC competition was in 2010 and started as a jointly organized competition between Delft University of Technology and Bar-Ilan University (Baarslag et al. 2012). After that, the local organization rotated between various international institutions. In 2011, ANAC was organized by 2010 winner Nagoya Institute of Technology. Subsequent competitions were organized by University of Southampton (2012), Ben Gurion University of the Negev (2013), Nagoya Institute of Technology and Tokyo University of Agriculture and Technology (2014), and Delft University of Technology (2015). Every competition has seen a growing number of participants: ANAC 2010 started with 7 teams from five different universities (Baarslag et al. 2012); by 2015, it featured 24 teams from nine universities.

Every year, new features are incorporated into the competition environment to increase realism and to encourage the development of flexible and practical negotiation agents (Baarslag 2014). After every ANAC, the participating teams have a closing discussion at AAMAS, yielding valuable suggestions for improving the design and introducing small innovations and challenges. Since 2010, the rules have included deals perishing over time (2011), outside options (2012), learning over multiple domains (2013), large and complex negotiations (2014), and multiparty negotiation (2015). Each year between $1000 and $2000 is awarded, with separate prizes for individual utility (that is, how good the deals are for the agent) and joint utility (that is, the social welfare emerging from the deal).

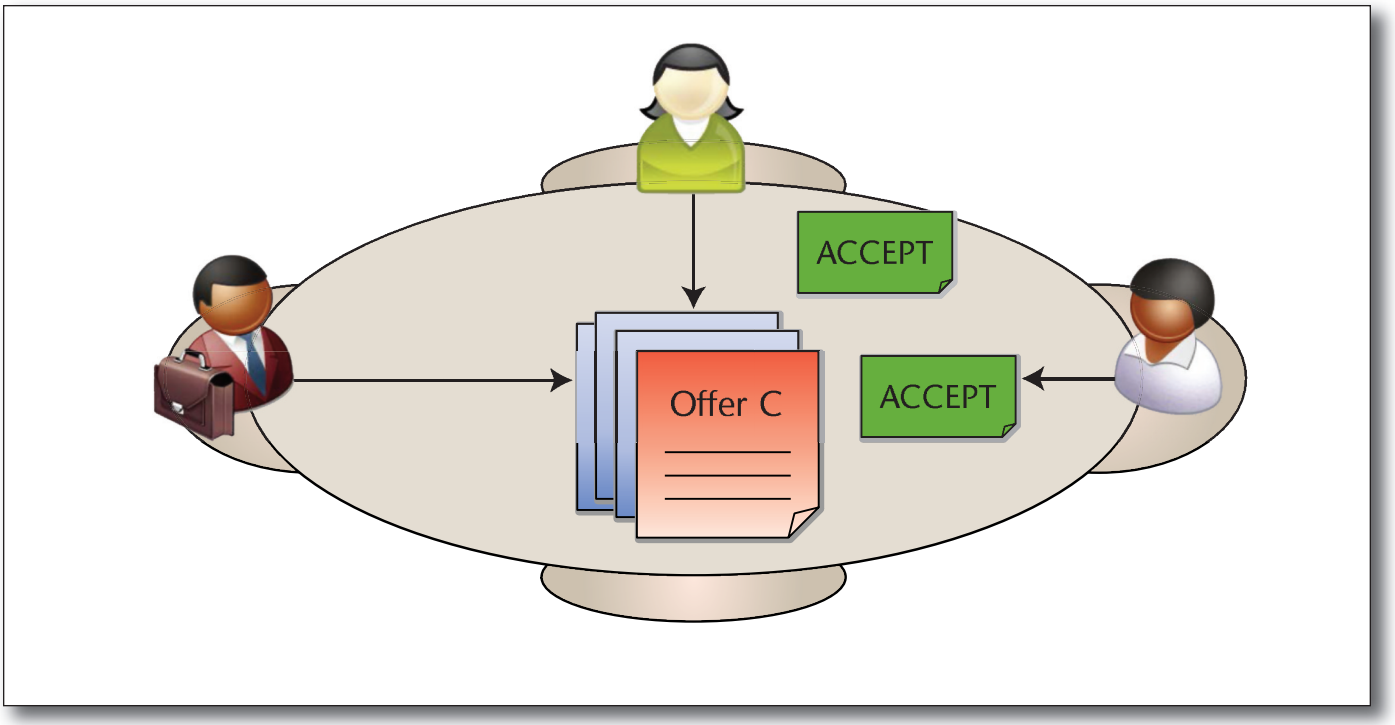

Figure. 2. Agents Can Place Offers on the Negotiation Table, Which Can Be Accepted or Rejected by the Other Parties.

Lessons Learned

The primary challenge in ANAC is to design and implement an intelligent agent that can facilitate multi-issue negotiation under uncertainty as to the opponent's preferences and strategy (figure 2). Through the competitions we learned that there is no single agent strategy that outperforms all other strategies over all possible negotiation scenarios. Some agent strategies are strong in a particular negotiation scenario and are weaker in other scenarios. Influencers of the performance of negotiation strategies are, among others, the size of the negotiation domain, the degree of competitiveness of the scenario, and the opponent strategy. Furthermore, if domain knowledge is available to the agent, that also improves the effectiveness of the agent.

Because the incentive is to win the competition, each year, more adaptive agents have entered the competition. Those agents take their opponent's strategy or opponent's preferences into account. A variety of machine-learning techniques such as Gaussian process regression, Bayesian classifiers, and so on have been applied to predict their opponent's concession or preferences. We also learned that in automated negotiations, given that human emotions don't play a role, it does not pay to be too nice, as nice agents will be exploited by noncooperative agents. For instance, Gahboninho introduced a new adaptive aspect — a metalearning strategy that aims to learn whether or not the opponent is adaptive to its opponent (that is, is a teacher or learner) and to exploit it accordingly (Baarslag et al. 2013). Furthermore, the winner strategy in ANAC 2012, CUHK, tries to avoid exploitation by its opponent while trying to maximize the acceptability of the current proposal by employing a reinforcement-learning-based approach (Hao and Leung 2014).

The Future of ANAC

The ANAC competition of May 2016, to be held in conjunction with AAMAS 2016 in Singapore, is expected to focus on multiparty negotiation under more complex situations. Part of the complexity comes from the nonlinear utility functions and learning over multiple domains, and dealing with those aspects are challenges of ANAC 2016. In future ANAC competitions we anticipate having one-to-many competitions (marketplaces or housing), mediator-based competitions, argumentation-based negotiations, and human-agent competitions. Through these types of competitions, we can focus on the specific domain for conflict resolution, such as the energy market, and the telecommunication business. News of ANAC can be found on the ANAC webpage.[1]

Acknowledgements

ANAC would not have been possible without all research teams who have participated in ANAC over the years. We thank them for their efforts in further-

ing the art and science of automated negotiation. We have thoroughly enjoyed their presence in the competition and their joint effort makes the ANAC competitions stimulating and highly challenging in research. We also would like to thank AAMAS and our sponsors over the years.

Note

1. ii.tudelft.nl/anac.

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Catholijn Jonker (1967) is head of the department of Design Engineering of the Faculty of Industrial Design and full professor of interactive intelligence at the Faculty of Electrical Engineering, Mathematics, and Computer Science of the Delft University of Technology. Jonker studied computer science, and did her Ph.D. studies at Utrecht University. After a postdoctoral position in Bern, Switzerland, she became assistant (later associate) professor at the Department of Artificial Intelligence of the Vrije Universiteit Amsterdam. From September 2004 until September 2006 she was a full professor of artificial intelligence and cognitive science at the Nijmegen Institute of Cognition and Information of the Radboud University Nijmegen. She chaired the De Jonge Akademie (Young Academy) of the KNAW (The Royal Netherlands Society of Arts and Sciences) in 2005 and 2006, and she was a member of the same organization from 2005 to 2010. She is a member of the Koninklijke Hollandsche Maarschappij der Wetenschappen. Since 2012 she has been a member of the Academia Europaea. She has been the president of the National Network of Female Professors (LNVH) in the Netherlands since September 2013. In 2015 she was selected as ECCAI Fellow. Her publications address cognitive processes and concepts such as trust, negotiation, teamwork, and the dynamics of individual agents and organizations. In Delft she works with an interdisciplinary team to create synergy between humans and technology by understanding, shaping, and using fundamentals of intelligence and interaction.