Guest Editorial Special Issue on Team AI in Games

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I. Introduction

RECENT years were marked by significant achievements of game artificial intelligence (AI) systems. Computer-controlled players excel in a wide range of environments, from traditional board games, like chess and *Go*, to fast arcade environments like *Super Mario Bros*. and one versus one fighting. One of the topical issues of today's research efforts aims at intelligent team behavior, relevant for a wide variety of games, including real-time strategy games, team sports, multiplayer online battle arena (MOBA), and even tabletop games like *Hanabi*. The notion of team behavior is very rich, ranging from the ability to exhibit a clear and consistent strategy of an AI-controlled team to the capability of "melting into" a group of human-controlled teammates and supporting their coordinated actions. Consequently, design goals of an AI system can be driven by a variety of considerations, including efficiency, creativity, believability, synergism, and contribution of the AI to the overall entertainment value of the game. There is also an imminent connection to artificial general intelligence, because distributed AIs have to be quite adaptive to new situations, including being confronted with other AIs that switch their behavior.

We chose the term "team AI" to describe the focus of this Special Issue, being aware that there are currently many related terms expressing similar ideas, as cooperative AI, human-centered AI, computer-supported cooperative work, and more. All these revolve around the challenges of AIs and humans working together. We would by no means argue that humans and AIs usually act in comparable ways. However, it is our impression that current AIs already largely fail at the aforementioned problem of adapting to the collaboration with previously unseen AIs. In famous recent successes of AI agents for team games, e.g., OpenAI Five for *DotA* 2, a well-known MOBA game, the human competitive bot team has been trained together, and integrating them into human teams later proved to be difficult. It seems that collaboration with humans who generally prefer many different ways of approaching the same problem is probably even harder than adapting to other AIs. However, in both cases, we have AIs that have to be able to interact meaningfully and collaborate with new intelligent agents they have not been trained to work with. Eventually, they have to act as a team to be successful, and that is what we try to express with the term "team AI."

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II. Summary of Contributions

For this special issue, we selected seven articles that reflect the landscape of today's team AI research: two articles discuss the game of soccer, and three articles analyze MOBA games. Other topics of interest include *Hanabi* and *Geometry Friends*, a game specifically designed as a vehicle for cooperative AI research.

The article "AI World Cup: Robot-soccer-based competitions" by Hong *et al.* introduces competitions organized within a framework of "AI World Cup," a recent soccer-based environment. AI World Cup departs from established events, such as RoboCup, by offering a somewhat simpler soccer setting, designed for low-threshold entry of new teams. The participants can focus on high-level decision-making, whereas low-level technical issues are handled by the system. AI World Cup also implements related challenges of "AI Reporter" and "AI Commentator," where the participants have to create methods for textual commentary and summary of soccer matches.

Antonioni *et al.* in their article "Game strategies for physical robot soccer players: A survey" focus on the challenges arising in RoboCup leagues featuring hardware robots. They provide a comprehensive survey of the current literature and examine how approaches to designing hardware and software robots differ nowadays, as well as which methods are used to make strategic decisions. This survey is a convenient starting point to understand the current state of the art in RoboCup, and identify the set of problems commonly examined in literature.

MOBA games can serve both as a challenging testbed for team AI decision-making systems, and as an online world where people meet and cooperate. Thus, the environments of games such as *DotA 2* can be used to study various aspects of human behavior. In "The influence of social ties on performance in team-based online games," Zeng *et al.* investigate the impact of social links between the players on their engagement and performance. The authors use a large dataset of *DotA 2* matches to show that players are more engaged when playing with friends, but friendly in-group cooperation may have negative impact on team performance in general.

The article "Win prediction in multiplayer Esports: Live professional match prediction" by Hodge *et al.* provides a literature review of methods of win prediction in *DotA 2*. The general goal of such algorithms is to identify a likely winner of a current match by observing its ongoing progress. The authors also describe an algorithm of their own design, based on standard machine learning and feature engineering methods.

Gourdeau and Archambault, in their article "Discriminative neural network for hero selection in professional *Heroes of the Storm* and DOTA 2," address one particular problem within

MOBA games: hero selection. Prior to the start of the game, the players have to perform "drafting" by alternately choosing game characters for their team. The authors show how a neural network can be used to automate this drafting phase and create a strong and balanced team, which can provide a noticeable advantage in a match.

An interesting take on playing *Hanabi* is provided in the article by Eger *et al.* "Operationalizing intentionality to play *Hanabi* with human players." A popular card-based cooperative game, *Hanabi* restricts possible ways of player–player communication, still leaving room for hidden information exchange. The authors propose an AI agent able to cooperate with human players, and to provide and interpret subtle hints using action timing. The article describes several versions of the proposed method and evaluates its performance.

Finally, the article "A game AI competition to foster collaborative AI research and development" by Salta *et al.* discusses the current state of *Geometry Friends* Game AI Competition. *Geometry Friends* is a physics-based puzzle game, requiring two characters of different abilities to cooperate in order to complete each level. The game has been used as a competitive platform since 2013, and a number of solutions have been proposed so far. The authors describe a variety of challenges arising in the game as well as the methods used to address them, and argue that *Geometry Friends* has a potential to incorporate more challenges and continue to serve as a valuable collaborative AI research environment.

III. Conclusion

This special issue of IEEE Transactions on Games showcases the diversity of problems considered relevant to team AI by the research community. Originally centered around the tasks related to "team behavior," the issue now includes works also dealing with assessment of human in-game behavior, teammate selection, and implicit player–player communication. We thank and praise the willingness of researchers to invest effort into creating new competitive research platforms and to extend the scope of possible tasks for AI systems.

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He is currently an Associate Professor with the University of Aizu, Aizuwakamatsu, Japan. He has a solid academic record of authoring or coauthoring more than 70 published articles and industrial-level software development experience. He is a co-founder of Helium9 Games company. His main research interests include natural language processing and artificial intelligence for computer games, and his current research is focused on how to apply machine learning technologies to the task of practical game AI creation.

Mike Preuss received the Ph.D. degree from TU Dortmund University, Dortmund, Germany, in 2013.

He is currently an Assistant Professor with Leiden University, Leiden, The Netherlands, and Member of the ERCIS network. Previously, he was with the Information Systems and Statistics Group, University of Münster, Münster, Germany. He believes that many game AI methods can be applied successfully in applied sciences, and that a large part of future AI developments will focus on AI/AI and AI/human cooperation, something that could be called *team AI*. His research interests include game AI, evolutionary algorithms for real-valued problems, especially niching methods, and social media computing.

Rafael Bidarra graduated in electronics engineering from the University of Coimbra, Portugal, in 1987, and received the Ph.D. degree in computer science from the Delft University of Technology, Delft, The Netherlands, in 1999.

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