

Modern Game AI Algorithms

Introduction: what are we dealing with?

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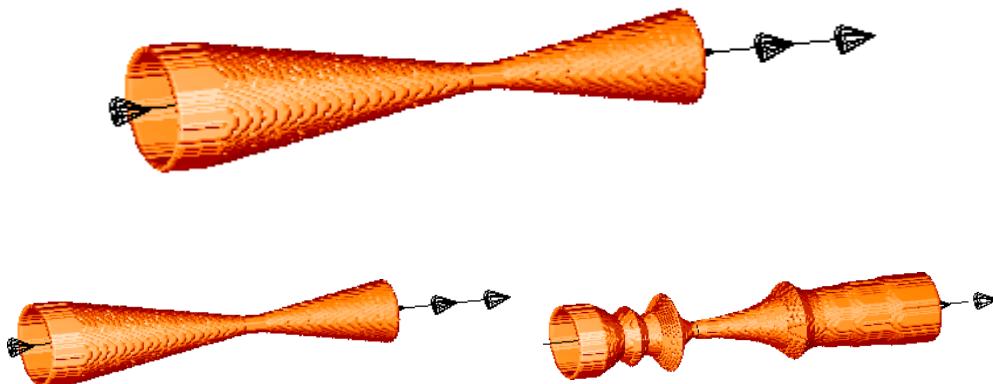
me

- assistant prof LIACs:
game AI, evolutionary algorithms, social media computing
- started programming with BASIC on Commodore C64 ~ 1983
(btw 320 x 200 display mode called hires, 38kB usable memory)
- first programming lecture by Hans-Paul Schwefel: Scheme
- physics minor with Dietrich Wegener (experimental particle physics)
- DW on physicists: “unbounded ignorance, but unlimited intelligence” ☺
- doctor father Hans-Paul Schwefel (pure co-incidence)
- PhD on Multimodal Optimization by Means of Evolutionary Algorithms
- since 2007 active in the (evolutionary) game AI field
- working on stuff like AlphaGo/Zero, Monte Carlo tree search (MCTS),
procedural content generation (PCG), realtime strategy (StarCraft), etc.



evolutionary computation

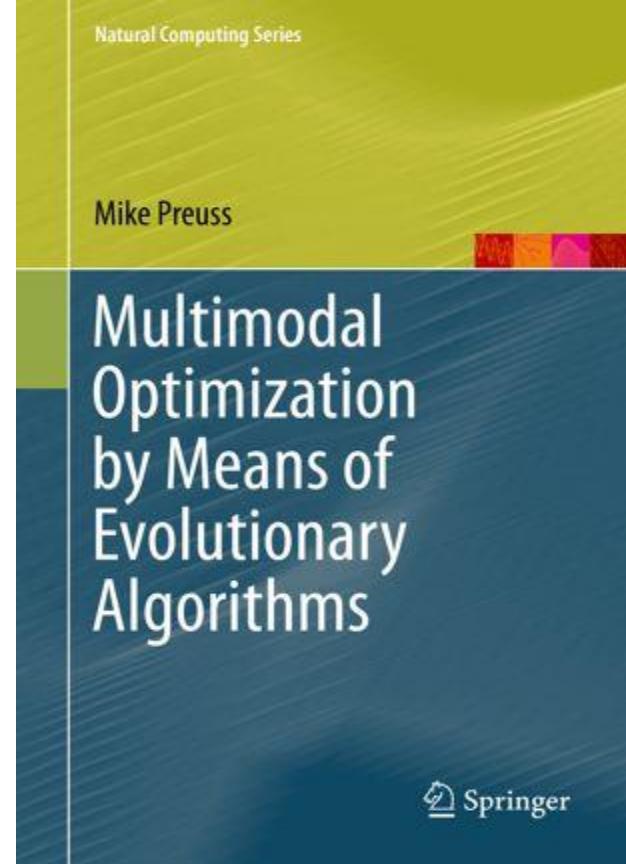
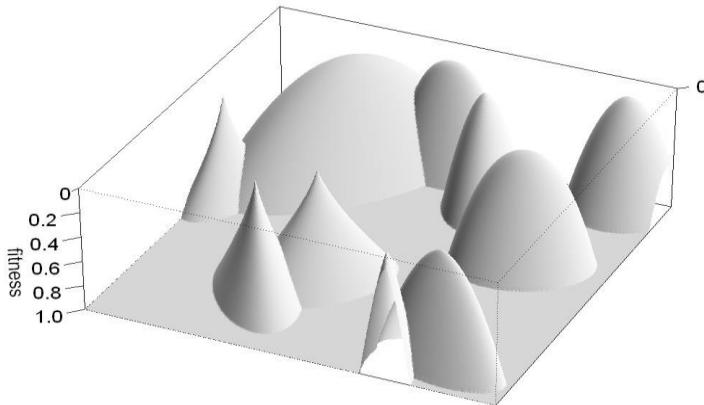
- last PhD student of Hans-Paul Schwefel
(co-inventor of the Evolution Strategy)
- his most important message: expect the unexpected
- focus on multi-modal optimization (detect several good, different solutions simultaneously)
- some work on experimental methodology



picture from Hans-Paul Schwefel

PhD (2013) and book (2015)

- the advantage of niching (if any) can only come from coordinated placement
- simulations/theory: unfortunately, we cannot speed up finding the global optimum
- but if we go for coverage (find many good optima) we can gain a lot
- invented NEA2 as top algorithm (2015), lesson learned: for niching, also use the objective values



game AI (since 2007)

- procedural generation of strategy game maps
- recently: facet orchestration (how to combine several generators, e.g. visuals, audio)
- organizing StarCraft I competitions, survey
- some works on balancing (also using EC):
 - there are often many solutions in balancing
 - the problem is very multi-modal
- very recently: transfer AlphaAnything to new problems (not from the games domain)
- understand how it works on small games
- some more weird stuff I will show later...



a paper**nature**
International journal of science

Access provided by Uni Muenster



Altmetric: 459

[More detail >>](#)

Article | Published: 28 March 2018

Planning chemical syntheses with deep neural networks and symbolic AI

Marwin H. S. Segler , Mike Preuss & Mark P. Waller

Nature 555, 604–610 (29 March 2018) | Download Citation

Abstract

To plan the syntheses of small organic molecules, chemists use retrosynthesis, a problem-solving technique in which target molecules are recursively transformed into increasingly simpler precursors. Computer-aided retrosynthesis would be a valuable tool but at present it is slow and provides results of unsatisfactory quality. Here we use Monte Carlo tree search and symbolic artificial intelligence (AI) to discover retrosynthetic routes. We combined Monte Carlo tree search



PDF

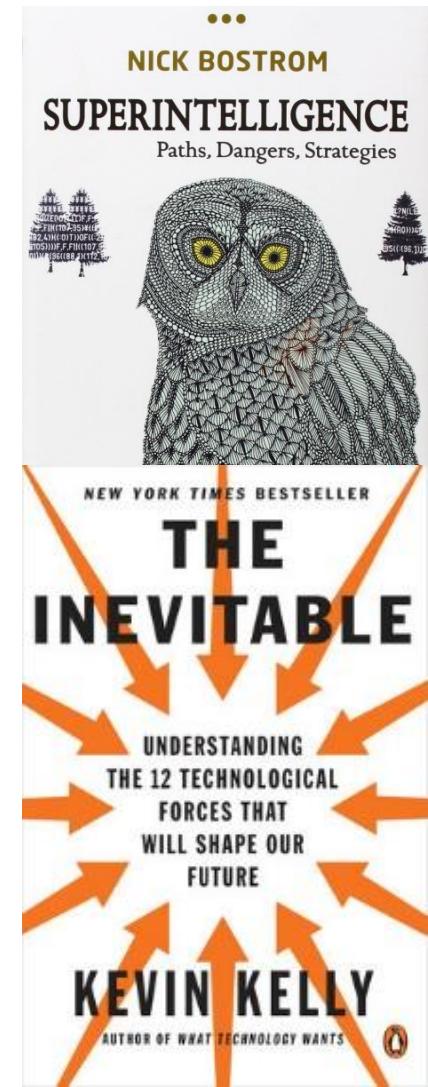
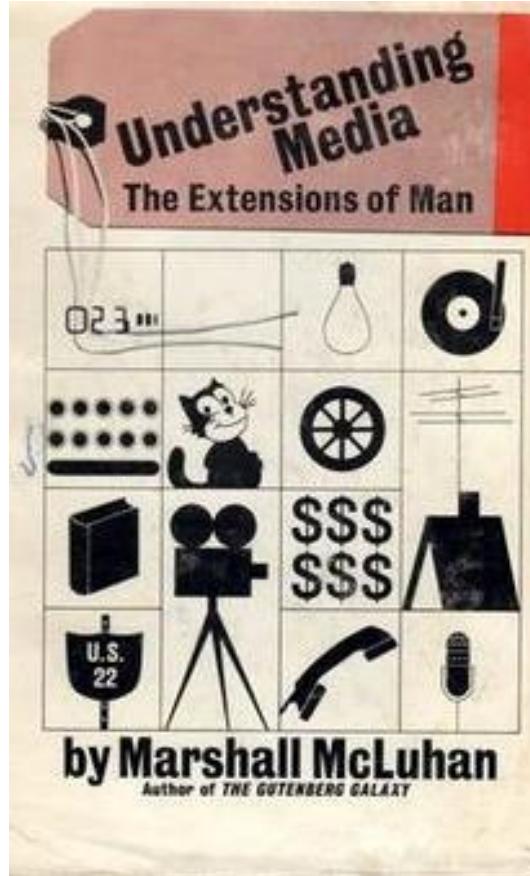
Editorial Summary

Computers teach themselves to make molecules

Chemical reaction databases that are automatically filled from the literature have made the planning of chemical syntheses, whereby... [show more](#)

[Sections](#)[Figures](#)[References](#)[Abstract](#)[Main](#)[Training the expansion and rollout policies](#)[Prediction with the in-scope filter network](#)[Integrating neural networks and MCTS](#)[Evaluating the performance characteristics of 3N-MCTS](#)[Quantitative evaluation](#)

AI as tool, teammate or what?



roadmap

lecture plan (Thursdays 14:15), https://smart.newrow.com/room/nr2/?room_id=stn-974

Feb	18	introduction	Apr	8	procedural content generation II
	25	learning and optimization		15	player experience modeling
Mar	4	procedural content generation I	Apr	22	spatial data analysis
	11	Monte Carlo tree search		29	believable behavior
	18	experimentation / ANN / GAN	May	6	team AI and mass behavior
	25	Vanessa: 1 year game industry...		13	realtime strategy AI
Apr	1	learning from pixels	May	20	free project presentations 1

labs plan (Thursdays 16:15)

Feb	18	no lab	Apr	8	free projects (assignment 3)
	25	single assignment: map generation		15	free projects (assignment 3)
Mar	4	single assignment (week 2)	Apr	22	free projects (assignment 3)
	11	single ass. deadline / start ass 2		29	free projects (assignment 3)
	18	assignment 2	May	6	free projects (assignment 3)
	25	assignment 2		13	deadline free projects
Apr	1	deadline ass. 2 / start free proj.	May	20	free project presentations 2

assessment

what is graded:

- single assignment 25%, smaller group assignment 30%,
free project assignment 45% (including presentation), no written exam

the single assignment will be issued next week:

- simple programming task requiring a bit creativity, Python

smaller group project (largely March):

- group work, most likely in a competition-based fashion on the GVGAI (new version)

free group project (free means you choose the topic):

- working in small groups (4-5 people, exceptions possible)
- during the second half of the tutorials, and in your preparation time



topics of today

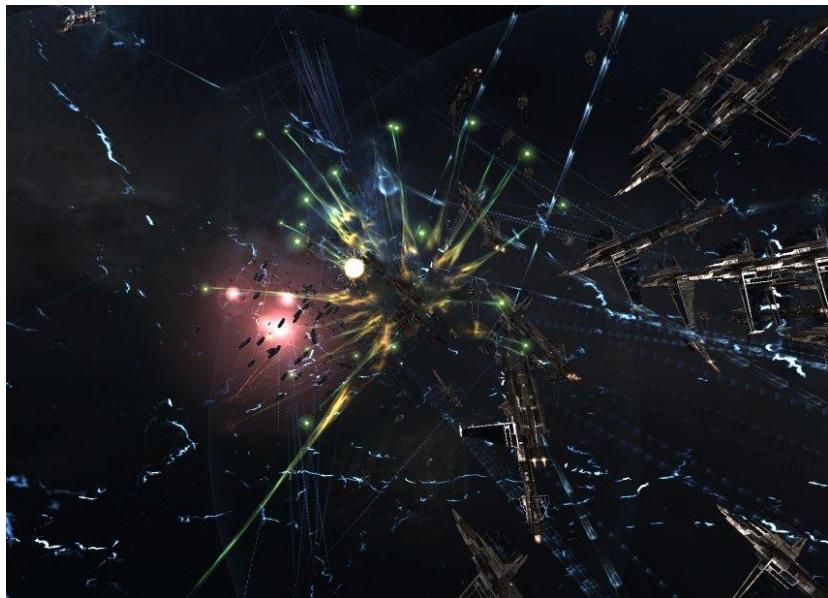
- recent trends in computer games
- history of games / AI in games
- big tech in game AI
- what is modern game AI?
- what we do not treat
- computational intelligence and games?



picture from Michael Gaida on Pixabay

some notes on recent developments

- more diversity and platforms: casual gamers, mobile games, **more** gamers!
- genre mixes, more serious (educational) games, games more recognized as form of **art**
- multi-platform games: Eve Online & Dust 514



Eve Online: Battle of Asakai (PC)
same game world, interaction possible



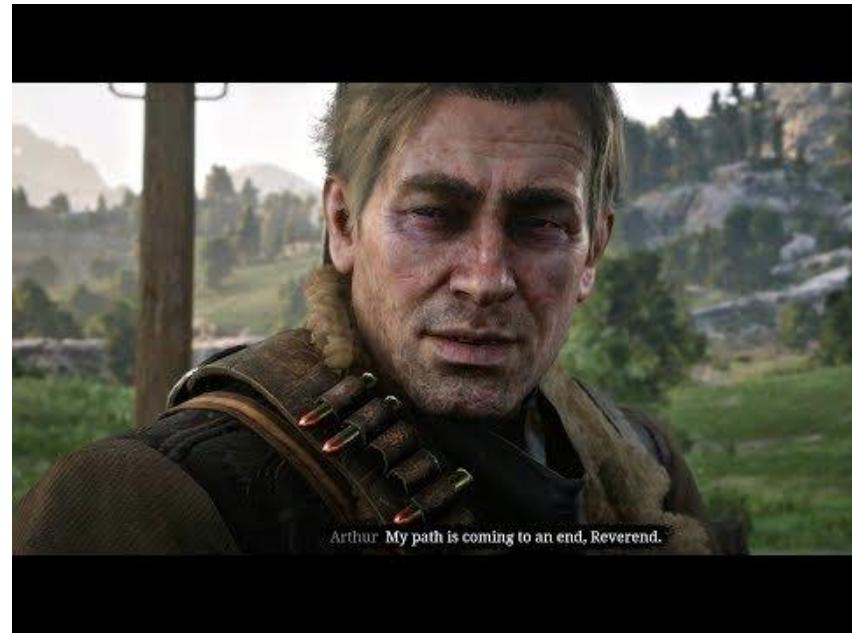
Dust 514 (Playstation)

more of everything: game worlds and perspectives

- massive game worlds (e.g. GTA V), freely explorable
- personalization: multiple characters, realtime switching
- characters with real problems



GTA V: world, 3 main characters



Red Dead Redemption II

sophisticated stories that heavily deal with AI

- sidenote: deliberate (considered risky) choice of female hero payed off!
- there is considerable game industry in NL... follow-up expected end of 2021 ☺



scene from „Horizon Zero Dawn“, Guerilla Games

Horizon Zero Dawn™ © 2017-2018 Sony Interactive Entertainment Europe. Published by Sony Interactive Entertainment Europe. Developed by Guerrilla. "Horizon Zero Dawn" is a trademark of Sony Interactive Entertainment Europe. All rights reserved.

less dumb games...

- more emphasis on atmosphere/narrative (NPC and player able to express personality -> personalization of game)
- NPC as sidekicks of main characters: development
- NPC must be much more complex, less scripting, more AI
- interaction quality varies (e.g. Red Dead Redemption vs Cyberpunk 2077)



"The last of us": 2 main characters,



"Bioshock infinite": sidekick

MOBA

- similarities to RTS (character building instead of base building)
- players always want more sophisticated bots
- "solved"? see OpenAI Five
- balancing is a major issue
- incredibly popular: lots of data, pushing e-sports (among other games as CS:GO)

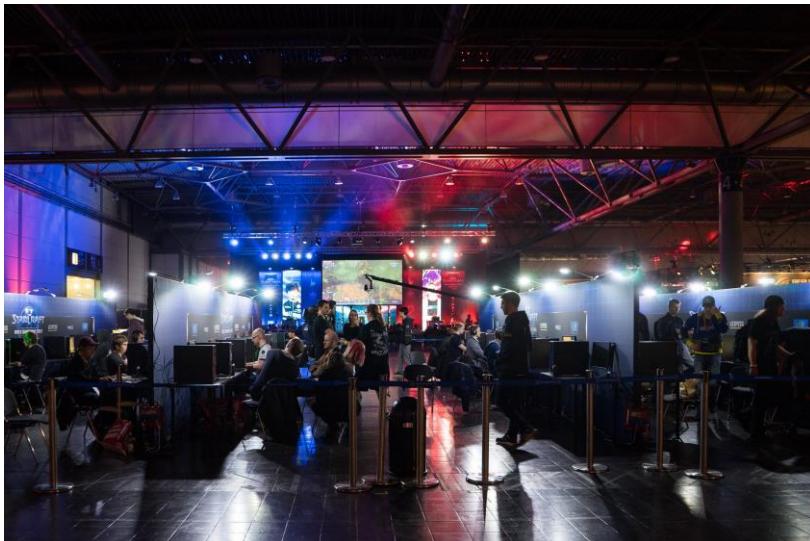


Image by dife88 from Pixabay



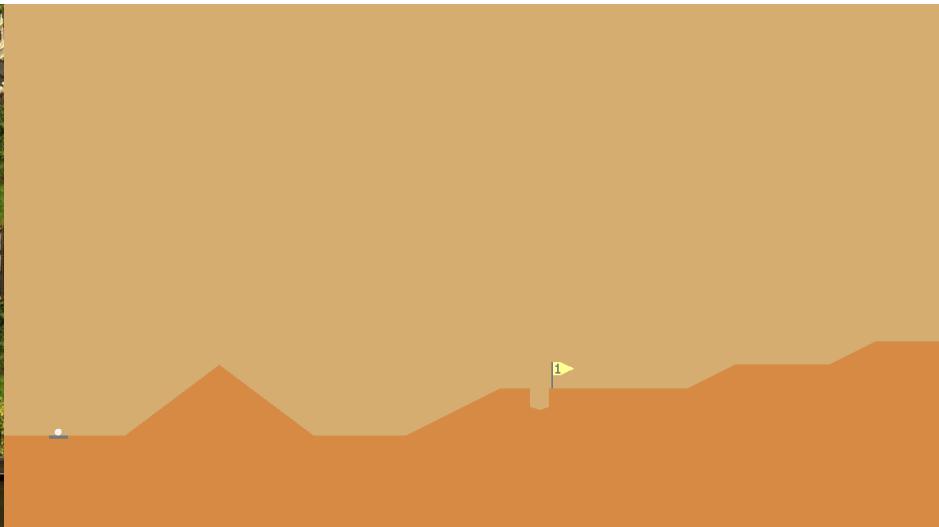
Image by Tomasz Mikołajczyk from Pixabay

browser / mobile games

- browser games can be as complex as stand-alone games now
- companies make a lot of money with browser games, still growing
- according to Statista, user penetration will be 14.6% in 2021
- mobile games are a huge market now, with a wide variety
- even in mobile games, procedural content generation is often used



the settlers online (BlueByte)

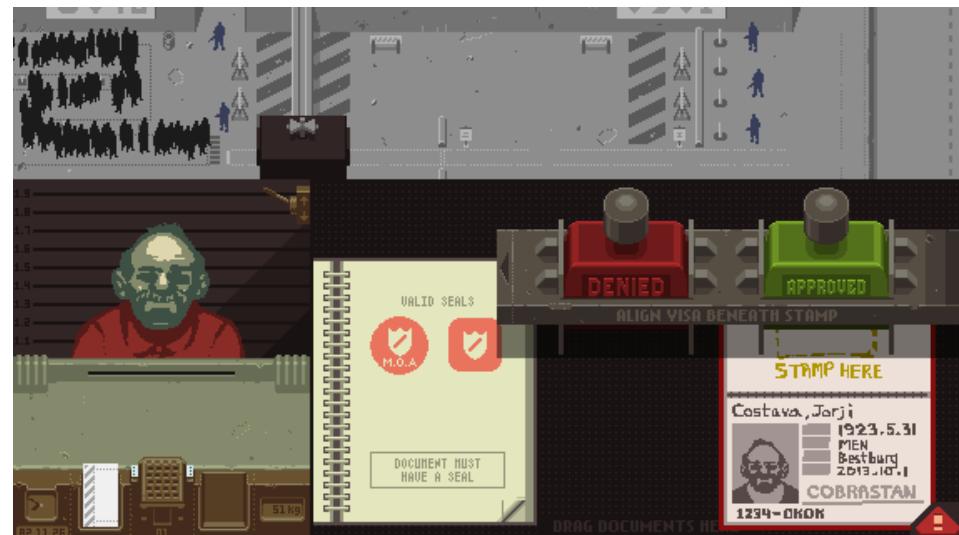


desert golf

innovative indie games

Papers, please!

- player stuck in conflict
- game puts player into strange atmosphere



80 days

- very explorative gameplay
- interactive narrative
- writing of narrative took 1/2 year alone



survival games

- single player or cooperative multi-player
- you can „make things“ in the game world and change the game world
- more and more used for educational purposes
- worlds heavily use procedural content generation -> ever changing possibilities



minecraft (rebuilt from Lego)

Image by dife88 from Pixabay



Valheim (by Iron Gate Studio)

Image from Valheim press kit

monetary aspects

- new business models: online distribution (e.g. add-ons),
- digital distributors more and more important (Steam, Epic, PlayStore, Origin, etc.)
- less subscription, more opt-in payment
- free2play with micro-transactions: balancing issues
- free players needed to fill game for high-revenue players
- churn prediction: provide incentives to stay with game before player leaves

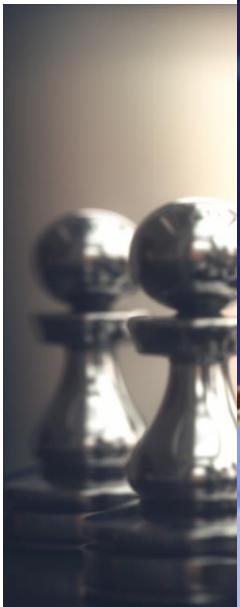
=> game mining, game analysis



recently in (Game) AI – short version

2019

1997



2017



<https://medium.com/syncedreview/humans-call-gg-openai-five-bots-beat-top-pros-in-dota-2-8508e59b8fd5>

and maybe even worse...



The international journal of science / 14 November 2019

nature



pictures from Springer / Nature and DeepMind press kit

but wait, this is games ?!?

big tech is doing this since around 2015 now

- games are well-defined problems
- mastering games shows “intelligence” also to wider audience
- game AI researchers can hardly cope with this progress (resource problem)

but what is the far goal (next to good publicity)?

- developing algorithms **fast**
- learn how to use and **combine** them
- approach important real-world problems
- happened to me as well (Nature paper)



big tech and games

- Minecraft is used as RL challenge, running at the most important AI conferences (NeurIPS)
- e.g. Microsoft is running a gaming and research summit Feb 24/25 (next week), maybe you can still register <https://www.microsoft.com/en-us/research/event/aiandgaming2021/>



Katja Hofmann, image from Microsoft Research <https://www.microsoft.com/en-us/research/project/project-malmo>



william
@wgussml



Wow, I am so excited! The #MineRL competition was featured in The Verge!

We've come a long way towards Minecraft AI in the past 2 years, but this competition is a great reminder that there are so many more challenges to solve!

Read More: [minerl.io](#)



The Verge  @verge

AI has bested chess and Go, but it struggles to find a diamond in Minecraft theverge.com/2019/12/13/210...



6:50 PM · Dec 13, 2019



1 61 11 Copy link to Tweet

a small history of gaming I

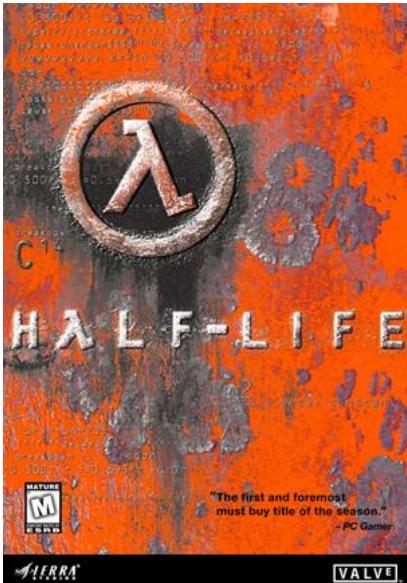
3000 BC	Dice, Senet
2300 BC	Go
500 AD	Chess
ca. 1600	Modern sports games
ca. 1800	Poker, Bridge
1871	Pinball
ca. 1935	Monopoly, Scrabble
1943	Game theory beginnings
1959	Diplomacy

a small history of gaming II

1961	Spacewar! – first computer video game
1971	Galaxy Game – first arcade video game
1972	Magnavox Odyssey console
1973	Game theory: Evolutionary stable strategies
1978–81	Space Invaders, PacMan, Donkey Kong
1983	I, Robot – first commercial 3D video game
1992	Wolfenstein 3D – popularization of FPS (first person shooters)
1997	Ultima Online – first massive multiplayer online (MMO) game
1997	Deep Blue beats Garry Kasparov
1999	Blondie24: Playing Checkers by means of CI
2006	Wii
2008	Checkers solved
2010	Kinect for Xbox (2012 for Windows)

history of ai in games - Half-Life, 1998, Valve

- FPS + puzzle solving
- opponent tactics
 - coverage, dodging, full-level navigation
- integration of AI into the story
- Valve hired Quake AI Mod developers for HL 2

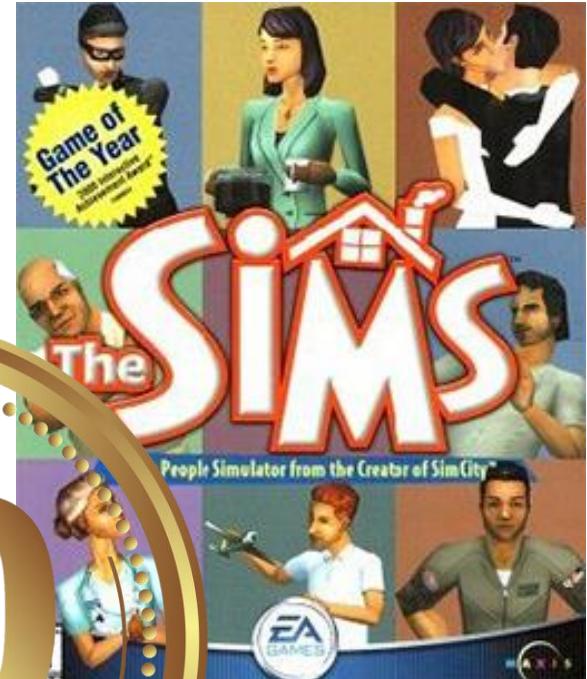


(selection taken from
slides of Georgios
Yannakakis, Uni Malta)



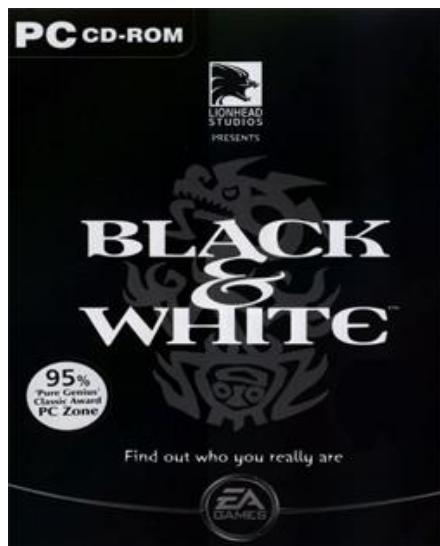
history of ai in games - Sims, 2000, EA

- over 100m copies sold
- no defined goal
- smart (interactive) terrains and objects
- complex modeling of persons, their behavior and relationships



history of ai in games - Black & White, 2000, EA

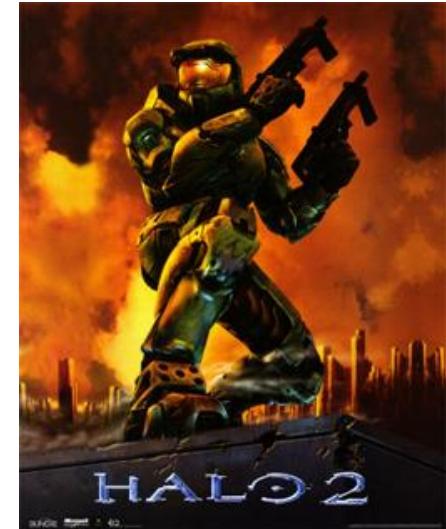
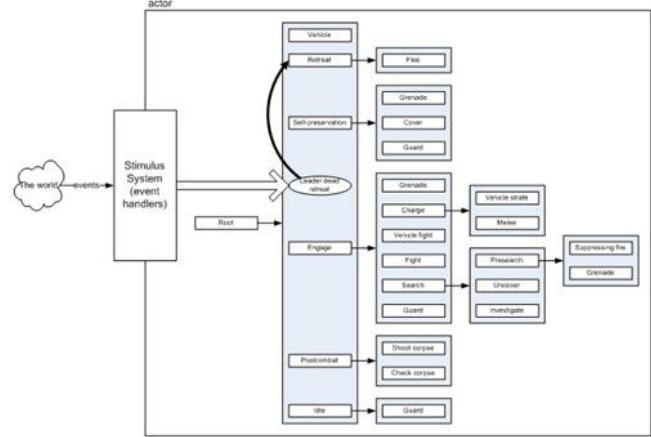
- perceptrons, decision Trees, belief-desire-intentions model
- imitation learning
- reinforcement learning: creature slapped or stroked
- gesture recognition
- learn to do weird stuff:
 - eat all villagers



history of ai in games - Halo 2, 2004, Ms game studios

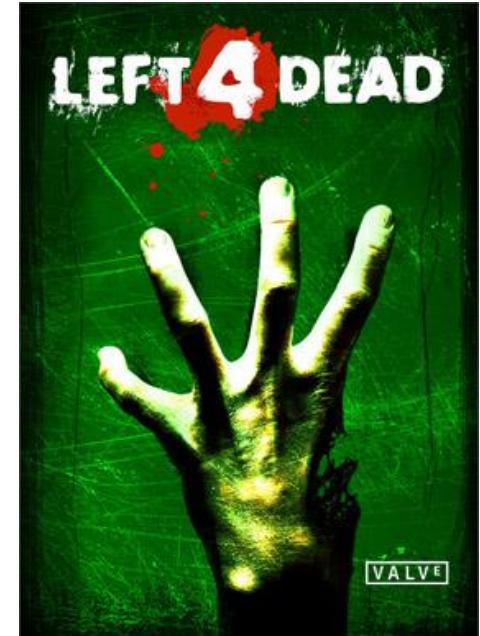
- the revolution of behavior trees!
- more human-like bots
- dynamic difficulty adjustment

Damian Isla: Handling Complexity in the Halo 2 AI
<http://www.naimadgames.com/publications/gdc05/gdc05.doc>



history of ai in games - Left4dead, 2008, Valve

- praise for dynamic difficulty adaptation (DDA) !
- AI director
 - estimation of emotional intensity
 - intelligent enemy placement
 - intelligent item placement
 - player emotional cues (visual effects, dynamic music)



classical AI techniques in games

even nowadays, lots of standard techniques in use
(growing but still small interest for change by developers):

- finite state machines (FSM)
- hierarchical FSM
- scripting

basically mostly used for NPC control

also:

- cellular automata
- influence maps
- basic optimization approaches
- game theory

(still useful for the right problem, but we have so much more now)

research trees

research approaches game problems (mainly) from 3 directions

- specialized algorithms:
exact algorithms or heuristics, e.g. applied to path finding (A^*)
- 'classic' (deterministic) AI/ machine learning (ML) approach:
general game playing (game description language GDL), tree search, also support vector machines (SVM) and reinforcement learning, strong in board games
- computational intelligence (CI):
evolutionary algorithms, fuzzy logic, artificial neural networks, swarm intelligence, Monte Carlo tree search, etc.

this is more and more blurred now, we have (deep) RL with evolutionary components etc.
and more and more big tech is using games as research base for algorithms!

when game AI becomes... artificially intelligent

current discussion in game AI: how intelligent is current game AI?
(especially now in the light of AlphaGo, AlphaStar, etc.)

see gamasutra post:

[http://www.gamasutra.com/view/news/253974/
When_artificial_intelligence_in_video_games_
becomesartificially_intelligent.php](http://www.gamasutra.com/view/news/253974/When_artificial_intelligence_in_video_games_becomesartificially_intelligent.php)

"My prediction is a little bit controversial.
I think the next giant leap of game AI
is actually artificial intelligence."

- Alex J. Champandard at GDC 2013

and now we play SuperAzurit... ☺



Alex Champandard, Vienna

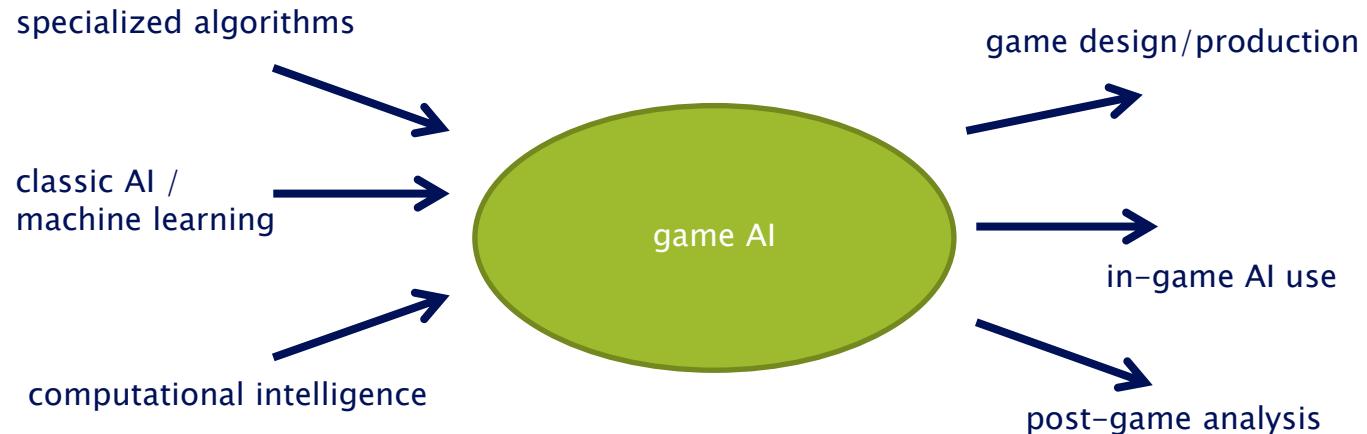
AI expert, co-founder of creative.ai

Director of the nuclai conference, expert on
machine learning & deep learning

modern approach

modern approach:

- *we treat all aspects of games, now also game design/production*
- *we use what fits best for a specific problem*



everything is an agent

- express game AI functionality via interactive agent concept



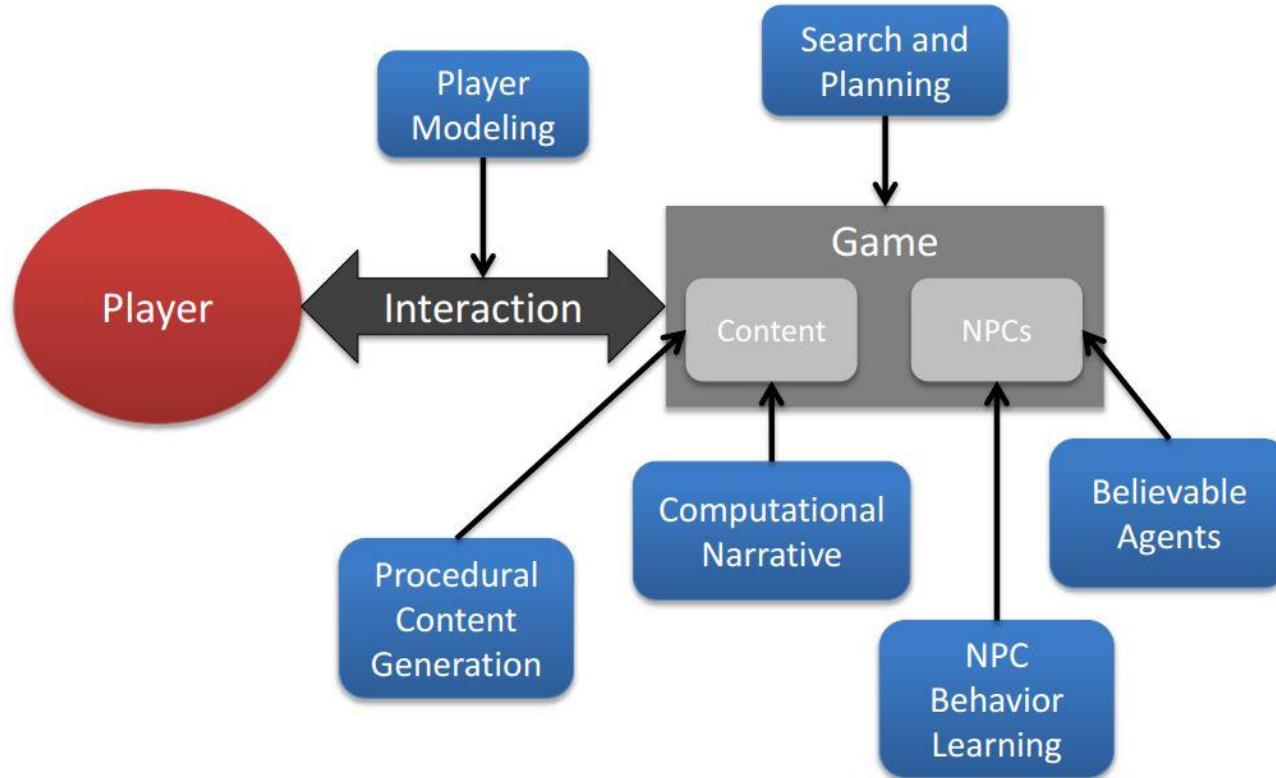
agent could be:

AI director, driver controller, content generator,

panoramic view

game AI components, player centric view, from:

Yannakakis, G.N.; Togelius, J., "A Panorama of Artificial and Computational Intelligence in Games," in IEEE TCIAIG, 2014



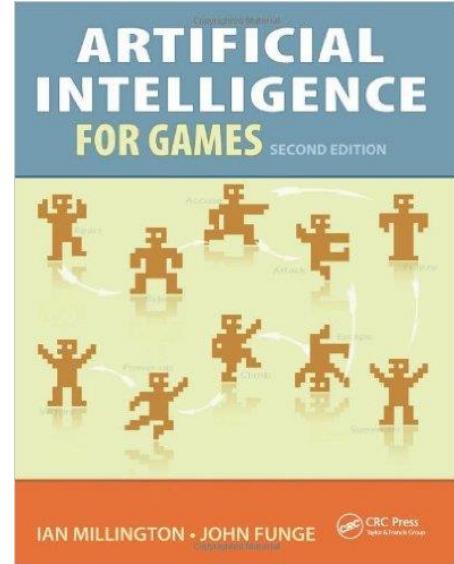
what we do not treat

large parts of the Millington book (2009):

- very little movement
- almost no pathfinding
- no state machines
- no scripting
- almost no planning, we rather treat it as search

why that?

- lots of new, (subjectively) more interesting stuff
- for the rest, there is a lot of literature
- the new role of game AI as design support is not well reflected



there is a better book now

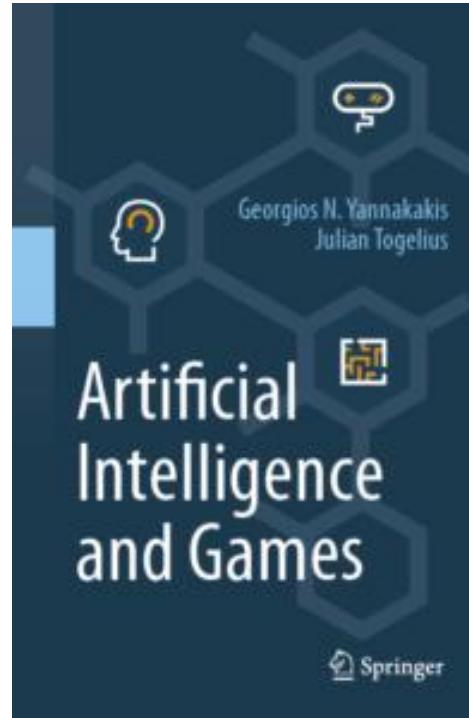
Yannakakis/Togelius (2018):

- games and AI
- AI methods
- playing games
- generating content
- modeling players
- the road ahead

what is new?

- game AI much wider now
(not only NPC stuff)
- new algorithms (MCTS,
deep learning)

<http://gameaibook.org/>



or read introductory survey paper (10 pages)

[←](#) [→](#) [C](#) [Home](#) arxiv.org/abs/2002.10433

 Cornell University the

arXiv.org > cs > arXiv:2002.10433 [Search...](#) [Help | Ad](#)

Computer Science > Artificial Intelligence

From Chess and Atari to StarCraft and Beyond: How Game AI is Driving the World of AI

Sebastian Risi, Mike Preuss

(Submitted on 24 Feb 2020)

This paper reviews the field of Game AI, which not only deals with creating agents that can play a certain game, but also with areas as diverse as creating game content automatically, game analytics, or player modelling. While Game AI was for a long time not very well recognized by the larger scientific community, it has established itself as a research area for developing and testing the most advanced forms of AI algorithms and articles covering advances in mastering video games such as StarCraft 2 and Quake III appear in the most prestigious journals. Because of the growth of the field, a single review cannot cover it completely. Therefore, we put a focus on important recent developments, including that advances in Game AI are starting to be extended to areas outside of games, such as robotics or the synthesis of chemicals. In this article, we review the algorithms and methods that have paved the way for these breakthroughs, report on the other important areas of Game AI research, and also point out exciting directions for the future of Game AI.

Subjects: Artificial Intelligence (cs.AI); Machine Learning (cs.LG)

Journal reference: KI - Kuenstliche Intelligenz (2020)

DOI: [10.1007/s13218-020-00647-w](https://doi.org/10.1007/s13218-020-00647-w)

Cite as: arXiv:2002.10433 [cs.AI]
(or arXiv:2002.10433v1 [cs.AI] for this version)

Bibliographic data

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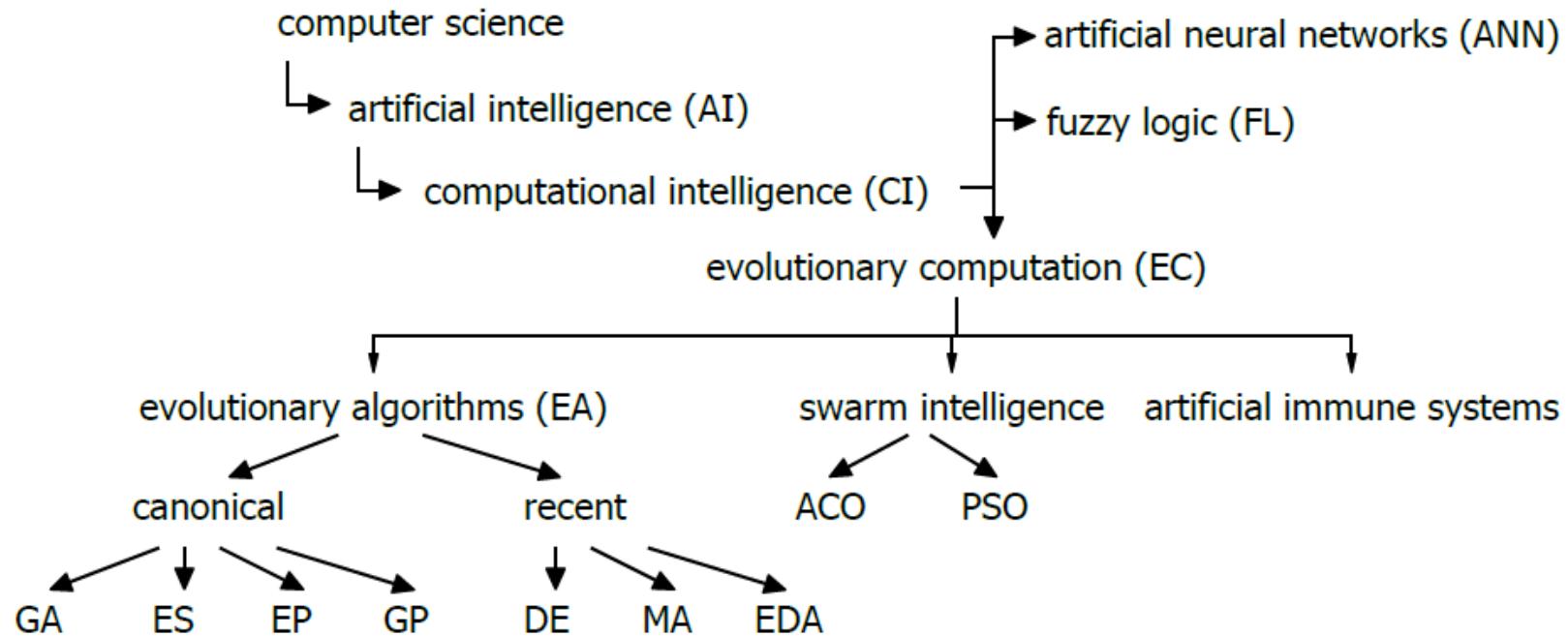
Submission history

From: Sebastian Risi [[view email](#)]

[v1] Mon, 24 Feb 2020 18:28:54 UTC (2,625 KB)

[Which authors of this paper are endorsers?](#) | [Disable MathJax](#) ([What is MathJax?](#))

computational intelligence?

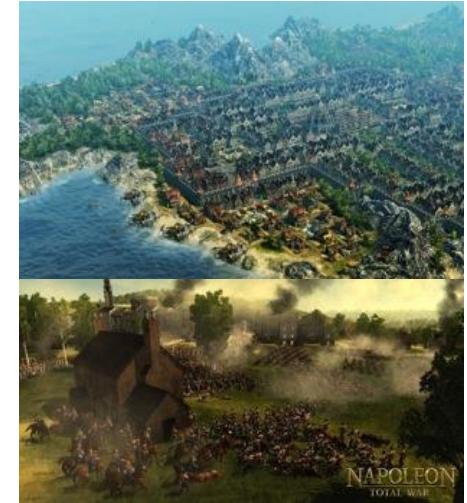


why apply CI methods to games?

- contrary to board games,
- game trees often not applicable -> MCTS
- incomplete information
- concurrency: during planning phase, game situation changes
- quantifying a game situation is not trivial

→ good and fast approximations are needed

- evolutionary optimization is
- versatile, flexible, still works (somehow)
- copes with noise and strange search spaces
- can be asked to deliver a result at any time



CI in games: a field forming (and assimilating)



- 1999: Blondie24, learning checkers with CI and human players
- 2005 first Computational Intelligence in Games (CIG) conference
- IEEE TCIAIG Journal (Transactions on CI and Artificial Intelligence in Games) since 2009
- EvoGames track in Evo* since 2009
- many “neighbor” conferences, etc. AIIDE, FDG, gameai conf. (not strictly CI, but CI welcome)
- general approach target oriented, not technique oriented
- 2012: first Dagstuhl seminar on AI and CI in Games
- 2014: CIG conference in Dortmund
- 2015: second Dagstuhl seminar
- 2017: third Dagstuhl seminar (AI-supported design)
- 2018/2019: journal and conference renamed to IEEE Transactions on Games (ToG) and IEEE Conference on Games (CoG)
- 2019: fourth Dagstuhl seminar (revolutions in game AI)

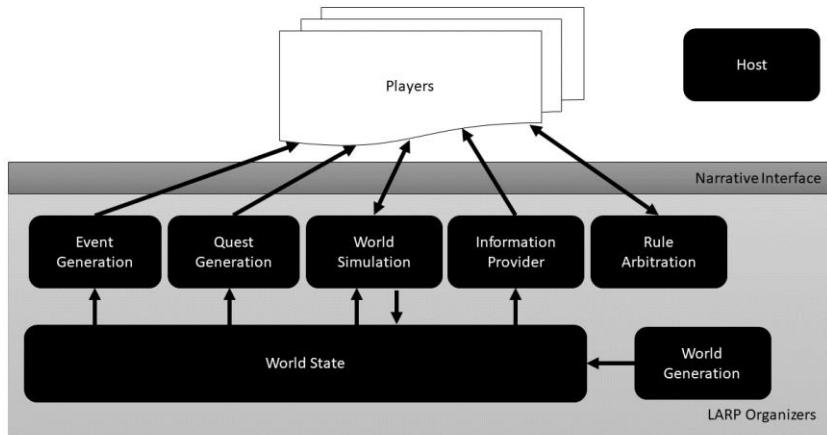
CI in games: a field forming (and assimilating)



DAGSTUHL – LZI GMBH
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- AI who understands the player
- Human AI collaboration, cooperation, competition HACC
- LARP AI
- Fast forward abstract models
- Discovering diversity of skills in open-ended fashion
- Forward models of game design
- Explainable AI and visualization
- Evolutionary computation for games/representation
- PCG for Minecraft
- Card games with hidden information

AI for LARP games



from [Christoph Salge](#), [Emily Short](#), [Mike Preuss](#), [Spyridon Samothrakis](#), [Pieter Spronck](#):
Applications of Artificial Intelligence in Live Action Role-Playing Games (LARP). [CoG 2020](#): 612-619

- almost untapped potential, AI could help with many tasks
- can serve well as “test case” for complex real-world organizational tasks
- AI can also enable super-LARPS as combination of LARPS in space and time

game AI hot topics

- procedural content generation (PCG)
 - large game worlds are expensive to make
 - represent specific (designer) styles
 - narrative generation
- believability of non-player character (NPC) behavior
 - more humanlike behavior (also evoke and show emotions)
 - better cooperation of units (team AI)
 - human/AI interaction
- personalization
 - preference modeling (what do they like?), player type analysis
 - dynamic adaptation of game content and mechanics

balancing is everywhere

```
graph TD; A[balancing is everywhere] --> B[procedural content generation]; A --> C[believability of non-player character]; A --> D[personalization]
```

whatever we change -> balancing

initial (more conceptual) work:

Markus Kemmerling and Mike Preuss.

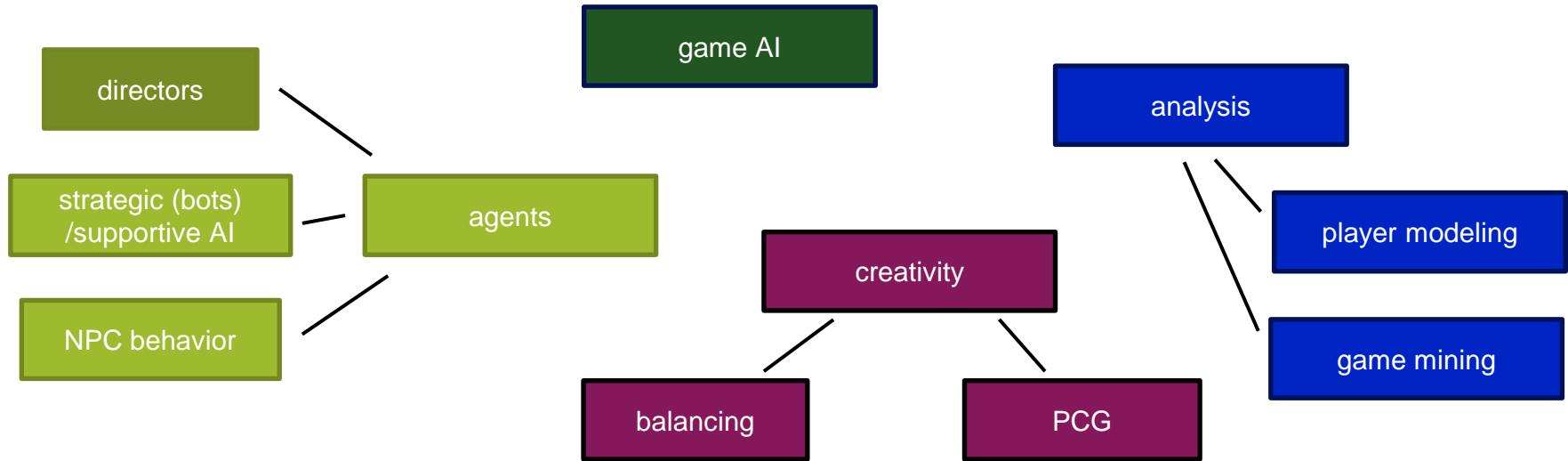
[Automatic Adaptation to Generated Content Via Car Setup Optimization in TORCS](#). IEEE CIG 2010.

test case Megaglest (Warcraft-clone):

- autorun interface (quick)
- balancing 7 factions impossible
- balancing 2 factions not trivial
- effects not gradual: little changes can tip over balance
- robust solutions needed



game AI overall view



- game AI traditionally encompasses mostly NPC behavior and bots
- agents/control happens during the game, creativity/design support before deployment
- design support is rather new, but a highly dynamic research area
- player modeling has ties to many other areas

LIACS lectures that have connections



Aske Plaat:
Reinforcement
Learning



Wojtek Kowalczyk:
Deep Learning



Marcello Gómez
Maureira (+me):
Games for Research
(coming Sep 2021)



Mike Preuss:
Modern Game AI
Algorithms
(this lecture)

take home

- games (and game worlds) are getting more complex
- we are gradually leaving the linear storyline path
- AI is not only NPC behavior any more
- modern game AI also supports design/production
- computational intelligence techniques well suited for games problems

- highly recommended: please read the survey article of Sebastian Risi and me



picture from OpenClipart-Vectors on Pixabay