

Theory and Algorithms of Puzzles and Games

1. Introduction, Organization & Dates

Augusto Blaas Corrêa, Liat Cohen and Malte Helmert

University of Basel

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Puzzles & Games

Puzzles & Games

puzzles and games:

- frequently studied in Computer Science
- illustrate many theoretical concepts
- used as testbed for algorithms
- interesting to the general public

Key Areas

- **Game Theory**: optimum strategies, Nash equilibria, ...
- **Computational Complexity**: P vs. NP, computability, ...
- **Artificial Intelligence**: heuristic search, neural nets, ...
- many more: linear algebra, probabilistic reasoning, ...

We will present the concrete topics in more detail later.

Format

Seminar Format

- theoretical part + programming project
- 6 ECTS points
- assessment: graded (1.0–6.0)

Grading

Grading

- written report (final version) (25%)
- peer review (15%)
- seminar presentation (25%)
- implementation for the programming project (25%)
- project presentation (10%)

Each component is graded individually on a scale of 1.0–6.0.
The final grade is the weighted average of all component grades.

Other Supervisors

- Spiegelgasse 1, room 04.002
 - Salomé Eriksson (salome.eriksson@unibas.ch)
- Spiegelgasse 1, room 04.005
 - Thomas Keller (tho.keller@unibas.ch)
 - Florian Pommerening (florian.pommerening@unibas.ch)
 - Silvan Sievers (silvan.sievers@unibas.ch)
- Spiegelgasse 5, room 04.001
 - Clemens Büchner (clemens.buechner@unibas.ch)
 - Remo Christen (remo.christen@unibas.ch)
 - Patrick Ferber (patrick.ferber@unibas.ch)

Course Links I

Seminar Homepage

<https://dmi.unibas.ch/de/studium/computer-science-informatik/lehrangebot-hs21/seminar-theory-and-algorithms-of-puzzles-and-games/>

- seminar description
- slides
- examples for good talks, reports, and reviews

Zoom Room

- used for all seminar sessions

Course Links II

Discord Server

- place to interact with us and with each other

ADAM Workspace

https://adam.unibas.ch/goto_adam_crs_1163945.html

- link to Zoom
- link to Discord
- recorded lectures by course organizers

Plagiarism

Plagiarism

- **plagiarism:** representing work or ideas of other people as your own
- consequence: failing the seminar
- if in doubt: **ask us in advance!**

Repeat offenders can be excluded from the study program.

Language

- The seminar is in English (reports, presentations, etc.).
- If you prefer a supervisor who speaks German, let us know.
- Discuss your programming language with your supervisor.

Questions about the Organization

Questions?

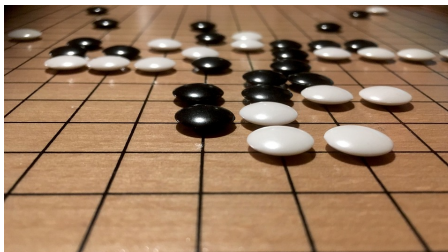
Topics

Chess



- history of Computer Chess
- from Shannon's paper in 1950 to Stockfish
- alpha-beta pruning, endgame databases, specific engines, . . .
- (AlphaZero part of other topic)

Go



- control more territory than opponent, capture opponent's pieces by surrounding them
- approximately $2.1 \cdot 10^{170}$ legal board configurations
- AlphaGo: machine learning meets Monte Carlo Tree Search

F.E.A.R.



- first-person shooter
- NPC and squad behavior controlled by automated planning
- going beyond finite state machines for controlling agents

Dragon Age: Origins



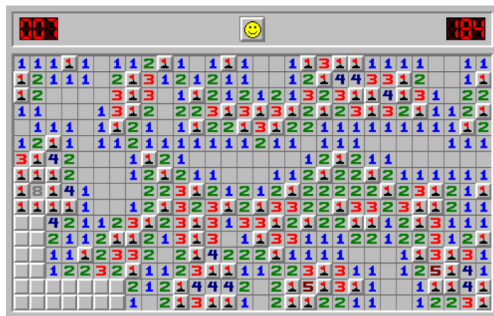
- pathfinding on 2D grids
- limited resources (memory, CPU time)
- abstractions (minimal-memory, Jump Point Search, ...)

Starcraft



- real-time strategy game
- requires complex long- and short-term decision-making
- DeepMind's Starcraft II agent AlphaStar

Minesweeper



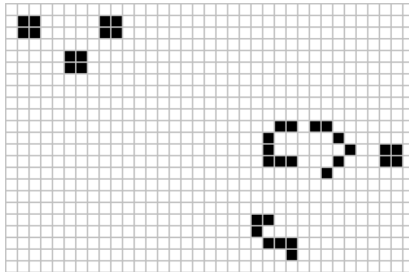
- clear board without clicking on the mines
- P vs. NP
- polynomial reductions, gadgets

Snake



- eat all food without colliding with walls or growing snake body
- different variants: internal walls, multiple food items, growth factors, ...
- How easy are these variants (P, NP-hard, PSPACE-complete)?

Conway's Game of Life



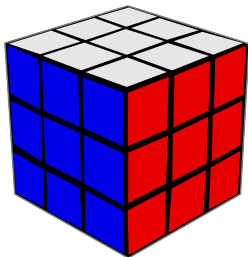
- cells stay/become **alive** or **dead** depending on number of alive neighbors
- simple rules but complex behavior
- with suitable initial conditions any computation possible (Turing-complete)

Magic: The Gathering



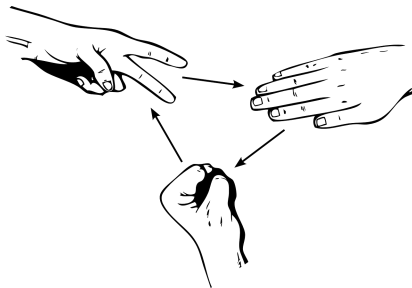
- card game where wizards combat each other by casting powerful spells
- (almost) unlimited deck-building possibilities
- MtG is Turing-complete

Rubik's Cube



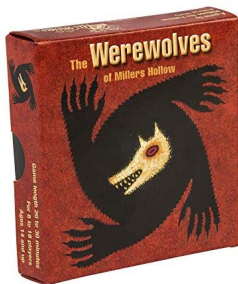
- famous combinatorial puzzle
- player turns faces of the cube to permute colors
- despite simple rules, hard to find short solutions
- techniques to find God's Number

Rock, Paper, Scissors



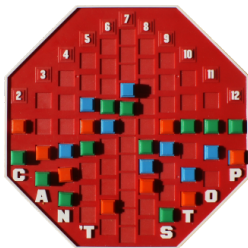
- two-player hand game
- game-theoretical properties, such as optimal strategies
- generalization to other games

Werewolf



- group game with hidden roles
- strategy depends on player's role and expected strategies of other players
- focus on Nash equilibrium

Secretary Problem



- optimal stopping problems deal with finding the right moment to take a specific action
- secretary problem has simple approximately optimal strategy
- board games like [Can't Stop](#) built on comparable ideas

Multi-Armed Bandit

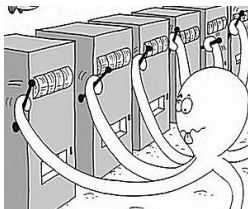


Image source: Microsoft Research

- repeated decision to select an arm of a multi-armed bandit (group of slot machines)
- unknown probabilistic payout for each arm
- goal to maximize payout
- underlying model for many game playing algorithms

Risk



- conquer territories to rule the world
- use probability theory to make good decisions
- Markov chains

Skat



Creative-Commons license, Manfred Heyde

- popular (originally German) trick-taking card game
- bidding phase and card-playing phase
- focus on algorithms for playing Skat: Monte Carlo simulation, inference and/or model-free learned policies

Poker



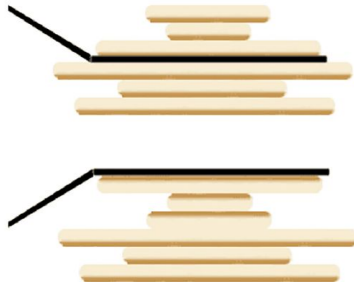
- multi-player card game with partial knowledge
- focus on strong algorithms based on game theory, in particular counterfactual regret minimization

Sudoku

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

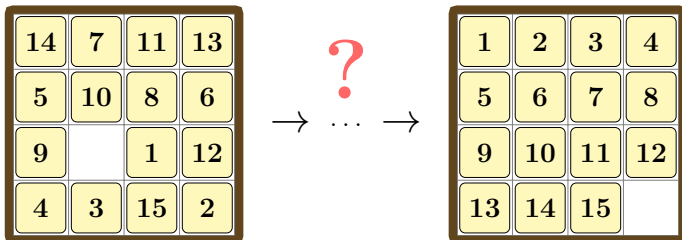
- combinatorial number-placement puzzle
- generalized Sudoku is NP-complete
- focus on Sudoku solvers and inference rules

Pancake Problem



- repeatedly flip top k pancakes to order the stack
- NP-hard to find shortest sequence of flips
- tight bounds on number of flips needed for n pancakes

15-Puzzle



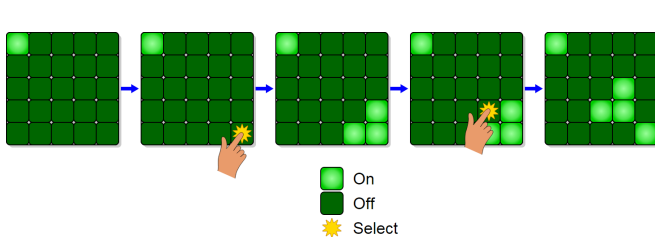
- rearrange sliding tiles into numerical order
- half of all positions are unsolvable
- How can this be proven?

Pop it!



- combinatorial game similar to [Nim](#)
- main difference: winning condition
- focus on winning strategies and the underlying theory

Lights Out



- turn all lights off using buttons that toggle multiple lights
- minimize number of switching actions
- solution techniques based on linear algebra

Topic Assignment

until next Thursday (September 30):

- make three topic suggestions
- for each case write a short paragraph:
why would you like to present this topic?
- send them to us ordered from most preferred to least preferred

If you don't send suggestions, we assume that you don't intend to participate in the seminar.

Next Steps

- We will send out the topics, supervisor assignments, and presentation dates next Friday.
- Contact your supervisor **early** and schedule meetings.
- Start reading the material **as early as possible**.

