Guest Editorial: Physics-Based Simulation Games

I. Introduction

Physics-based simulation games (PBSGs) such as *Angry Birds, Cut the Rope, Gears*, or *Feed Me Oil* have become increasingly popular in recent years with the wide availability of touchscreen devices. These games are based on a physics simulator that has complete information about all the physical properties of all game objects and the game world. As such, each move and its consequences can be exactly simulated and displayed, which makes the physical behavior of the game appear quite realistic. These games are easy to play as the possible moves are simple. What makes these games particularly hard and challenging for AI is that the number of possible moves can be very large and effectively infinite, and that the consequences of moves are unknown in advance. The large number of moves is due to the effect of the exact location and/or timing of moves, where small changes may result in differences in the outcome of the physics simulation. Often, noise is added to the simulator to make these games more challenging. Without actually simulating a move, its outcome is very hard to predict. It becomes even harder if the exact physical properties of the objects or the behavior of the simulator are unknown for the AI beforehand and have to be learned through observation. The task of an AI agent is not only to predict the outcome of an individual move, but to identify a move that achieves the desired outcome.

Playing these games as well as or better than the best human players requires a successful AI agent to solve a number of challenging problems from different areas of AI. The impact of successful solutions to these problems goes way beyond games and will be an essential feature of intelligent agents that interact with the physical world.

In this special issue, we focus on AI for specific PBSGs competitions such as *Angry Birds* and computational pool, as well as on further developments of physics simulators in order to launch the next generation of PBSGs. The nine papers accepted for publication in this special issue investigate these aspects. The aim of this special issue is to provide a snapshot of current work in PBSGs and to identify future research.

II. *Angry Birds*

Angry Birds is the most popular of PBSGs. The *Angry Birds* AI Competition (aibirds.org) was initiated by J. Renz in 2012 and has been held annually ever since. AI agents only obtain screenshots of the live game and have to use computer vision to detect all relevant objects. This adds to the difficulty of selecting good actions and to determine their consequences, as it is not possible to obtain exact physical parameters of the game objects. On the other hand, it makes the AI gameplay very human-like as the agents get exactly the same information humans get when playing the game. It is the declared goal of the competition to build AI agents that are better than the best human players on new game levels. In order to test if the goal has been reached, each AI competition is followed by a Human versus Machine Challenge where humans and AI agents compete on the same new game levels. While AI agents are improving every year, so far humans always won the challenge. Therefore, the AI challenge to build an agent who can beat humans is still wide open and offers participants an exciting and competitive domain to develop AI techniques that can successfully deal with physical environments.

Five papers in this special issue resulted from AI agents who participated in the AIBIRDS competition in the past and describe the specific methods and techniques they used to build a successful agent. As can be seen, a wide variety of techniques have been used, ranging from machine learning, heuristic search, advanced simulations, qualitative reasoning to knowledge representation, and combinations thereof.

In their paper "A Bayesian ensemble regression framework on the *Angry Birds* game," Tziortziotis *et al.* present an agent that employs a Bayesian ensemble inference mechanism to promote decision making abilities. It is based on an efficient tree-like structure for encoding and representing game screenshots, which translates the task of game playing into a regression analysis problem. A Bayesian ensemble regression framework is presented by considering that every combination of objects material and bird type has its own regression model, which is then trained using an efficient online learning procedure. Action selection is modeled as a multiarmed bandit problem.

In "AKBABA—An agent for the *Angry Birds* AI Challenge based on search and simulation," Schiffer *et al.* present their agent AKBABA that uses search and simulation to find appropriate parameters for launching birds. Their agent combines simulation and adjustable abstractions to efficiently traverse the possibly infinite search space. It features a hierarchical search scheme where different levels of abstractions are used. Simulation is used to rate subspaces that should be further explored in more detail.

"Angry-HEX: An artificial player for *Angry Birds* based on declarative knowledge bases" by Calimeri *et al.* presents an agent that is based on a combination of traditional imperative programming and declarative programming for modelling discrete knowledge about the game and the current situation. The agent makes use of HEX programs, which are an extension of answer set programming (ASP) programs toward the integration of external computation sources, such as 2-D physics simulation tools.

In "s-birds Avengers: A dynamic heuristic engine-based agent for the *Angry Birds* problem," Dasgupta *et al.* use heuristic

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techniques to analyze unseen game structures. Their agent aims to discover vulnerable points in game structures using a prior parameter learning training algorithm. This is then used to decide where to hit the structure with the birds.

The agent presented in "Qualitative physics in *Angry Birds*" by Wałęga *et al.* uses a qualitative spatial representation to model game levels. Different models of impact are studied. One model predicts which elements of a structure fall if a supporting block gets destroyed. Another model simulates force propagation between adjacent elements after one of them gets struck. Experiments demonstrate that the physical consequences are correctly predicted in a large number of cases.

A sixth related paper deals with the computer vision problem of automatically identifying objects in video games without having hardcoded or learned them in advance. The paper "Visual detection of unknown objects in video games using qualitative stability analysis" by Ge *et al.* proposes a method based on integrating stability analysis with computer vision to assist in detecting unknown objects in video games. It managed to detect all *Angry Birds* objects by only hardcoding the pigs, and was also tested successfully with other games.

III. Physics Simulators

In "PEARS: Physics extension and representation through semantics," Eckstein *et al.* present an alternative approach to purely numerical physics simulation. They use a semantic representation of physical properties and processes as well as a reasoning engine to model cause and effect between objects, based on their material properties. The proposed system applies high-level state descriptions to low-level value changes, which are directly mapped to a graphical representation of a physical scene. The ability to support multiple complex, causally connected physical, and chemical processes is demonstrated by simulating a Goldberg machine.

IV. Computational Pool

Computational Pool can be regarded as the classic PBSG. It was one of the first domains where a competition was organized to foster research in the area of PBSGs. M. Greenspan initiated the first tournament at the ICGA Computer Olympiad in 2005. It was followed by two other tournaments at the Olympiads of 2006 and 2008, attracting six different competitors in the process.

In "A distributed agent for computational pool," Archibald *et al.* present their agent CueCard, winner of the last edition of the pool tournament. The article discusses the CueCard's distributed architecture, designed for being able to grant further time for shot simulation and analysis through the utilization of many CPUs. An analysis of the distributed component of the agent is given, as well as how much the extra planning time obtained contributed to its success.

In their article "A straight approach to planning for *14.1 Billiards*," Landry *et al.* introduce *Straight Billiards*, a variant of the previous computational pool tournament. For this game, the planning of a sequence of shots is slightly different and the exchange of safety shots during the game is of a greater importance. The key components for an agent here are optimal control and planning. The authors present a new model for the optimal control of the cue ball to break clusters in between games, as well as a model for the execution of defensive shots. Next, they propose a planning approach to select the sequence of balls to pocket on the table.

Jochen Renz
Research School of Computer Science
Australian National University
Canberra, ACT 2601 Australia
jochen.renz@anu.edu.au

Risto Miikkulainen, *Fellow, IEEE*
Department of Computer Sciences
The University of Texas at Austin
Austin, TX 78712 USA
risto@cs.utexas.edu

Nathan Sturtevant
Department of Computer Sciences
University of Denver
Denver, CO 80208 USA
sturtevant@cs.du.edu

Mark H.M. Winands
Department of Data Science and
Knowledge Engineering,
Maastricht University
Maastricht, The Netherlands
m.winands@maastrichtuniversity.nl

Jochen Renz received the Ph.D. degree in Artificial Intelligence from the University of Freiburg, Freiburg im Breisgau, Germany, in 2000 and the Habilitation degree in Information Systems from the Vienna University of Technology, Wien, Austria, in 2003.

He is a Professor in the Research School of Computer Science, Australian National University (ANU) Canberra, ACT, Australia, and the Head of the ANU Artificial Intelligence group. His main research interests include qualitative spatial reasoning, both its theoretical foundations and its applications. He initiated the *Angry Birds* AI competition in 2012 as a testbed for developing and integrating different AI technologies.

Risto Miikkulainen (F'16) received the M.S. degree in engineering from the Helsinki University of Technology, Finland, in 1986 and the Ph.D. degree in computer science from University of California, Los Angeles, CA, USA, in 1990.

He is a Professor of Computer Science at the University of Texas at Austin, Austin, TX, USA and a Fellow at Sentient Technologies, Inc., San Francisco, CA, USA. His current research interests include methods and applications of neuroevolution, as well as neural network models of natural language processing, and self-organization of the visual cortex.

Dr. Miikkulainen is a Member of the Board of Governors of the Neural Network Society, and an Action Editor of *Cognitive Systems Research* and the IEEE Transactions on Computational Intelligence and AI in Games.

Nathan R. Sturtevant received the M.S. and Ph.D. degrees in computer science from the University of California, Los Angeles, CA, USA, in 2000 and 2003, respectively.

He is an Associate Professor in the Computer Science Department at the University of Denver, Denver, CO, USA. His scientific research interests include artificial intelligence and search in single-agent and multiagent settings, including applications to real-time environments, such as games, and more competitive environments. He runs the Grid-Based Pathfinding Competition (GPPC) and his research was implemented in the commercial game *Dragon Age: Origins*.

Mark H. M. Winands received the Ph.D. degree in artificial intelligence from the Department of Computer Science, Maastricht University, The Netherlands, in 2004.

He is currently an Assistant Professor at the Department of Data Science & Knowledge Engineering, Maastricht University, Maastricht, The Netherlands. His research interests include heuristic search, machine learning, and games.

Dr. Winands is a Section Editor of the *ICGA Journal*, Editor of *Games & Puzzle Design*, and an Associate Editor of the IEEE Transactions on Computational Intelligence and AI in Games.