

hendrik baier

artificial intelligence researcher

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research interests

I am fascinated by *artificial intelligence* and *games*.

Decision making is a basic activity in our lives, and an essential feature of intelligent autonomous agents. I am interested in creating agents that are able to succeed in a wide range of complex decision-making tasks, in order to help human users solve real-world problems. To achieve this, my research focuses on *planning*, required for acting towards long-term goals; on *learning*, required for acting in unknown environments; and on the *explainability* of planning and learning, required for successful human-AI collaboration.

In order to tackle these challenges, I use the unifying framework of reinforcement learning – of learning by trial and error – and aim at pushing its boundaries in a variety of traditional and digital games as testbeds, as well as transferring game AI technology to non-game domains in collaborative projects with industry.

research experience

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|----------------|---|-----------------------------|
| 2018 – present | Centrum Wiskunde & Informatica
<i>Researcher</i>
Intelligent and Autonomous Systems Group
In collaboration with industry, taking a leading role in applying AI and machine learning to the optimal management of energy producers and consumers on future energy markets with an increasing share of renewable energy; developing a related research vision for explainable search-based AI | Amsterdam, The Netherlands |
| 2016 – 2018 | University of York
<i>Research associate in artificial intelligence and data analytics</i>
Digital Creativity Labs
Explored the integration of search algorithms and machine learning in increasingly complex commercial video games; explored ethical and societal issues around AI in interdisciplinary workshops | York, United Kingdom |
| 2015 – 2016 | European Space Agency
<i>Research fellow in artificial intelligence</i>
Advanced Concepts Team
Worked on “blue sky” research with potential future impact for the space sector, as well as serving as an internal science consultant for the European Space Research and Technology Centre | Noordwijk, The Netherlands |
| 2010 – 2015 | Maastricht University
<i>Ph.D. researcher</i>
Department of Knowledge Engineering
Improved sequential decision making based on Monte Carlo Tree Search both in adversarial as well as single-agent environments | Maastricht, The Netherlands |

education

2007 – 2010	M.Sc. Cognitive Science Grade: “excellent with distinction” Specialization: artificial intelligence and linguistics Thesis title: “Adaptive Playout Policies for Monte-Carlo Go”	Universität Osnabrück, Germany
2006 – 2007	Linguistics	Universität Leipzig, Germany
2001 – 2006	B.Sc. Computer Science Grade: “very good”, ranked top 2% Thesis title: “Der Alpha-Beta-Algorithmus und Erweiterungen bei Vier Gewinnt”	Technische Universität Darmstadt, Germany
1990 – 2000	Gymnasium (secondary school) GPA (German): 1.0, ranked second out of 128	Leibniz-Gymnasium, Offenbach, Germany

teaching experience

2021	Utrecht University <i>Guest lecturer</i> Taught introductory class on reinforcement learning in games	Utrecht, The Netherlands
2017	Lancaster University <i>Workshop instructor</i> “AI - the Right to Explanation and Consent” at the PACTMAN workshop (academic audience)	Lancaster, United Kingdom
2017	University of York <i>Workshop instructor</i> “Decision-making AI for Games” at the GamesLab Emerging Tech workshop (industry audience)	York, United Kingdom
2017	University of York <i>Workshop assistant</i> “Machine Learning for Game AI” at the iGGI 2017 conference (Ph.D. student audience)	York, United Kingdom
2013 – 2014	Maastricht University <i>Teaching assistant in computer science</i> Taught “skills class LaTeX” for undergraduates	Maastricht, The Netherlands
2011 – 2013	Maastricht University <i>Teaching assistant in computer science</i> Taught data structures and algorithms for undergraduates	Maastricht, The Netherlands
2009 – 2010	IDF Language School <i>English teacher</i> Taught grammar and conversational courses for individuals and groups	Osnabrück, Germany
2005	Technische Universität Darmstadt <i>Teaching assistant in mathematics</i> Taught introduction to logic for second-year students	Darmstadt, Germany
2004	Technische Universität Darmstadt <i>Teaching assistant in computer science</i> Taught introduction to programming for first-year students	Darmstadt, Germany

supervision experience

2021	Centrum Wiskunde & Informatica <i>MSc co-supervisor</i> Daniele Foffano, “Learning and Planning in Combinatorial Action Spaces”	Amsterdam, The Netherlands
2021	Centrum Wiskunde & Informatica <i>MSc co-supervisor</i> Obada Aljabasini, “Planning with Opponent Models”	Amsterdam, The Netherlands
2021	Centrum Wiskunde & Informatica <i>MSc co-supervisor</i> Bart van Laatum, “Real-time Decision Making in Continuous Spaces”	Amsterdam, The Netherlands
2020	Centrum Wiskunde & Informatica <i>MSc co-supervisor</i> Sorin Dragan, “Value Estimation in MCTS Negotiation”	Amsterdam, The Netherlands
2020	Centrum Wiskunde & Informatica <i>PhD internship supervisor</i> Daniel Hernandez, “Opponent Modelling in Expert Iteration”	Amsterdam, The Netherlands
2019	Centrum Wiskunde & Informatica <i>MSc internship supervisor</i> Daniel Willemsen, “Value Targets in AlphaZero”	Amsterdam, The Netherlands
2018	Queen Mary University of London <i>External Ph.D. supervisor</i> Raluca Gaina, “Rolling Horizon Evolutionary Algorithm Improvements for General Video Game Playing in Single and Multi-Player Games”	London, United Kingdom
2017 – 2018	University of York <i>Ph.D. co-supervisor</i> Daniel Hernandez, “Multi-Agent Reinforcement Learning for Game AI and Robotic Control”	York, United Kingdom
2017 – 2018	University of York <i>Ph.D. co-supervisor</i> Peter York, “Applying Tree Search and Reinforcement Learning to Competitive and Human-Like MOBA AI”	York, United Kingdom
2016 – 2018	University of York <i>Ph.D. co-supervisor</i> Adam Sattaur, “The Use of Gameplay Data to Inform High-Level AI Decision Making”	York, United Kingdom
2017	University of York <i>Digital Creativity Labs Summer School co-supervisor</i> Joseph Hesketh, Jonathan Levinkind, David Vaughan-Jackson, “Decision Making AI for Games”	York, United Kingdom
2013	Maastricht University <i>B.Sc. supervisor</i> Jonathan Brouwers, “Monte Carlo Tree Search in Connect Four”	Maastricht, The Netherlands

admin experience

2013 – 2015	Department of Knowledge Engineering <i>Ph.D. coordinator</i>	Maastricht, The Netherlands
	Supported and represented Ph.D. students at the department level	
2011 – 2015	Ph.D. Academy of Maastricht University <i>Member, from 2013 board member, in 2014 chair of Ph.D. Academy</i>	Maastricht, The Netherlands
	Organized social, cultural and academic events for Ph.D. students; funded by Maastricht University	
2013 – 2014	University Council <i>Co-founder of a group representing Ph.D. researchers</i>	Maastricht, The Netherlands
	Elected as one of six representatives of scientific staff in the University Council of Maastricht University	

invited talks and research visits

2019	Queen Mary University of London	London, United Kingdom
	Talk at the game AI group seminar: “Evolutionary MCTS in Game AI and the ‘Real World’”	
2017	University of York	York, United Kingdom
	Talk at the AI group seminar: “Monte-Carlo Tree Search Enhancements in One-Player and Two-Player Domains”	
2017	University of Essex	Colchester, United Kingdom
	Talk at the School of Computer Science and Electronic Engineering seminar: “MCTS for Decision-making in Games”	
2016	New York University Tandon School of Engineering	New York City, NY, USA
	Talk at the NYU Game Innovation Lab seminar: “A Rollout-Based Search Algorithm Unifying MCTS and Alpha-Beta”	
2013	University of Alberta	Edmonton, Canada
	Talk at the AI group seminar: “Monte-Carlo Tree Search and Minimax Hybrids”	
2012	Reykjavik University	Reykjavik, Iceland
	Research visit to the Center for Analysis and Design of Intelligent Agents; funded by the Netherlands Organisation for Scientific Research (NWO)	

impact and engagement

2018	Pint of Science Festival	York, United Kingdom
	Talk about artificial intelligence and games at the “To the future... and beyond” session	
2017	Yorkshire Games Festival	Bradford, United Kingdom
	Talk about artificial intelligence and games at the “Lates: Gaming” session at the National Science and Media Museum	
2017	Science out of the Lab	York, United Kingdom
	Organized the activities of the Digital Creativity Labs at a science outreach event as part of the “York Festival of Ideas”; reached about 2000 members of the public	

2016	ESTEC Open Day Co-organized the activities of the Advanced Concepts Team at the open day of the European Space Research and Technology Centre; reached about 9000 members of the public	Noordwijk, The Netherlands
2013	Career Day Informed students on academic careers at the Department of Knowledge Engineering's career information day, Maastricht University	Maastricht, The Netherlands
2012	DKE Open Day Represented the game AI group at the Department of Knowledge Engineering's open day, Maastricht University	Maastricht, The Netherlands

other activities

2011 – present	Professional Service <i>Program committee member</i> for conferences and workshops in the field of game AI, such as the IEEE Conference on Computational Intelligence and Games, the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment, the International Conference on the Foundations of Digital Games, the Computer Games Workshop at the International Joint Conference on Artificial Intelligence, and the International Conference on Advances in Computer Games. <i>Reviewer</i> for publications and conferences in the fields of game AI, general AI and related fields, such as the International Joint Conference on Artificial Intelligence, the European Conference on Artificial Intelligence, the Journal of Autonomous Agents and Multi-Agent Systems, Theoretical Computer Science, Engineering Optimization, the IEEE Transactions on Games, and the ICGA Journal.	
2017-2018	IEEE Conference on Computational Intelligence in Games 2017 and 2018 <i>Co-Organizer</i> of Text-Based Adventure AI Competition	New York, NY, USA/Maastricht, The Netherlands
2017	CHERISH-DE initiative of the EPSRC <i>Participant</i> of Digital Economy Crucible, a seven-day development program for young academics	Swansea/Edinburgh/London, United Kingdom
2013	Artificial Intelligence and Interactive Digital Entertainment Conference 2012 <i>Participant</i> of AIIDE Doctoral Consortium	Stanford, CA, USA
2008 – 2012	Interdisciplinary College Spring School <i>Participant</i> in courses on artificial intelligence, cognitive science, and related topics	Günne, Germany
2006 – present	Mensa Germany <i>Member; instructor</i> "Time Management and Productivity Methods" at MinD Academy 2008	

awards and funding

2017	£5000 Digital Economy Crucible "Research Priming" Award <i>Co-Investigator and workshop organizer</i> Project title: "Building Trust in AI – Designing for Consent"	
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publications

journal articles

Value Targets in Off-policy AlphaZero: A New Greedy Backup

D. Willemsen, H. Baier, M. Kaisers
Neural Computing and Applications. Accepted.

The Text-Based Adventure AI Competition

T. Atkinson, H. Baier, T. Copplesone, S. Devlin, J. Swan
IEEE Transactions on Games 11.3. Pp. 260–266. 2019

Emulating Human Play in a Leading Mobile Card Game

H. Baier, A. Sattaur, E. J. Powley, S. Devlin, P. I. Cowling, J. Rollason
IEEE Transactions on Games 11.4. Pp. 386–395. 2019

MCTS-Minimax Hybrids with State Evaluations

H. Baier, M. H. M. Winands
Journal of Artificial Intelligence Research 62. Pp. 193–231. 2018

Time Management for Monte Carlo Tree Search

H. Baier, M. H. M. Winands
IEEE Transactions on Computational Intelligence and AI in Games 8.3. Pp. 301–314. 2016

MCTS-Minimax Hybrids

H. Baier, M. H. M. Winands
IEEE Transactions on Computational Intelligence and AI in Games 7.2. Pp. 167–179. 2015

The Power of Forgetting: Improving the Last-Good-Reply Policy in Monte Carlo Go

H. Baier, P. Drake
IEEE Transactions on Computational Intelligence and AI in Games 2.4. Pp. 303–309. 2010

conference articles

ME-MCTS: Online Generalization by Combining Multiple Value Estimators

H. Baier, M. Kaisers
30th International Joint Conference on Artificial Intelligence (IJCAI 2021). Accepted.

Guiding Multiplayer MCTS by Focusing on Yourself [nominated for best paper]

H. Baier, M. Kaisers
2020 IEEE Conference on Games (CoG 2020), pp. 550–557. 2020

Opponent-Pruning Paranoid Search [exceptional paper award]

H. Baier, M. Kaisers
2020 International Conference on the Foundations of Digital Games (FDG 2020), 10:1–10:7. 2020

Evolutionary MCTS for Multi-Action Adversarial Games [nominated for best paper]

H. Baier, P. I. Cowling
2018 IEEE Conference on Computational Intelligence and Games (CIG 2018), pp. 1–8. 2018

Evolutionary MCTS with Flexible Search Horizon

H. Baier, P. I. Cowling
14th AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment (AIIDE 2018), pp. 2–8. 2018

Decentralized Online Planning for Multi-Robot Warehouse Commissioning [nominated for best paper]

D. Claes, F. Oliehoek, H. Baier, K. Tuyls
16th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2017), pp. 492–500. 2017

Monte-Carlo Tree Search and Minimax Hybrids

H. Baier, M. H. M. Winands
2013 IEEE Conference on Computational Intelligence and Games (CIG 2013), pp. 129–136. 2013

Beam Monte-Carlo Tree Search

H. Baier, M. H. M. Winands

2012 IEEE Conference on Computational Intelligence and Games (CIG 2012), pp. 227–233. 2012

Nested Monte-Carlo Tree Search for Online Planning in Large MDPs

H. Baier, M. H. M. Winands

20th European Conference on Artificial Intelligence (ECAI 2012), pp. 109–114. 2012

Time Management for Monte-Carlo Tree Search in Go

H. Baier, M. H. M. Winands

13th International Conference on Advances in Computer Games (ACG 2011), pp. 39–51. 2012

Active Opening Book Application for Monte-Carlo Tree Search in 19x19 Go

H. Baier, M. H. M. Winands

23rd Benelux Conference on Artificial Intelligence (BNAIC 2011), pp. 3–10. 2011

workshop articles and extended abstracts

Novelty and MCTS

H. Baier, M. Kaisers

1st Evolutionary Reinforcement Learning Workshop at GECCO 2021 (EVORL 2021). Accepted.

Towards Explainable MCTS

H. Baier, M. Kaisers

AAAI 2021 Workshop on Explainable Agency in AI. 2021

Explainable Search

H. Baier, M. Kaisers

2020 IJCAI-PRICAI Workshop on Explainable Artificial Intelligence. 2020

Value Targets in Off-policy AlphaZero: A New Greedy Backup

D. Willemsen, H. Baier, M. Kaisers

2020 Adaptive and Learning Agents Workshop at AAMAS (ALA 2020). 2020

MCTS-Minimax Hybrids with State Evaluations (Extended Abstract)

H. Baier, M. H. M. Winands

27th International Joint Conference on Artificial Intelligence (IJCAI 2018), pp. 5548–5552. 2018

A Rollout-Based Hybrid Unifying MCTS and Alpha-Beta

H. Baier

Computer Games: Fifth Workshop on Computer Games (CGW 2016), pp. 57–70. 2017

Monte-Carlo Tree Search and Minimax Hybrids with Heuristic Evaluation Functions

H. Baier, M. H. M. Winands

Computer Games: Third Workshop on Computer Games (CGW 2014), pp. 45–63. 2014

Nested Monte-Carlo Tree Search for Online Planning in Large MDPs (Extended Abstract)

H. Baier, M. H. M. Winands

24th Benelux Conference on Artificial Intelligence (BNAIC 2012), pp. 273–274. 2012

theses

Monte-Carlo Tree Search Enhancements for One-Player and Two-Player Domains

H. Baier

Ph.D. thesis. Department of Knowledge Engineering, Maastricht University, Maastricht, The Netherlands. 2015

Adaptive Payout Policies for Monte Carlo Go

H. Baier

Master's thesis. Institute of Cognitive Science, Osnabrück University, Osnabrück, Germany. 2010

Der Alpha-Beta-Algorithmus und Erweiterungen bei Vier Gewinn

H. Baier

Bachelor's thesis. Department of Computer Science, Technische Universität Darmstadt, Darmstadt, Germany. 2006